

LIFE CYCLE ASSESSMENT (LCA) OF AN ESPRESSO CUP OF COFFEE MADE FROM A NESPRESSO PRO CAPSULE AND OTHER COFFEE SYSTEMS IN SWITZERLAND, IN A BUSINESS ENVIRONMENT

FINAL REPORT

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PROJECT INFORMATION

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Abbreviations and acronyms

AAA	Nespresso AAA Sustainable Quality™ Program
ASI	Aluminium Stewardship Initiative (https://aluminium-stewardship.org/)
CFF	Circular Footprint Formula
CO₂	Carbon Dioxide
DALY	Disability Adjusted Life Years
EF	Environmental Footprint
EMPA	Swiss Federal Laboratories for Materials Science and Technology
EOL	End of Life
EPFL	Ecole Polytechnique Fédérale de Lausanne
eq	equivalents
FA or FAuto	Full automat
FOEN	Federal Office for the Environment (in Switzerland)
GWP	Global Warming Potential
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LEED	Leadership in Energy and Environmental Design
LSR	Liquid Silicon Rubber
LUC	Land Use Change
MSW	Municipal solid wastes
NN	Nespresso
NNCH	Nespresso Switzerland
PDF*m²*y	Potentially Disappeared Fraction per Square Meter of land per Year
PEF	Product Environmental Footprint
PEFCR	Product Environmental Footprint Category Rules
R&G coffee	Roast and Ground coffee
RoW	Rest of the World (regionalisation in ecoinvent for the non-specified other countries)
VDE	German certification and testing institute www.vde.com

1 Introduction

Heightened concern around the environmental and social sustainability of society's consumption habits has focused attention on understanding and proactively managing the potential environmental and societal consequences of production and consumption of products and services. Nearly all major product producers now consider environmental and social impacts as a key decision point in material selection, and sustainability is a recognized point of competition in many industries, including food and agriculture.

A leading tool for assessing environmental performance is life cycle assessment (LCA), a method defined by the International Organization for Standardization (ISO) 14040-14044 standards (ISO 2006a; ISO 2006b). LCA is an internationally-recognized approach that evaluates the relative potential environmental and human health impacts of products and services throughout their life cycle, beginning with raw material extraction and including all aspects of transportation, manufacturing, use, and end-of-life treatment. It is important to note that LCA does not exactly quantify the real impacts of a product or service due to data availability and modelling challenges. However, it allows to estimate and understand the potential environmental impacts which a system might cause over its typical life cycle, by quantifying (within the current scientific limitations) the likely emissions produced and resources consumed. Hence, environmental impacts calculated through LCA should not be interpreted as absolute, but rather relative values within the framework of the study. Ultimately, this is not a limitation of the methodology, since LCA is generally used to compare different systems performing the same function, where it's the relative differences in environmental impacts which are key for identifying the solution which performs best.

Among other uses, LCA can identify opportunities to improve the environmental performance of products, inform decision-making, and support marketing, communication, and educational efforts. The importance of the life cycle view in sustainability decision-making is sufficiently strong that over the past several decades it has become the principal approach to evaluate a broad range of environmental problems, identify social risks and to help make decisions within the complex arena of socio-environmental sustainability.

Through the use of LCA, Nespresso, a leading company in the portioned coffee sector, has engaged in an effort to understand the environmental impacts of a cup of espresso coffee prepared from its own Pro capsules system in a business environment on the Swiss market. Nespresso has commissioned Quantis to perform the current study, that aims also to benchmark the Nespresso Pro coffee system with full automat coffee systems available on the Swiss market and soluble coffee preparation. It is the intention that this LCA conforms to the International Organization for Standardization (ISO) 14040 and 14044 standards (ISO 2006a; ISO 2006b) for public disclosure of comparative statements. The study has been peer-reviewed as a requirement of ISO LCA standards.

2 Goal of the study

2.1 Objectives

This study evaluates the environmental impacts related to the preparation of a cup of coffee made from a Nespresso Pro capsule, in a business environment.

The specific goals of this study are as follows:

- I. Carry out an ISO 14040/14044 compliant Life Cycle assessment of a cup of coffee made from a Nespresso Pro system (capsule for business environment).
- II. Compare the results obtained with several a system of full automat machines, suitable for business environment, and benchmark with a soluble coffee.

While it is possible that the different systems may have qualitative differences, such as taste or caffeine content resulting from differences in extraction efficiency and amount of R&G coffee per cup, for the purpose of the present study, it is assumed the systems can be evenly compared on the basis of a cup of coffee.

2.2 Intended audiences

The project report is intended to provide results in a clear and useful manner to inform about Nespresso environmental performance first internally (for strategic sustainability decision and communication preparation) and then externally. The level and quality of support for the conclusions have been evaluated during the critical review to ensure that the results are appropriate to support a public disclosure of the LCA findings.

2.3 Disclosures and declarations

Nespresso seeks to evaluate and compare the environmental performance of an espresso cup of coffee made from a Nespresso Pro capsule and full automat coffee systems. The project conforms to the ISO 14040 and 14044 standards and includes a critical review by a panel of external experts.

- Roland Hischier, Swiss Federal Laboratories for Materials Science and Technology - EMPA (reviewer and chairman of the panel)
- Hélène Rochat, Topten Sàrl (reviewer)
- François Maréchal, Swiss Federal Institute of Technology Lausanne - EPFL (reviewer)

The results of this attributional life cycle assessment are intended to be used by Nespresso for internal and external communication about Nespresso's Pro espresso coffee compared to the full automat coffee systems assessed in the current report.

3 Scope of the study

This section describes the scope of the assessment. It includes a description of the products functions and products systems, the system boundaries, data sources, and methodological framework. This section also outlines the requirements for data quality as well as review of the analysis.

3.1 Comparative basis

3.1.1 Functional unit and scenarios of use

Life cycle assessment relies on a "functional unit" (FU) for comparison of alternative products that may substitute each other in fulfilling a certain function for the user or consumer. The functional unit describes this function in quantitative terms and serves as an anchor point of the comparison ensuring that the compared alternatives do indeed fulfil the same function. It is therefore critical that this parameter is clearly defined and measurable. The functional unit for this study is:

To provide an espresso cup of coffee in a business environment, in Switzerland

The exact volume of coffee in the espresso cup is 40 ml for all systems compared. The espresso is chosen as it is the most sold coffee in the business environment according to Nespresso sales volumes and sales experts. Espresso cups of 40 ml would also be representative for the hotels, restaurants and cafés.

Even if the taste or caffeine content is not defined in the functional unit and there can be difference in the systems assessed regarding these criteria, the cup of coffee has still to provide a "good coffee" in the sense that diluting too much the coffee to obtain a lower impact would not lead to a coffee eligible for the comparison.

Two different scenarios of use are assessed, with different coffee consumption intensities, corresponding to smaller or larger companies. The first **use scenario is meant to assess a consumption of 4 000 cups per year and machine and the second one of 10 000 cups per year and machine**. The use scenario will define the type of machine used: with a low consumption

intensity, smaller machines can be used, while for the higher consumption, larger machines, able to brew more coffees per day will be considered. These 4 000 and 10 000 cups/year and machine have been determined based on Nespresso machine park and annual sales for the different machines: for the Nespresso Zenius professional machine, the average capsules sold per machine in Switzerland is 4 000 cups/year while for the Gemini CS200 and Momento 100, the average capsule sold per machine is 10 000 cups/year. These use intensities, corresponding to the representative average consumption of Nespresso business consumers in Switzerland, have been considered as representative of the Swiss companies in general. The choice of machines for the full automat systems has been therefore defined according to these same use intensities (see section 3.3). These two use intensities correspond to cups per year **and** machine (even if, for simplicity reasons, the report mentions sometimes only 4 000 cups/year and 10 000 cups/year). This means a larger company can have several machines with a use intensity of 10 000 cups/year and reach a much higher number of cups for the company in the year.

3.2 System boundaries

The system boundaries identify the life cycle stages, processes, and flows considered in the LCA and should include all activities relevant to attaining the above-mentioned study objectives. The following paragraphs present a general description of the system as well as temporal and geographical boundaries of this study.

3.2.1 General system description

This study assesses the life cycle of an espresso coffee cup from the extraction and processing of all raw materials through the end-of-life of all components, as depicted in Figure 3-1.



Figure 3-1: Life cycle of an espresso cup of coffee evaluated in this study (DC: Distribution Center; HQ: Head Quarter; HO: Head Office).

As is generally done in LCA, within the above shown steps, the assessment considers all identifiable “upstream” activities to provide as comprehensive a view as possible of the product’s cradle-to-grave life cycle. For example, when considering the environmental impact of transportation, not only are the emissions of the truck or ship considered, but also included are the impacts of additional processes and inputs needed to produce the fuel and the vehicle. In this way, the production chains of all inputs are traced back to the original extraction of raw materials.

For the purposes of this analysis, the system was grouped into the following principal life cycle stages.

- 1) Green coffee supply
- 2) Packaging production and delivery
- 3) Manufacturing
- 4) Distribution
- 5) Use stage
- 6) Overheads / Support
- 7) End-of-life

3.2.2 Temporal and geographic boundaries

This LCA is considered to be representative of an espresso cup of coffee sold on the Swiss market in 2020, even if some data have been collected in 2017, 2018 or 2019. Data and assumptions are intended to reflect current equipment, processes, and market conditions. It should be noted, however, that some processes within the system boundaries might take place anywhere or anytime. For example, the green coffee cultivation takes place outside Switzerland. In addition, certain processes may generate emissions over a longer period of time than the reference year, e.g. emissions from tailings related to energy generation (coal) or metal extraction.

3.3 Coffee systems assessed

The scenarios assessed cover the Nespresso Pro and full automat coffee systems, as well as the soluble coffee system. The Nespresso Pro coffee system uses Pro capsules and Nespresso Pro machines (Zenius, Gemini CS200 or Momento 100) while the full automat coffee system uses coffee beans in pouches and full automat machines (efficient and non-efficient machines).

The machines considered for the assessment correspond for Nespresso to the recommended machines for the two scenarios of use. The Momento 100 is a new generation of machines corresponding to the same scenario of use than the Gemini CS200.

For the full automat machines, Nespresso asked three companies usually delivering coffee solutions to business consumers (Lyreco, Nurissa and Dallmayr) in addition to their own internal experts on B2B which full automat machines they sold the most commonly to Swiss companies for the two coffee consumption patterns defined (i.e., for 4 000 and for 10 000 cups per year and machine). The sales partners selected among all the full automat machines they sell for a typical use of 4 000 cups per year and machine the three most sold machines. Because they are adequate for a same use intensity, these machines are comparable to the Nespresso Zenius machine. They then selected the three most sold full automat machines for a 10 000 cups per year and machine scenario for the comparison with the Nespresso Gemini CS200 and Momento 100 that are suitable for this use intensity. Among these 3 machines per use scenario, only the more and less efficient machines have been kept for the assessment. This efficiency is a combination of the mass of the machine and its energy consumption. This means that the two full automat machines selected for the study for each use intensity are not the most and least efficient machines among all machines available on the market but the most and least efficient among the three most sold.

The Figure 3-2 shows pictures of the machines assessed. It has to be noted that the different machines have different specificities or functions. For example, the Nespresso Gemini CS200 and Momento 100 have a cup heating system embedded in the machine. The full automat Franke A200 MS EC machine exists also with a separate refrigerated milk compartment or a

separated cup heating compartment but in the current study, the machine without these additional compartments is considered.

Cups/year-machine	Nespresso Pro	Full automat
4 000	 Zenius	 Jura ENA Micro 1 Delonghi Magnifica S 22.110.SB
10 000	 Gemini CS200 Momento 100	 Jura WE6 Franke A200 MS EC




Figure 3-2: Machines considered in the assessment for the two use intensities and the Nespresso and full automat coffee systems

Next to the Nespresso and full automat coffee systems, it has been decided to show for comparison the impacts of an espresso coffee prepared with soluble coffee and using an electric kettle. This scenario is not widely used in business environment but is known as being an efficient way of preparing coffee. As this scenario is meant as a simple comparison point to see how Nespresso and full automat perform compared to a system known as efficient, it is only based on literature data (mostly the PEFCR for coffee) and not on data specific to the Swiss business environment. In a business environment, soluble coffee would be more commonly consumed through vending machines or maybe with small portions in sticks but these scenarios have not been assessed in the current study (sticks portions are estimated through a sensitivity analysis).

The different coffee systems assessed do not have the same extraction efficiency and are simply different products. For this reason, the amount of coffee per cup varies from one product to another. While the amount of roast and ground coffee is well determined in a Nespresso capsule, it can vary a lot in a full automat machine depending on machine setups.

The soluble coffee is spray dried coffee, a most concentrated product than roast and ground coffee that enables to have a reduced amount per cup. The amounts of coffee per cup are further detailed in section 4.2.3 and 4.2.5.

Table 3-1: Scenarios assessed in the study, including the Nespresso Pro and full automat coffee systems and the two use scenarios of 4 000 and 10 000 cups/year.

				
	Cups/ year	Nespresso Pro	Full automat	Soluble coffee
			Efficient machine	Non-efficient machine
Machine	4 000	Zenius	Jura ENA Micro 1	Delonghi Magnifica ECAM 350.75.SB
	10 000	Gemini CS200	Jura WE6	Franke A200 MS EC
		Momento 100		
	Coffee	6.1 g/cup	9 g /cup	2 g/cup
	Packaging	Capsule Pro	Roasted beans in 1 kg pouch	Soluble coffee in glass jar for 200 g

3.4 Critical Review

A critical review has been conducted by Roland Hischier, Hélène Rochat and François Maréchal, three independent experts.

Roland Hischier is an expert in LCA, heading the group on LCA at the EMPA (Swiss Federal Laboratories for Materials Science and Technology) and presiding the board of ecoinvent. He is the chairman of the review panel for this critical review. H  l  ne Rochat is from the company Topten s  rl, a company specialized in the assessment and comparison of a wide set of products, among others coffee machines. Fran  ois Mar  chal is an expert in process modeling and energy conversion with a large expertise in LCA, professor at EPFL (Swiss Federal Institute of Technology Lausanne) and leading the laboratory of industrial process and energy systems engineering.

This review checked that the study followed the stipulations set forth in the ISO 14040 and 14044 standards (ISO 2006a, 2006b).

The critical review process was carried out at the end of the study through the following steps:

- 1) Quantis sent the report to the 3 reviewers in April 2020. The reviewers listed their comments that have been then concatenated by the panel chairman and sent back to Quantis;
- 2) The reviewers, Nespresso and Quantis discussed the main comments, answered the most important questions;
- 3) Quantis updated the report and answered in a separate document to all of the reviewers' comments;
- 4) The 3 reviewers checked the updated report and the answers to the comments and provided a final feedback that was consolidated by the panel chairman. This final feedback constitutes the critical review report that can be found in **Erreur ! Source du renvoi introuvable..**

4 Approach

4.1 Allocation methodology

A common methodological decision point in LCA occurs when the system being studied is directly connected to a past or future system or produces co-products. When systems are linked in this manner, the boundaries of the system of interest must be widened to include the adjoining system, or the impacts of the linking items must be distributed—or allocated—across the systems. While there is no clear scientific consensus regarding an optimal method for handling this in all cases (Reap et al. 2008), many possible approaches have been developed, and each may have a greater level of appropriateness in certain circumstances.

ISO 14044 prioritizes the methodologies related to applying allocation. It is best to avoid allocation through system subdivision or expansion. If that is not possible, then one should perform allocation using an underlying physical relationship. If using a physical relationship is not possible or does not make sense, then one can use another relationship.

4.1.1 Circular footprint formula

The so-called circular footprint formula (CFF), developed by the European Commission and described in the PEF method (European Commission, 2019), is used in this study as an allocation methodology. This is the method judged as the most state-of-the-art and it is recommended to use it for LCA in the framework of the Product Environmental Footprint initiative of the European Commission.

The circular footprint formula takes into account the state of the market for recovered material and balances accordingly the credit in part to the user of the recycled material and in part to the provider of the recyclable material.

The Appendix A – Circular Footprint Formula (section 8.1) presents the details of the formula.

This Circular Footprint Formula is applied for all processes of the foreground system (i.e. processes modelled specifically for this study using data specific to the assessed products), while all processes coming from the ecoinvent database (described below) used for modelling the background system (i.e. upstream activities for which generic information is used in the model, such as production of energy and raw materials or emissions from transport) are using a cut-off¹ allocation methodology. This means that the wastes incineration (e.g., occurring in the aluminium or cardboard supply chain) does not take into account the energy recovery from the incinerator or that the wastes recycling does not include the avoided primary production related to the secondary material produced. This is not expected to have an important influence on the results as the most important wastes for the cup of coffee take place in the foreground system, e.g., at the roasting and grinding factory or at the end-of-life for the coffee grounds and packaging.

4.2 Life cycle inventory

The quality of LCA results is dependent on the quality of data used in the evaluation. Every effort has been made for this investigation to implement the most credible and representative information available.

4.2.1 Data sources and assumptions

4.2.1.1 Primary and secondary data

Life cycle inventory (LCI) data collection mainly concerns the materials used, the energy consumed and the wastes and emissions generated by each process included in the system boundaries. Primary data have been collected directly from Nespresso and have been completed with data from publications and expert judgments.

One major source of secondary data is the draft Product Environmental Footprint Category Rule (PEFCR) for the coffee sector. The Product Environmental Footprint or Organization Environmental Footprint (PEF or OEF) is a European initiative to establish rules on how to perform LCA in various sectors, among others the coffee sector. This pilot on coffee stopped

¹ “The underlying philosophy of this approach is that primary (first) production of materials is always allocated to the primary user of a material. If a material is recycled, the primary producer does not receive any credit for the provision of any recyclable materials. As a consequence, recyclable materials are available burden-free to recycling processes, and secondary (recycled) materials bear only the impacts of the recycling processes.” (Ecoinvent)

during the process but a draft document has been established and it contains a lot of useful data (PEF coffee Technical Secretariat, 2016, called “Draft PEFCR coffee” in the current report). This pilot stopped because no consensus was found about the labelling/comparison part, not because of the data. This draft document, including the part on data it contains has been validated by the European Commission and the coffee stakeholders.

This PEF/OEF initiative also delivered generic guidance and default data that are applicable for all types of products or sectors. These default data are described in a document called “Suggestions for updating the Product Environmental Footprint (PEF) method” and published by the European Commission (European Commission, 2019). This document is used to model several elements in the current assessment (this document is called “PEF method” in the current report). A previous version of this document called “Product Environmental Footprint Category Rules Guidance” version 6.3 of December 2017 (European Commission, 2017) is also sometimes used when the data are not anymore available in the PEF method. This document is called “PEFCR guidance v6.3” in the current report.

For the background processes, most of the data come from the *ecoinvent* database v3.3. All life cycle inventory data sources from the *ecoinvent* database v3.3 are in the cut-off by classification allocation model (Weidema et al. 2013). Ecoinvent is recognized as one of the most complete background LCI databases available, from a quantitative (number of included processes) and a qualitative (quality of the validation processes, data completeness, etc.) perspective. Historically focused on European production activities, it has reached a global coverage of thousands of commodities and industrial processes. The ecoinvent version 3.3 is not the latest available today but it has been chosen as it was used in a previous study made on Nespresso Original capsules and it enables to have consistent results in the two studies. It is not expected to obtain different conclusion with a more recent version of the database.

4.2.2 Electricity mix

The electricity mix used for all activities occurring in Europe (including Switzerland) is the ENTSO-E mix (European Network of Transmission System Operators for Electricity), representing the average electricity mix consumed in Western Europe through the highly interconnected electric grid. Indeed, if there is an increase of electricity consumption in Switzerland, it will not influence the production of hydropower or nuclear power (corresponding to the main part of the Swiss mix) as it is not foreseen to build new hydro or nuclear power plants. A change in the consumption influences therefore the amount of electricity imported or exported and this latter is considered as the average European electricity mix. The use of the ENTSO-E mix enables also to compare with previous studies performed for Nespresso that also apply this electricity mix.

For green coffee cultivation and treatment, the electricity consumed is based on the electricity mix from various coffee production countries.

The use of the Swiss electricity mix for activities occurring in Switzerland is applied in a sensitivity analysis.

As coffee is a product consumed all the yearlong without difference (no seasonal effect), it was not necessary to test a seasonal electricity mix in a sensitivity analysis.

4.2.3 Green coffee supply and Deforestation

The green coffee supply has been modelled according to the PEFCR for coffee that provides a life cycle inventory for a global cultivation of coffee cherries and their treatment into green coffee. The PEFCR for coffee specifies that the irrigation rate, deforestation and delivery to Europe should be adapted according to the origin countries of the coffee blend used in the product studied. This has been done in the current study according to the origin countries for the entire Nespresso supply in 2017 as described in the Table 4-1.

The coffee used for the different coffee systems (NNCH, FAuto, soluble) is considered to be the same and only the amount of coffee varies per product as shown in Table 4-2. Indeed, without specific data about the coffee origin for the other products studied, it has been decided not to differentiate the systems regarding the green coffee supply impacts (the amount of roast and ground coffee per cup for each of the systems is the only differentiating element).

The mass of coffee in the Nespresso Pro capsules corresponds to a weighted average for all espresso capsules sold in Switzerland.

The impacts related to the deforestation stage correspond to the impacts from land use change. The land use change has an impact on various elements, among others on soil properties (carbon content, nutrient leaching, etc.), on biodiversity, on evapotranspiration, on climate (greenhouses gas emissions from biomass burned or degraded, on soil organic carbon, etc.). Only the greenhouse gas emissions from land use change are considered in the current study.

The amount of land transformed over the last 20 years for the different countries of coffee origin and from forest or grassland to perennial cropland (coffee cultivation) is based on FAOstat data and taken from the direct land use change assessment tool from Blonk Consultant (Quantis modified version).

These data are then combined with PAS 2050 (BSI, 2011) data giving greenhouse gas emissions in t CO₂-eq/ha-y for land use change from forest or grassland to perennial cropland for various countries. This approach is in line with the PEFCR coffee and the ENVIFOOD Protocol (ENVIFOOD, 2013) (i.e., using the GHG protocol approach on a country basis).

The land use change is therefore corresponding to statistical land use change in the current study, i.e., related to the average land use change for a certain crop in a given country and not

to data collected per farm or direct land use change. This means that efforts that could be performed on farms and ensured through certification schemes (such as the AAA Sustainability Program in the case of Nespresso or such as other programs for other coffee producers) are not visible in the results of this study.

Table 4-1: Producing countries for the Nespresso blend and data considered for the modelling. The yields correspond to averaged yields from 2004 to 2014 according to FAOstat while the irrigation correspond to data from Pfister blue water (Pfister et al. 2011). The LUC is calculated according to the direct land use change assessment tool from Blonk consultant (for the m² forest or grassland lost/ha-year) and to PAS 2050 data (for the t CO₂/ha-year related to forest and grassland lost). The delivery distances are based on www.searates.com and Google map.

	Fraction of the blend	Yield (kg green coffee/ha-y)	Irrigation (m ³ / t green coffee)	LUC (kg CO ₂ -eq/ha green coffee)	Delivery to Europe (km by ship)	Delivery to Europe (km by truck)	Electricity mix used
Brazil	Confidential data, see Appendix D - – Confidential data	1212	1104	0	7800	2000	Brazil
Colombia		808	1421	0	9600	500	Columbia
Costa Rica		1077	1487	0	9200	100	Costa Rica
India		814	2204	1203.2	12000	800	India
Guatemala		998	2143	121	9000	300	RoW*
Ethiopia		687	1220	10700	8600	500	RoW*
Kenya		329	6429	950	11700	700	RoW*
Mexico		351	3314	0	9500	800	Mexico
Nicaragua		720	1799	9516	10200	300	RoW*
Others		576	4218	11061	12990	484	RoW*

*RoW stands for Rest of the World and correspond to an averaged electricity mix for countries with un-modelled electricity mix in the ecoinvent database.

Nespresso sources its major fraction of coffee (94% in 2019) through its sustainability program named the Nespresso AAA Sustainable Quality™ Program hereafter referred as Nespresso AAA. It is partly certified as FairTrade and Rainforest Alliance (56%). These 3 labelling (AAA, FairTrade and Rainforest Alliance) are not considered in the current study as it is unknown for the other coffee systems which type of coffee is used: Is it also sustainably sourced? Are the certification criteria different or similar to the Nespresso criteria? Where is it sourced? To avoid differentiating the systems on uncertain parameters, it has been decided to keep the same green coffee cultivation for all.

Table 4-2: Green coffee supply data for the coffee systems studied.

	NNCH	FAuto	Soluble
Coffee cultivation	Average Nespresso green coffee supply (2017 blend), see Table 4-1		
Delivery to factory	Average NN green coffee supply (2017 blend)		
R&G coffee g/cup	6.1 g/40 ml (weighted average for the Swiss market). Range is from 6 to 6.3 g/40 ml. Data source: Primary data - Nespresso CH 2019.	9 g/40 ml Data source: The draft PEFCR coffee gives 9 g roasted beans for a 40 ml coffee. Variation of this parameter is tested in the sensitivity analyses.	2 g/40 ml Data source: Draft PEFCR coffee. 2 g is for a lungo coffee, assumed to be the same for an espresso. Variation of this amount is tested in a sensitivity analysis.

4.2.4 Packaging production

The packaging production includes the production of the materials and their forming for the primary, secondary and tertiary packaging.

The primary packaging corresponds to the capsule for the NNCH coffee system, a laminated pouch of 1 kg roast coffee beans for the FAuto and a glass jar with plastic cap for the soluble coffee. The secondary packaging corresponds to the sleeve containing 50 capsules for the NNCH and there is no secondary packaging for the FAuto and soluble coffee systems. The tertiary packaging consists in a corrugated board box, a pallet and an LDPE film for Nespresso and a carton board tray containing several pouches or glass jars for the soluble coffee plus the pallet and LDPE film for FAuto and soluble systems.

The packaging production for the NNCH coffee system is based on primary data from Nespresso. For the FAuto and soluble coffee systems, the packaging data come from the PEFCR study for coffee or own measurement. Packaging details for all coffee systems are provided in Table 4-3.

Table 4-3: Packaging production data for the coffee systems studied. All data are given per functional unit, i.e., per cup of espresso coffee except is specified otherwise in the table.

	NNCH	FAuto	Soluble
Primary packaging	Laminate: - 0.36 g alu - 0.0736 g PET - 0.06 g PP - 0.0309 g adhesive Data source: Primary data - Nespresso HQ	- 0.030 g PET - 0.039 g alu - 0.269 g LDPE Data source: own measurement for the total pouch weight (13.2 g/500 g R&G coffee pouch), draft PEFCR coffee for the composition of the pouch (PET12/alu8/LDPE6)	- 4.84 g glass jar - 0.18 g PP cap - 0.004 g alu membrane - 0.022 g PE wad - 0.018 g paper label Draft PEFCR coffee describes the soluble coffee packaging for a 100 g soluble coffee as 242 g glass, 9.2 g PP, 0.2 g alu, 1.1 g PE, 0.9 g paper.

	NNCH	FAuto	Soluble
Secondary packaging	0.75 g solid bleached board Data source: Primary data - Nespresso HQ	None	None
Tertiary packaging	Tertiary box: Corrugated board: 0.41 g LDPE film: 0.01 g Pallet (wood): 0.011 g Data source: Primary data - Nespresso HQs	1.47 g carton board and 0.045 g LDPE film (box), 0.006 g pallet and 0.002 g LDPE film (pallet) Data source: draft PEFCR coffee (16.3 g CB and 0.5 LDPE film (box) for 100 g, 1 pallet and 150 g LDPE film (pallet) for 792 kg R&G coffee)	0.066 g corrugated board and 0.02 g LDPE film (box), 0.01 g pallet and 0.005 g LDPE film (pallet) Data source: draft PEFCR coffee (3.3 g CB and 1.5 g LDPE film (box), 0.001 pallet and 0.25 g LDPE film (pallet)/100 g)
Packaging delivery	Capsule: 131 km Sleeve and tertiary packaging: 180 km All transports are per truck 16-32 t EURO 4. Data source: Primary data - Nespresso HQ	Truck (16-32 t EURO4): 230 km Train: 280 km Ship: 360 km Data source: PEF guidance v6.3	

4.2.5 Manufacturing

This life cycle stage includes the energy, water, gases, building, machinery that are needed for the processing of green coffee into roast and ground coffee. The wastes generated and their treatment are also considered. The data have been collected by the Nespresso HQ for 2017 and correspond to a weighted average of the production center of Orbe, Avenches and Romont (weighted by the amount of espresso Pro capsules produced in the three manufacturing sites of Nespresso). The same data are considered for the processing into roasted coffee for the full automat coffee system. Indeed, without specific data for the other systems, it was decided to consider the same data to avoid an artificial differentiation on this life cycle stage. The full automat system does not use ground coffee but the grinding stage is judged to have a very small energy consumption compared to the roasting according to the PEFCR coffee Technical Secretariat experts.

The manufacturing main inputs considered are the following:

- Input of green coffee: 1.2 kg green coffee/kg R&G coffee
- Energy: renewable electricity, natural gas and diesel
- Water and gases (CO₂ used as protective atmosphere gas)
- Building and machinery. The building lifetime considered is 50 years, while the machinery is 10 years.
- Wastes: coffee wastes sent to biodigester (outside manufacturing site), various packaging wastes (mainly cardboard)
- Emissions of CO₂ used as protective atmosphere

Because of their confidential character, the numbers are described in the **Erreur ! Source du renvoi introuvable.**

One of the Nespresso factories (Romont) has the LEED certification (this is a certification for buildings respecting various criteria in relation to the energy consumption of the building and the building material used). This effort is visible through the energy consumption of the building but not for the building construction as for this latter, a generic data is considered. However, the construction of the building is a negligible contributor to the factories impacts in comparison with all the operations (2% of the manufacturing carbon footprint).

As the same manufacturing impacts per kg of coffee are considered for the full automat, it means this latter uses renewable electricity too. This favours the competitive system as its manufacturing is not necessarily using renewable electricity, but it is also safe side in the context of the study with Nespresso comparing its environmental impacts with other coffee systems. The renewable electricity stays modelled as renewable mix (mix of solar photovoltaic, wind power and micro-hydropower) in the sensitivity analysis changing the average European electricity mix into Swiss grid mix.

The manufacturing for the soluble coffee is based on data from the PEFCR coffee, themselves based on Humbert et al. 2009. Here are the flows considered for 1 kg of spray dried soluble coffee:

- 2.22 kg green coffee
- 2.3 kWh electricity
- 29 MJ natural gas
- 1.3 kg coffee grounds burned
- 11 L freshwater, from well
- 19 L tap water

4.2.6 Overheads / Support

The overheads for Nespresso include the activities related to the global headquarter administrative center, the Swiss market head office, the Swiss after sales centers and the Swiss call center.

For each of these elements, the system includes the building, electricity, natural gas, paper and water use, the IT equipment, the employees commuting and the business travels. For the global headquarters, there are in addition to the administrative center activities, some services that are quantified through their costs using the US input-output database. This database gives environmental impacts per USD spent in 2002 in various economy sectors. The inflation and exchange rates are used to go up to the 2002 data from the database. These services are

therefore assessed based on their cost and not on physical flows. The following services are considered: advertising, auditor fees, legal services and security.

In total for all overheads the flows per cup of coffee is as follows: 0.09 cm² of building, 1.1 Wh electricity, 7.7 kJ natural gas, 25 g water, 0.2 g paper, a commuting done 54% by car, and for the business travels, 0.01 pkm by car, 0.0008 pkm by train and 0.001 pkm by plane.

The same data are considered for the Overheads / support for all coffee systems studied. Indeed, without specific data for the other systems, it was decided to consider the same data for all to avoid an artificial differentiation on this life cycle stage.

4.2.7 Distribution

This life cycle stage covers the transportation of the production from the manufacturing site to the consumer. Detailed data regarding this life cycle stage are provided in Table 4-4.

For the Nespresso capsules, the distribution can be done either via delivery partners or via postal delivery. The postal distribution includes the transport from the manufacturing site to the “arrival post”, then the postal delivery from the post office to the consumers’ location. The electric consumption related to the internet use for the order is also included. The distribution via delivery partners is very similar with a transport from the manufacturing site to the client and an internet order. The delivery partners are companies selling office products to companies, e.g., Lyreco delivers Nespresso capsules to companies.

For the two other systems, (the roasted coffee in laminated pouch used for the FAuto, and the glass jar of soluble coffee), the distribution is assumed to be done by delivery partners, considering the same data as for Nespresso. Indeed, these data are suitable for a Swiss market and more precise (various transportation means, number of parcels) than the default data from the PEF guidance v6.3 (which correspond to a default data for Europe). In addition, the delivery partners distributing Nespresso capsules to businesses also suggest roasted coffee beans and other type of coffee solutions to their clients.

For the three systems, it is assumed the companies order about once per month, i.e, for the 4 000 cups/year scenario: 300 capsules, 3 pouches of 1 kg R&G coffee or 3 glass jars of 200 g soluble coffee per order and for the 10 000 cups/year scenario: 800 capsules, 8 pouches of 1 kg R&G coffee and 8 glass jars of soluble coffee.

Losses on the supply chain are considered for all products during the distribution. The additional fraction of product that has to be produced and distributed up to the retailer is considered, as well as the end-of-life treatment of these losses. For all products, the losses on the supply chain are assumed to take place at the retailer and they correspond to 1% losses (based on PEF method).

Table 4-4: Distribution data considered for the different coffee systems.

	NNCH	FAuto	Soluble
Distribution	<p>Distribution shares by delivery partners or post: 64% via delivery partners and 36% by post</p> <p>Manufacturing site to client via delivery partner: 155 km, 84% by 7.5-16 t truck, 13% by van, 3% by 3.5-7-5 t trucks. 120 parcels delivered/trip (400 capsules/parcel)</p> <p>Manufacturing site to arrival post: 105 km, 50% by train, 40% by truck, 10% by van</p> <p>Postal delivery: 30 km by van for 150 parcels delivered. 1 parcel assumed for the 4 000 cups/year system and 2 parcels assumed per order for the 10 000 cups/year (to take into account the higher amount of products per order).</p> <p>In both cases (delivery partner/postal delivery): Internet order: assumption of 2 minutes of a computer and network use (100 W) for an order of capsules</p> <p>Data source: NNCH 2017 data for the split among delivery partners and postal distribution and for delivery partners data, previous NN studies for the postal delivery (based on Postlogistic data from 2012) and the internet order.</p>		<p>100% distribution via delivery partners is considered by default. The same distance and type of transport is considered as for the NNCH (i.e., 155 km, 84% by 7.5-16 t truck, 13% by van, 3% by 3.5-7-5 t trucks), also for the internet order.</p> <p>1 parcel assumed for the 4 000 cups/year systems and 2 parcels assumed per order for the 10 000 cups/year (to take into account the higher volume occupied).</p> <p>Data source: NNCH 2017 data and assumptions.</p>

4.2.8 Use stage

The use stage includes the machine production fraction, the cup production, the coffee brewing (machine use), the machine cleaning and the cup washing. For the full automat, the production and distribution of the regularly changed water filter is also included. Detailed data regarding this life cycle stage are provided in Table 4-5.

For all systems, no wastes of coffee or water during the use stage are considered. The inclusion of coffee or water wastes is considered in sensitivity analyses. The baseline takes into account the heat wastes by machines considering the energy losses related to the machine heating, ready-to-use or standby modes.

4.2.8.1 Machine selection

As specified in section 3.1.1, two consumption scenarios are considered for this study, corresponding to different use intensities in companies:

- 4 000 cups/year

- 10 000 cups/year

These use intensities have been defined considering Nespresso average capsule sales per machine type in Switzerland and have been applied to all machines compared.

The coffee machines to be used for the different use scenarios are different, indeed, for a more intense use, the machines have to deliver coffee faster and be more robust. The type of machine used for each scenario is detailed in Table 4-5. For the selection of full automat machines, Nespresso sales forces managers provided a broad list of main competing products available on the Swiss market in the relevant product category. A survey was then conducted with external partners who also commercialize non-Nespresso coffee machines in 2019: Lyreco, Nurissa and Dallmayr. They had to define a list of the machine stock for the 2 use intensities scenario. Among this set of full automat machines, three were selected for each of the use scenario according to the sales volumes. Among these 3 most sold machines per use intensity, only the best (efficient) and worst (non-efficient) performing machines have been kept for the assessment. This performance combines the mass of the machine and its energy consumption.

4.2.8.2 Machine production

The machine production fraction life cycle stage includes the production of the machine as well as its distribution up to the consumer. The machine production includes the production of the different materials, their delivery up to the machine production place and their forming into pieces. The packaging of the machine is neglected and not included in this study. The data for machine composition is based on Nespresso data for the capsule machine, and on the PEFCR for coffee for the full automat machine, as well as for the kettle used for the soluble coffee preparation. A default machine lifetime of 10 years has been proposed by Nespresso as a fair assumption, considering the contract duration with customers and the time the replacement pieces are available. This same lifetime is considered for the full automat machine by default as no information was available for this kind of machines for business use. The lifetime of the machines is a parameter tested in the sensitivity analyses.

Regarding the maintenance, only the water filter that needs to be changed regularly for the full automat has been included (production and end-of-life treatment of the filters). No repair activities are included.

The machine distribution is a distribution via delivery partners as modelled for the coffee beans pouch or the glass jar delivery (see section 4.2.7).

4.2.8.1 Machine use

The coffee brewing corresponds to the electricity consumption by the machine to prepare a cup of coffee (including the energy consumed for machine heating, stand by, keeping warm,

coffee preparation, etc.) and the tap water consumed in the cup. The full automat machines used for the scenario with 4 000 cups/year are machines that can be used for private use too and therefore, an electricity consumption is published on the energy label. This electricity consumption corresponds to the annual electricity consumption by the machine according to the measurement protocol EN 60661 (CENELEC 2014). This energy label gives the total annual electricity consumption of the machine following the EN 60661 protocol. This latter includes 3 coffee periods during which 1 cup of 40 ml, 1 cup of 120 ml and 2 cups of 40 ml are prepared (240 ml per coffee period), i.e., 262.8 L/year. The yearly energy consumption is divided by the total volume of coffee prepared annually and then the ratio for 40 ml is calculated. The corresponding Nespresso machine (Zenius), is designed to use a capsule format only available in professional sales channels (Pro capsules). To be consistent with the full automat machines it is compared with, it has been decided to calculate the energy consumption following this same EN 60661 protocol. The energy consumption of the Zenius machine following this EN 60661 protocol has been measured by the German company VDE, a world renowned certification company, that is therefore specialized in this kind of measurements.

The energy consumption for professional machines to be used in offices and restaurant is calculated according to another protocol (indeed, the number of coffee cups prepared per day is much higher, leading to a division of heating or standby phases into much more cups of coffee). This protocol for energy consumption calculation for such machines is detailed in the DIN 18873-2 norm (German National Standard, 2012). This norm explains the protocol to follow to measure the energy losses of the machines. For this study, these data were taken on the HKI Cert website (<https://grosskuechen.cert.hki-online.de/en>). The daily energy losses due to machine heating, keeping warm, standby, etc. are calculated considering a certain time the machine is ON. For this study, we considered the machine is ON for 12 hours a day, 260 days/y (5 days over 52 weeks). Then, this energy consumption is divided by the number of cups prepared per day (15 cups/machine-day for the 4 000 cups/year scenario and 38 cups/machine-day for the 10 000 cups/year scenario). The energy consumption for the coffee brewing itself is defined by the HKI Cert website as 3.5 Wh for a 40 ml cup for all full automat machines. This is what was considered in the study. For the Nespresso Gemini CS200 and Momento 100 machines from Nespresso, the energy losses measurement according to this same DIN 18873-2 was performed by the German company VDE. In addition, VDE measured a consumption for brewing of 4.7 Wh/cup instead of the 3.5 Wh/cup from the HKI Cert website. As all machines of the HKI Cert website have the 3.5 Wh/cup consumption for the brewing of 40 ml espresso, it has been decided to consider this energy consumption for Nespresso machines also (no reason to have a difference for brewing) and the consumption of 4.7 Wh/cup has been applied for all machines in a sensitivity analysis.

The Nespresso Gemini CS200 and Momento 100 machines have a function of cup heating. It is possible to decide if one would like to use this function or not in the machine setups. The energy consumption data used in this report consider the cup heating function is ON as the tests

performed by VDE include it. This is therefore a conservative approach and not in favor of Nespresso in the framework of this comparative study. A sensitivity analysis considers that this function is not selected by the user and the energy consumption is reduced.

The electricity consumption of the kettle used for the soluble coffee is based on the PEFCR coffee.

4.2.8.1 Machine cleaning

The machine cleaning includes the water used for the cleaning as well as the energy needed to heat the water when needed, and the wastewater treatment. The amount of water used for cleaning is based on the PEFCR coffee and is the same for capsule and full automat machines, and different for the kettle.

4.2.8.1 Cup production and washing

A ceramic cup is considered, with a mass and lifetime based on the PEF guidance v6.3. The cup production corresponds to the production of the ceramic cup and its distribution via supermarket (based on the PEFCR guidance v6.3). There are no losses considered on the supply chain according to the PEF method. The cup is assumed to be washed 100% in a dishwasher. The dishwasher production, its electricity, water and soap consumption for a cycle and its end-of-life treatment are considered and are based on the PEF method.

Table 4-5: Data considered to model the use stage.

	NNCH	Full automat		Soluble
Scenario 4 000 cups/year				
Machine considered	Zenius	Jura ENA Micro 101	Delonghi Magnifica S ECAM 22.110.SB	Draft PEFCR coffee average kettle
Machine weight	7.3 kg ^a	8.9 kg ^b	9 kg ^c	1.1 kg ^d
Machine composition	19% ABS, 15.5% alu, 11.6% zamak, 9.7% SAN, 9.7% PP, 9.7% PA, 8.6% steel, 4.9% copper, 4.7% electronic components, 3.4% rubber, 3.2% PVC ^e	26% ABS, 18% electric motor, 17% PP, 17% PC, 13% steel, 7% plastic misc, 3% electronic components, <1% others ^d		77% PP, 11% steel, 5% rubber, 3% phenolic resin, 3% brass, 1% copper ^d
Machine delivery	See section 4.2.7			
Machine lifetime	10 years ^e	10 years ^f		5 years ^d
Consumables	None	Filter: 190 g (modelled as 100% PE), changed every 50 L coffee brewed. ^g		None
Coffee brewing	8.2 Wh/cup ^h	8.2 Wh/cup ⁱ	9.0 Wh/cup ^j	0.125 kWh/L boiled water. i.e.,

	NNCH		Full automat		Soluble
electricity consumption					5 Wh/cup of 40 ml ^d
Scenario 10 000 cups/year					
Machine considered	Gemini CS200	Momento 100	Jura WE6	Franke A200 MS EC	Same data as for the 4 000 cups/year scenario
Machine weight	15 kg ^l	16 kg ^m	10 kg ⁿ	25 kg ^o	
Machine volume	0.081 m ³ ^l	0.063 m ³ ^m	0.055 m ³ ⁿ	0.115 m ³ ^o	
Machine composition	28.5% ABS, 17.5% steel, 14.6% alu, 8.2% SAN, 8.2% PP, 8.2% PA, 5.6% copper, 4.8% electronic component, 2.4% rubber, 2.2% zamak ^e	Assumed same as Zenius. ^p	26% ABS, 18% electric motor, 17% PP, 17% PC, 13% steel, 7% plastic misc, 3% electronic components, <1% others ^d		
Machine delivery	See section 4.2.7				
Machine lifetime	10 years ^e		10 years ^f		Same data as for the 4 000 cups/year scenario
Consumables	n.a.		Filter: 190 g (modelled as 100% PE), changed every 50 L coffee brewed. ^g		
Coffee brewing electricity consumption	19.8 Wh/cup ^q	19.7 Wh/cup ^q	7.5 Wh/cup ^r	23.5 Wh/cup _s	
Scenario 4 000 and 10 000 cups/year					
Coffee wastes	Baseline scenario: no prepared coffee waste considered.				
Cup production and washing	Cup production: 120 g ceramic, 365 uses over its lifetime. ^d Cup distribution: see section 4.2.7, without losses over the supply chain. ^k Cup washing: 1/40 of the dishwasher cycle (1.2 kWh, 15 L water and 10 g detergent per cycle, production and end-of-life of the dishwasher included). ^k				
Machine cleaning	2 l of water at the temperature of 35°C every 300 brews ^d				2 l of boiled water every 3 months ^d

^a <https://www.nespresso.com/pro/ch/fr/pages/machine-zenius-landing-page>

^b https://jp.jura.com/-/media/global/pdf/manuals-global/home/ENA-Micro/download_manual_jura_ena-micro1.pdf?la=fr&hash=2FA1407F99DD237512905CF24053D4E28551E423&em_force=true

^c <https://www.delonghi.com/fr-ch/produits/cafe/machines-a-cafe/machines-a-cafe-automatiques/magnifica-s-ecam-22110sb-0132213074>

^d PEFCR coffee

^e Nespresso CH data completed with some assumptions taken from DG ENER 2011 for the composition of an average coffee pod machine.

^f Assumption: same as Nespresso CH data

^g Own measurement for the mass, assumption for the composition, https://ch.jura.com/fr/support/conseils-d-entretien/faq#H_for_the_lifetime

^h Measurement of Nespresso machine by VDE, applying EN 60661 protocol (to be consistent with the full automat machines energy consumption data). VDE is a testing and certification institute used to perform energy measurement following the existing measurement protocols. www.vde.com

ⁱ Energy label of the machine, visible on <https://www.fust.ch/fr/p/cuisine/jura-a-propos-du-cafe/machines-a-cafe-automatiques-jura/jura/ena-micro-101-micro-black-8183906.html>, applying the EN 60661 protocol: 53.8 kWh/y.

^j https://www.topten.ch/private/products/coffee_machines, applying the EN 60661 protocol: 59 kWh/y.

^k PEFCR guidance v6.3

^l <https://www.nespresso.com/pro/ch/fr/pages/machine-gemini220-landing-page>

^m <https://www.nespresso.com/pro/ch/fr/pages/machine-momento100-landing-page#Caract%C3%A9ristiques>

ⁿ <https://ch.jura.com/fr/produits-professional/machine-automatique-a-cafe/WE6-CH-15140/Specifications#tabs>

^o https://www.franke.com/main/fr/cs/produits/fully-automatics/a200%20ms%20ec_detail.html

^p No data on Momento composition was available. The most impacting composition of the two available Nespresso machines was considered for the baseline, i.e., the Zenius machine. In reality, the Momento machine is expected to have more electronic components (large screen) and contains more pieces in metal. A sensitivity analysis is performed on the machine composition.

^q Measurement for Nespresso machines by VDE, applying DIN 18873-2 protocol (consistent with the full automat machines energy consumption data) for the energy losses. For the coffee brewing, the electricity consumption per ml prepared from the HKI Cert website (<http://grosskuechen.cert.hki-online.de>) of 0.087 Wh/ml is considered to be aligned with the full automat machines. VDE is a testing and certification institute used to perform energy measurement following the existing measurement protocols. www.vde.com

^r <http://grosskuechen.cert.hki-online.de/en/geraet-anzeigen?id=237>

^s <http://grosskuechen.cert.hki-online.de/en/geraet-anzeigen?id=237>

4.2.9 End-of-life

The end-of-life stage includes the collection and treatment of the different packaging items, the coffee grounds, the machine and the cup. Detailed data regarding this life cycle stage are provided in Table 4-6. The wastes occurring at the coffee farms, at the factories or at the Nespresso headquarters are included respectively in the green coffee supply, manufacturing and overheads life cycle stages.

It is considered that 15% of the coffee goes in the cup and that the coffee grounds contain 60% water (Nespresso HQ data). This means that for 1 kg R&G coffee packed in capsules, there are 2.1 kg coffee grounds. The same assumption is made for the coffee used for full automat.

4.2.9.1 Collection

The collection for all wastes except capsules sent to recycling is assumed to be a 30 km truck transport (municipal collection). A plastic bag is also considered for all wastes except for the cardboard, the machines that are recycled and the pallets: 6.7 g PP per kg waste according to the PEF method.

The collection for recycling of the Nespresso capsules is based on specific data collected on the Swiss market. There are 2 different reverse logistic routes existing for the Pro capsules on the Swiss market and one of them represents 99% of the volume. This latter is therefore considered for the total volume and it corresponds to:

- 100 km by 7.5-16 t truck
- 40 km by 16-32 t truck

4.2.9.2 Incineration

In Switzerland, 100% of the trashed wastes are incinerated. Incineration with energy recovery is considered, with the average heat and electricity recovery rate in Switzerland, i.e., 23% of the energy recovered as heat and 11% as electricity (PEF method). The heat is assumed to replace heat from natural gas while the electricity replaces the average European electricity mix (ENTSO-E, mix used as input for all electricity flows, except for coffee processing on farm).

The incineration of the different materials is built according to the CFF (circular footprint formula) following the PEF method document (see also section 4.1.1).

The following lower heating values are considered to calculate the energy recovery:

- Plastics: PET 23 MJ/kg, PP 32.8 MJ/kg, PE 42.5 MJ/kg, LDPE 42.5 MJ/kg
- Paper and cardboard: paper 14.1 MJ/kg, cardboard 15.9 MJ/kg
- Others: glass 0.05 MJ/kg, wooden pallet 14 MJ/kg, coffee grounds with 60% water 7 MJ/kg

For the aluminium, an oxidation rate is applied. The oxidized fraction provides energy (31.6 MJ/kg according to the PEF method), while the non-oxidized part goes into the bottom ashes. Aluminium foil with a thickness of 6 to 50 μm is 55% oxidized according to the PEF method. Another expert data on aluminium oxidation in incinerator estimated the foils up to 30 μm are fully oxidized². Based on this latter information and knowing the aluminium foil in the Pro capsule, in the laminated pouch of R&G coffee and for the sealing membrane of the glass jar are less than 30 μm thick, the current study considers a full oxidation of the aluminium in the incinerator and no aluminium recovery from bottom ashes.

4.2.9.3 Recycling

The recycling of the different materials is built according to the CFF (circular footprint formula) following the PEF method document (see also section 4.1.1).

A part of the burdens (transport and processing) and credits (primary material production avoided) are allocated to the systems studied, while a part will be allocated to the user of the secondary material. This allocation factor is defined by the European Commission in the PEF method document and depends on the market. For aluminium, copper and steel, and cardboard, 80% of the burdens and credits are allocated to the system sending waste to the recycling route, i.e., in this case to the systems studied here (see Appendix A – Circular Footprint Formula, section 8.1).

² Personnal communication with Rainer Bunge from HSR Rapperswil, July 2018

The average recycling rate of cardboard in Switzerland is 81% and the recycling rate of glass is 94% (according to 2017 FOEN statistics³). For cardboard, this recycling rate is considered for all cardboard wastes, wherever they occur (at user, i.e., at company or during distribution).

³ <https://www.bafu.admin.ch/dam/bafu/fr/dokumente/abfall/statistik/abfallmengen-recycling-ueberblick-2017.pdf.download.pdf/D%C3%A9chets%202017%20-%20Quantit%C3%A9s%20produites%20et%20recycl%C3%A9es.pdf>

Table 4-6: End-of-life data considered in the modelling.

	NNCH	FAuto	Soluble
Primary packaging and coffee grounds treatment type	<p>The capsules are 78% incinerated and 22% recycled (NNCH data for 2019).</p> <p>Coffee grounds goes 78% to incineration (with the capsule) and 22% to biodigester (when capsule is recycled) (NNCH data).</p>	<p>The laminated pouch is 100% incinerated: there is no recycling option existing in Switzerland for this kind of packaging.</p> <p>The coffee grounds go 50% to trash (i.e., incineration), 25% to compost and 25% to a biodigester according to PEF method default treatment for food wastes. The fact that the coffee grounds not incinerated is half composted and half sent to a biodigester is confirmed for Switzerland by a study on organic wastes performed for the FOEN (Mandaliev and Schleiss 2016).</p>	<p>The glass jar is assumed to be partly recycled (94%, see above), while the caps and wad are trashed (i.e., 100% incinerated). The paper label goes to glass recycling with the glass and is incinerated once separated from the glass stream.</p>
Primary packaging and coffee grounds to trash	<p>Incineration: collection and treatment, see above.</p>	<p>Incineration: collection and treatment, see above.</p>	<p>Incineration: collection and treatment, see above.</p>
Primary packaging to recycling	<p>Recycling Collection: see above Capsule separation: per kg input material, 1.5 m of 16-32 t truck (from Henniez to Moudon), 33 Wh electricity and 0.33 MJ natural gas (NNCH data) Aluminium recycling: 1254 km truck from Moudon to remelter in Germany (NNCH data), the PET, PP and glue layers burn during the remelting process while the aluminium is remelted into secondary aluminium. This avoids the use of primary aluminium (wrought alloy)^a. (PEF method and assumptions). The remelting yield considered is of 60% (NNCH assumption).</p>	<p>Recycling: the pouch is considered to be 100% incinerated.</p>	<p>Recycling Collection: see above Glass jar recycling: it is assumed the glass jar is recycled considering the PEF method average glass recycling data and the paper label on the jar is assumed as incinerated.</p>

	NNCH	FAuto	Soluble
Coffee grounds to recycling	Coffee grounds to biodigester: for 1 kg of coffee grounds with 87% dry matter (water content measured by NNCH after the capsule separation that includes also a drying process) is transported to Henniez (10 km), then mixed with other organic wastes to produce 4.3 MJ heat that is 60% sold and 0.79 kWh electricity that is 92% sold. A part of the remaining heat is used to dry capsules before the capsule separation and therefore enables to reduce the heat consumption at Moudon site. The digestate is transported to farms in the surrounding and used as a fertilizer without being previously composted. (NNCH data and PEF method).	<p>Composting: collection, see above. The composting modelled is industrial composting. The handling of the compost, the direct emissions (CH₄, NH₃, CO₂ and N₂O) and infrastructures are considered as well as the benefits related to the compost use, i.e., mineral fertilizers production avoided, improvement of yield and peat use avoided. This is based on Quantis internal database.</p> <p>Biodigestion: collection, see above. Biodigestion is based on the Henniez plant and data from NNCH (see NNCH system data).</p>	No coffee grounds for soluble system (treated at the manufacturing stage)
Secondary packaging	<p>Sleeve collection: see above</p> <p>Sleeve treatment: 81% recycling and 19% incineration (see above)</p>	<p>Tray/box collection: see above / Tray/box treatment: 81% recycling and 19% incineration (see above)</p> <p>LDPE film collection : see above / LDPE film treatment: assumed 100% trashed, i.e., incinerated</p>	
Tertiary packaging	<p>Tertiary box collection: see above / Tertiary box treatment: 81% recycling and 19% incineration (see above)</p> <p>Wooden pallet and LDPE film are assumed 100% trashed, i.e., incinerated.</p>		
Machine	<p>Machine collection: see above</p> <p>Machine treatment: for all types of machines, it is considered they are dismantled and then the metallic parts are assumed to be 100% recycled while the plastic parts are 100% incinerated. The dismantling is assessed through a generic dataset for electric waste shredding.</p>		
Cup	The cup is sent to an inert material landfill according to the draft PEFCR coffee.		

^a Primary aluminium has a carbon footprint of 9.4 kg CO₂-eq/kg while secondary has a carbon footprint of 7.7 kg CO₂-eq/kg, mainly related to a lower electricity consumption.

4.2.10 Data quality assessment

Foreground processes and data sources are assessed by the practitioner on the basis of time-related coverage, geographical coverage, technology coverage, precision, completeness, representativeness, consistency, reproducibility, reliability of data source and uncertainty of the information as prescribed in ISO 14044. The pedigree matrix for rating inventory data appears below, with a score of one being most favorable and a score of five being least favorable. A complete discussion of this topic can be found in Weidema et al. (2013). The criteria specified for the different scores in Table 4-7 are not always relevant or applicable. In such cases, the scores are given comparing the different systems assessed and common sense, but the scores remain quite subjective.

Table 4-7: Pedigree matrix used for data quality assessment.

Indicator score	1	2	3	4	5
Reliability	Verified data based on measurements	Verified data partly based on assumptions or non-verified data based on measurements	Non-verified data partly based on qualified estimates	Qualified estimate (e.g. by industrial expert)	Non-qualified estimate
Completeness	Representative data from all sites relevant to the market considered, over an adequate period to even out normal fluctuations	Representative data from >50 of the sites relevant for the market considered, over an adequate period to even out normal fluctuations	Representative data from only some sites (<<50) relevant for the market considered or >50 of sites but from shorter periods	Representative data from only one sites relevant for the market considered or some sites but from shorter periods	Representativeness unknown or incomplete data from a smaller number of sites and from shorter periods
Temporal correlation	Less than 3 years of difference to the time-period of the dataset	Less than 6 years difference to the time-period of the dataset	Less than 10 years difference to the time-period of the dataset	Less than 15 years difference to the time-period of the dataset	Age of data unknown or more than 15 years of difference to the time-period of the dataset
Geographical correlation	Data from area under study	Average data from larger area in which the area under study is included	Data from area with similar production conditions	Data from area with slightly similar production conditions	Data from unknown or distinctly different area
Further technological correlation	Data from enterprises, processes and materials under study	Data from processes and materials under study but from different enterprises	Data from processes and materials under study but from different technology	Data on related processes or materials	Data on related processes on laboratory scale or from different technology

The data quality assessment performed for this study is presented in Table 4-8. The scores into brackets correspond to: reliability, completeness, temporal correlation, geographical correlation, technological correlation. Then the average score is calculated. A score of 1 to 1.6 means an excellent quality, from 1.6 to 2, a very good quality, from 2 to 3 a good quality, from 3 to 4 a fair quality and from 4 a poor quality.

Table 4-8: Data quality assessment. The green coffee supply and the use stage are the most impacting life cycle stages, the packaging and overheads are medium contributors while the manufacturing, distribution and end-of-life are very small contributors to the life cycle impacts.

		NNCH	FAuto	Soluble
Green coffee supply		3; 1; 1; 3; 2 = 2, good quality	3; 2; 1; 3; 3 = 2.4, good quality	
Green coffee supply amount		1;1;1;2;1 = 1.2, excellent quality	2;2;2;2;2 = 2, very good quality	2;2;2;2;2 = 2, very good quality
Packaging production	Primary packaging	1; 1; 1; 2; 2 =1.4, excellent quality	2; 2; 1; 2; 2 = 1.8, very good quality	
	Secondary packaging	1; 1; 1; 2; 2 =1.4, excellent quality	2; 2; 2; 2; 2 = 2, good quality	
	Tertiary packaging	2; 1; 1; 2; 2 = 1.6, very good quality	3; 2; 2; 2; 2 = 2.2, good quality	
Manufacturing		1; 1; 1; 1;1 =1, excellent quality	1; 4; 1; 3; 2 = 2.2, good quality	2; 3; 2; 3; 2 = 2.4, good quality
Distribution	Manufacturing site to post	2; 2; 1; 2; 2 = 1.8, very good quality	Not applicable	
	Postal delivery	2; 2; 3; 2; 2 = 2.2, good quality		
	Manufacturing site to consumer via delivery partner	3; 3; 1; 1; 1 = 1.8, very good quality	3; 3; 1; 1; 2 = 2, very good quality	
	Internet order	4; 3; 3; 2; 3 = 3, fair quality		
	Losses over supply chain	4; 3; 2; 3; 2 = 2.8, good quality		
Support	Global HQ	1; 2; 2; 1; 2 = 1.6, very good quality	3; 3; 1; 1; 3 = 2.2, good quality	
	Global services	2; 3; 2; 4; 4 = 3, fair quality	3; 3; 3; 4; 4 = 3.4, fair quality	
	Market HO, call centers and after sales centers	1; 2; 2; 1; 2 = 1.6, very good quality	3; 3; 2; 1; 3 = 2.4, good quality	
Use stage	Machine production	Zenius/Gemini: 2; 1; 1; 1; 1 = 1.2, excellent quality Moment: 2; 1; 1; 1; 3 = 1.6, very good quality	2; 2; 2; 2; 2 = 2, good quality	2; 2; 2; 2; 2 = 2, good quality
	Machine distribution	3; 2; 2; 2; 2 = 2.2, good quality		
	Consumables or replacement pieces	Not applicable	3;3;2;2;3 = 2.6, good quality	Not applicable
	Coffee brewing	2; 1; 1; 1; 2 = 1.4, excellent quality	2; 1; 1; 1; 2 = 1.4, excellent quality	3; 3; 2; 2; 2 = 2.4, good quality
	Cup production and washing	2; 2; 2; 2; 2 = 2, good quality		
	Machine cleaning	3; 1; 2; 2; 3 = 2.2, good quality	3; 1; 2; 2; 3 = 2.2, good quality	3; 1; 2; 2; 3 = 2.2, good quality
End-of-life	Primary packaging and coffee	2; 1; 1; 1; 2 = 1.4, excellent quality	3; 2; 1; 1; 2 = 1.8, very good quality	3; 2; 1; 1; 2 = 1.8, very good quality

		NNCH	FAuto	Soluble
	Secondary packaging	3; 2; 1; 1; 2 = 1.8, very good quality		
	Tertiary packaging	3; 2; 1; 1; 2 = 1.8, very good quality		
	Machine	3; 2; 1; 1; 3 = 2, good quality		
	Cup	3; 2; 1; 1; 3 = 2, good quality		

4.3 Impact Assessment

4.3.1 Impact assessment method and indicators

4.3.1.1 LCIA used for baseline assessment

In this work, environmental impacts are assessed through six indicators corresponding to midpoint and endpoint level indicators and they are aligned with international guidance on life cycle assessment (in particular the JRC ILCD Handbook recommendations in LCIA methodologies, and the Consumer Goods Forum recommendation in the Global Project for Packaging Sustainability). These environmental indicators and the methods used in this study are described in Table 4-9.

Table 4-9: Environmental indicators assessed for this study.

ENVIRONMENTAL INDICATOR	DEFINITION
Greenhouse gas emissions (kg CO ₂ -eq)	Greenhouse gas emissions indicator measures the potential impact on Climate change from greenhouse gas emissions associated with a product, process or organization. It takes into account the capacity of a greenhouse gas to influence radiative forcing, expressed in terms of a reference substance and specified time horizon. The midpoint characterization factors are calculated over a 100 years time horizon. This indicator is based on IMPACT 2002+ vQ2.21 (Jolliet et al. 2003, Humbert et al. 2012). The impact metric is expressed in kg CO ₂ -eq.
Non-renewable resources depletion (kg Sb-eq)	Non-renewable resources depletion indicator measures the potential impact on resource depletion from resource use associated with a product, process or organization. It takes into account impacts due to the use of Non-renewable energy (fossil fuel as oil, coal and gas, and uranium) and scarce minerals (copper, rare earth minerals, etc.). It corresponds to the Abiotic depletion indicator from CML 2001 v2.05 (Guinée et al. 2001) and it is based on EU-JRC ILCD Handbook 2011 v1.01 (Oers et al. 2002). The impact metric is expressed in kg Sb-eq (kg antimony equivalents).

Land use (m ² -y)	Land use indicator (inventory) measures the potential impact on land use caused by direct land use associated with a product, process or organization. It simply corresponds to the sum of all land use categories from the inventory dataset, e.g., urban occupation for buildings, annual crop occupation for crop cultivation and forest occupation for wood products. The impact metric is expressed in m ² -year.
Impact on ecosphere/ Ecosystem quality (PDF-m ² -y)	Impact on ecosphere / Ecosystems quality indicator measures the potential impact on ecosystems (biodiversity, species and their inhabitant) caused by emissions of harmful substances associated with a product, process or organization. It takes into account aquatic ecotoxicity, terrestrial ecotoxicity, terrestrial acidification and nutrification, aquatic eutrophication and aquatic acidification (water turbined and land use are excluded). It characterizes the fraction of species disappeared on one m ² surface during one year. This indicator is based on IMPACT 2002+ vQ2.21 (Jolliet et al. 2003; Humbert et al. 2012). The impact metric is expressed in PDF-m ² -y ("Potentially Disappeared Fraction of species over one m ² and during one year").
Water withdrawal (m ³)	Water withdrawal includes all freshwater withdrawal categories from the regionalized inventory dataset, except salted water (ocean) and turbined water. The impact metric is expressed in m ³ .
Human health (DALY)	Human health measures the impacts of emissions of harmful substances having effects on human health through their toxicity (carcinogenic and non-carcinogenic), their effect on respiratory system (respiratory inorganic and respiratory organic), their effect on ozone depletion or related to ionizing radiations. This indicator is based on IMPACT 2002+ vQ2.28 (Jolliet et al. 2003; Humbert et al. 2012). It is measured in DALYs (Disability Adjusted Life Year). It excludes health effect of nutrition and only focuses on indirect effects.

The following points should also be noted regarding the environmental indicators selected:

- Biodiversity loss from deforestation is not accounted for in the Impact on ecosphere/Ecosystem quality indicator but in the Land use indicator.
- Turbined water is not accounted for in any impact category.
- The following flows are not accounted for in the Non-renewable resources depletion indicator:
 - Energy, gross calorific value, in biomass.

- Energy, gross calorific value, in biomass, primary forest.
- Energy, gross calorific value, in peat.
- All other "Energy, gross calorific value, XYZ" substances.

The SimaPro software was used to calculate the potential impacts related to the inventoried emissions.

LCIA results are relative expressions of potential impacts. They do not predict real impacts on category endpoints, the exceeding of thresholds, safety margins or risks.

4.3.1.2 LCIA used for sensitivity analysis

A sensitivity analysis is performed with another LCIA method: the Environmental Footprint Method (EF Method). This is the new European Commission consensual method developed under the umbrella of the PEF/OEF initiative, replacing the ILCD Midpoint 2011 method. It is described in details in the PEF Method document (European Commission, 2019) and the indicators are listed in Table 4-10.

Table 4-10: EF Method impact categories.

Impact category	Indicator	Unit	Recommended default LCIA method	Source of CFs
Climate change	Radiative forcing as Global Warming Potential (GWP100)	kg CO ₂ eq	Baseline model of 100 years of the IPCC (based on IPCC 2013)	EC-JRC, 2017
Ozone depletion	Ozone Depletion Potential (ODP)	kg CFC-11eq	Steady-state ODPs as in (WMO 1999)	EC-JRC, 2017
Human toxicity, cancer effects	Comparative Toxic Unit for humans (CTU _h)	CTUh	USEtox model (Rosenbaum et al, 2008)	EC-JRC, 2017
Human toxicity, non- cancer effects	Comparative Toxic Unit for humans (CTU _h)	CTUh	USEtox model (Rosenbaum et al, 2008)	EC-JRC, 2017
Particulate matter/Respiratory inorganics	Impact on human health	Deaths	PM method recommended by UNEP (UNEP 2016)	EC-JRC, 2017
Ionising radiation, human health	Human exposure efficiency relative to ²³⁵ U	kBq ²³⁵ U	Human health effect model as developed by Dreicer et al. 1995 (Frischknecht et al, 2000)	EC-JRC, 2017
Photochemical ozone formation	Tropospheric ozone concentration increase	kg NMVOCeq	LOTOS-EUROS (Van Zelm et al, 2008) as applied in ReCiPe 2008	EC-JRC, 2017
Acidification	Accumulated Exceedance (AE)	mol H+ eq	Accumulated Exceedance (Seppälä et al. 2006, Posch et al, 2008)	EC-JRC, 2017
Eutrophication, terrestrial	Accumulated Exceedance (AE)	mol N eq	Accumulated Exceedance (Seppälä et al. 2006, Posch et al, 2008)	EC-JRC, 2017

Eutrophication, aquatic freshwater	Fraction of nutrients reaching freshwater end compartment (P)	fresh water: kg P equivalent	EUTREND model (Struijs et al, 2009) as implemented in ReCiPe	EC-JRC, 2017
Eutrophication, aquatic marine	Fraction of nutrients reaching marine end compartment (N)	fresh water: kg N equivalent	EUTREND model (Struijs et al, 2009) as implemented in ReCiPe	EC-JRC, 2017
Ecotoxicity (freshwater)	Comparative Toxic Unit for ecosystems (CTU _e)	CTU _e	USEtox model, (Rosenbaum et al, 2008)	EC-JRC, 2017
Land use	<ul style="list-style-type: none"> - Soil quality index - Biotic production - Erosion resistance - Mechanical filtration - Groundwater replenishment 	<ul style="list-style-type: none"> - dimensionless - kg biotic production - kg soil - m³ water - m³ groundwater 	Soil quality index based on LANCA (Beck et al. 2010 and Bos et al. 2016)	EC-JRC, 2017
Water scarcity	User deprivation potential (deprivation-weighted water consumption)	m ³ world eq. deprived	Available WAtER REmaining (AWARE) as recommended by UNEP, 2016	EC-JRC, 2017
Resource use, mineral	Abiotic resource depletion (ADP ultimate reserves)	kg Sb-eq	CML 2002 (Guinée et al., 2002) and van Oers et al. 2002.	
Resource use, energy carriers	Abiotic resource depletion – fossil fuels (ADP-fossil)	MJ	CML 2002 (Guinée et al., 2002) and van Oers et al. 2002	EC-JRC, 2017

4.3.2 Limitations of LCIA

Life cycle impact assessment results present potential and not actual environmental impacts. They are relative expressions, which are not intended to predict the final impact or risk on the natural media or whether standards or safety margins are exceeded. Additionally, these categories do not cover all the environmental impacts associated with human activities. Impacts such as noise, odors, electromagnetic fields and others are not included in the present assessment. The methodological developments regarding such impacts are not sufficient to allow for their consideration within life cycle assessment. Other impacts, such as potential benefits or adverse effects on biodiversity, are also only partly covered by current impact categories.

4.4 Calculation tool

SimaPro 8.5 software, developed by PRé Consultants (www.pre.nl) was used to assist the LCA modelling and link the reference flows with the LCI database and link the LCI flows to the relevant characterization factors. The final LCI result was calculated combining foreground data (intermediate products and elementary flows) with generic datasets providing cradle-to-gate background elementary flows to create a complete inventory of the various coffee systems.

4.5 Scenarios for sensitivity analyses

The parameters, methodological choices and assumptions used when modeling the systems present a certain degree of uncertainty and variability. It is important to evaluate whether the choice of parameters, methods, and assumptions significantly influences the study's conclusions and to what extent the findings are dependent upon certain sets of conditions. Following the ISO 14044 standard, a series of sensitivity analyses are used to study the influence of the uncertainty and variability of modeling assumptions and data on the results and conclusions, thereby evaluating their robustness and reliability. Sensitivity analyses help in the interpretation phase to understand the uncertainty of results and identify limitations.

The sensitivity analyses conducted in the study are detailed in Table 4-12. Two types of parameters were selected:

- Parameters related to methodological choices as the electricity grid mix choice, the LCIA method and the use intensity defined as main scenario (i.e., 4 000 and 10 000 cups/year)
- Parameters related to data and assumptions as, e.g., recycling rate of capsules and other packaging items, variation of R&G or soluble coffee amount, extra water boiled, etc.

Based on the results obtained, a “Best Case” and a “Worst Case” scenarios were defined gathering the best and worst set of data for all parameters related to data and assumptions (these Best Case and Worst Case exclude the variations on methodological choices).

The best or worst case scenario do not correspond to best or worst scenarios in absolute but to the best combination among sensitivity analyses performed. Indeed, the best case in absolute could include an improvement in many more criteria than the ones considered in the report.

One of the most importing sensitivity analyses is the one testing the amount of coffee per cup. For the Nespresso variation, the data have been provided by Nespresso. For the soluble coffee, some measurements have been done for a small teaspoon just full and a very full large teaspoon. This showed the amount could range from about 1 to 3 g. For the full automat, the range was established checking various references listed in Table 4-11 below.

Table 4-11: Variation of coffee amount for the full automat systems. All websites visited in January-February 2020. It is not possible to simply calculate the coffee amount per 40 ml cup as the relationship is not linear (for longer cups, the amount of coffee is not simply a scale up of a smaller cup). However, these references show the amount of coffee for a cup of espresso (of a content of 30-40 ml) ranges from 6 to 14 g.

Coffee (g/cup)	Cup size (ml/cup)	Reference
10 g	25-40 ml	https://www.moevenpick-cafe.com/blog/fr/mythe-autour-du-cafe-cest-lespresso-qui-contient-le-plus-de-cafeine/
7 +/-0.5 g	25 +/-2.5 ml	http://lekawa.fr/la-recette-de-lespresso/
8.3 g 7 g 10 g	150 ml 125 ml 180 ml	Golden ratio EU brewin standard US brewing standard https://espressocoffeeguide.com/how-much-coffee-per-cup/
7-14 g	“cup”	https://grain-noir.ch/machines/
8-10 g 6.5-7 g	30 ml 30 ml	Espresso Professional espresso https://www.larbreacafe.com/fr/blog/guide-pratique-comment-faire-un-bon-cafe-n17#5
7 g	“espresso”	http://www.hotellerie-restauration.ac-versailles.fr/cafeologie/diaporama/facteurs_de_qualite.pdf
8.25 g	150 ml	https://sca.coffee/research/coffee-standards
10.6 g	180 ml	https://www.roastycoffee.com/measure-coffee/
6-14 g	“cup”	https://www.miele.ch/pmedia/ZGA/TX2070/10526210-000-02_10526210-02.pdf

Table 4-12: Sensitivity analyses performed.

Sensitivity analyses name	NNCH	FAuto	Soluble	Description of the analysis
Amount of coffee	✓	✓	✓	<p>Objective: Test the influence of the amount of R&G coffee per capsules, per FAuto coffee, or of the soluble coffee amount per cup. It has to be noted that the range for Nespresso is clear (based on the different types of existing capsules) while the range is more uncertain for full automat for which the consumer behavior has an influence.</p> <p>Application: 6 to 6.3 g R&G coffee/capsule for NNCH (Nespresso data), 6-14 g R&G coffee/cup for FAuto (see Table 4-11), 1 to 3 g soluble coffee/cup for soluble (measurements of a small to a large teaspoon)</p> <p>Baseline: 6.1 g R&G coffee/capsule for NNCH, 9 g R&G coffee/cup for FAuto, 2 g soluble coffee/cup for soluble</p>
Coffee brewing electricity consumption increase	✓	✓		<p>Objective: Test the influence of a higher electricity consumption for coffee brewing for 10 000 cups/year machines.</p> <p>Application: For the higher energy consumption: 4.7 Wh/40 ml cup for coffee brewing considering measurement from VDE for Nespresso machines applied for Gemini, Momento, full automat efficient and non-efficient machines for 10 000 cups/year instead of the 3.5 Wh/40 ml cup coming from the HKI Cert website. This brewing consumption is added to the daily energy losses (i.e., ready-to-use, heating, etc.) of the machines that is different for all of them and that is measured by VDE for Nespresso machines and provided by HKI Cert website for full automat machines for 10 000 cups/year. Total energy consumption in Wh/cup: Gemini (21), Momento (20.9), FAuto efficient (8.7), FAuto non-efficient (24.7)</p> <p>For the lower energy consumption: for the Gemini and Momento machines, it appears that the cup heater function can correspond to up to 75% of the ready-to-use mode. This cup heater was used for the measurement made by VDE. The energy losses have been therefore decreased for these two machines, considering only 25% of the ready-to-use energy losses. The total energy consumption is then 9.2 and 9.6 Wh/cup for Gemini and Momento respectively</p> <p>Baseline: 3.5 Wh/40 ml cup coming from the HKI Cert website. Total energy consumption in Wh/cup: Gemini (19.8), Momento (19.7), FAuto efficient (7.5), FAuto non-efficient (23.5).</p>
Full automat A++		✓		<p>Objective: Test the influence of having a A++ machine for the FAuto 4 000 cups/y scenario. This is not done for the 10 000 cups/y scenario as the efficient machine considered in the study is already the best performing according with topten.ch.</p> <p>Application: The most efficient FAuto for 4 000 cups/y scenario consumes 39.2 kWh/y (Koenig Finessa, according to topten.ch)</p> <p>Baseline: 53.8 kWh/y for the efficient FAuto machine for 4 000 cups/y (selected among the three most sold).</p>
Nespresso energy consumption without cup heating	✓			<p>Objective: Test the influence of excluding the cup heating for the Gemini and Momento Nespresso machines. According to an expert from VDE, this could lead to a reduction of 50 to 75% of the electricity losses (estimate).</p> <p>Application: Most optimistic reduction of the energy losses of 75%, i.e., 9.2 and 9.6 Wh/cup, respectively for the Gemini and the Momento machine.</p> <p>Baseline: 19.8 and 19.7 Wh/cup for Gemini and Momento respectively.</p>
Kettle energy consumption			✓	<p>Objective: Test the influence of using a more efficient kettle</p> <p>Application: use of an efficient kettle, consuming 0.1 kWh/L (according to topten.ch website efficient kettles). For comparison, the theoretical minimum energy requirement to heat the water for the soluble coffee calculated considering a temperature increase of 15°C to 80°C would be 0.08 kWh/L.</p> <p>Baseline: 0.125 kWh/L for an average kettle according to PEFCR coffee</p>
Machine lifetime	✓	✓		<p>Objective: Test the influence of the machine lifetime for Nespresso and FAuto</p> <p>Application: 6 -12 years lifetime</p> <p>Baseline: 10 years lifetime</p>

Sensitivity analyses name	NNCH	FAuto	Soluble	Description of the analysis
0-100% recycling	✓	✓	✓	<p>Objective: Test the influence of the recycling rate of used capsules, cardboard boxes and glass jar</p> <p>Application: 0% and 100% capsule recycling.</p> <p>Baseline: 22% recycling for capsules, 81% for cardboard boxes, 94% for glass (remaining being trashed, i.e., incinerated in CH)</p>
Good coffee grounds management		✓		<p>Objective: Test the influence of having a better coffee grounds management at the end-of-life for the FAuto scenarios. For Nespresso, all capsules recycled in Switzerland have their coffee grounds methanized (no alternative option): this sensitivity analysis was performed only on the full automat systems.</p> <p>Application: 100% of coffee grounds sent to methanization</p> <p>Baseline: 50% of coffee grounds sent to incineration, 25% to methanization and 25% to composting</p>
High amount of water boiled			✓	<p>Objective: Test the influence of boiling too much water for the soluble coffee preparation</p> <p>Application: 100 ml water boiled for a 40 ml cup</p> <p>Baseline: 40 ml water boiled</p>
Shopping trip		✓	✓	<p>Objective: Test the influence of a distribution via supermarket instead of via delivery partners</p> <p>Application: 100% of R&G coffee pouches and soluble coffee glass jars bought at supermarket with a shopping trip (following PEF method)</p> <p>Baseline: 100% distribution via delivery partners, directly to the office.</p>
100 cups coffee/day	✓	✓		<p>Objective: Test the influence of a higher consumption intensity.</p> <p>Application: 100 cups/day prepared, i.e., 26 000 cups/year. This influences the fraction of coffee machine produced per cup and for the systems originally for 10 000 cups/year, it influences the electricity for coffee preparation.</p> <p>Baseline: 4 000 or 10 000 cups/year depending on the coffee system</p>
Green coffee supply	✓	✓	✓	<p>Objective: Test the influence of the coffee cultivation stage. Indeed the coffee cultivation model is based on the PEFCR coffee and adapted to Nespresso origins adapting the irrigation, the land use change and the delivery. The other elements constituting the coffee supply are generic (e.g., fertilizers and pesticides application, energy consumption for cherries processing, etc.). Because it is unknown which coffee is used for FAuto and soluble coffee and because a huge variety of products exists, the same coffee is used for all system to not differentiate based on this parameter.</p> <p>Application: A low impacting and high impacting coffee in terms of GHG emissions from the World Food LCA Database are used for the coffee supply. This sensitivity analysis is performed only for the carbon footprint as the low impacting coffee regarding climate change is not necessarily a low impacts coffee for other indicators.</p> <p>Baseline: PEFCR coffee adapted to Nespresso coffee origin is used.</p>
Portioned packaging for soluble			✓	<p>Objective: Test the influence of a portioned packaging for soluble coffee (sticks).</p> <p>Application: An approximation for laminated single portion pouches, solid board box and tertiary packaging constituted of a corrugated board box, a pallet and LDPE film is considered for soluble coffee, with still 2 g soluble coffee per cup.</p> <p>Baseline: Glass jar containing 200 g soluble coffee.</p>
CH electricity mix	✓	✓	✓	<p>Objective: Test the influence of using the Swiss electricity mix instead of the European electricity mix</p> <p>Application: Use of the Swiss electricity grid mix for activities taking place in Switzerland</p> <p>Baseline: Use of the European average electricity grid mix (ENTSO)</p>
LCIA method	✓	✓	✓	<p>Objective: Test the influence of the conclusions considering another LCIA method</p> <p>Application: EF method (European Commission recommended method) is applied (see section 4.3.1.2). This choice has been made because the EF method is expected to become the commonly used method in Europe and because it is consensual.</p>

Sensitivity analyses name	NNCH	FAuto	Soluble	Description of the analysis
				Baseline: Nestlé method is applied (mix of IMPACT 2002+ and other LCI indicators)

5 Results

This chapter presents the environmental performance' results for the preparation of an espresso cup of coffee prepared with the Nespresso Original coffee system (NNCH) and the different coffee alternatives assessed in the study: various full automat (FAuto) coffee systems and a soluble coffee system (soluble).

The impacts on climate change are first shown in detail as this indicator is well known and understood, and it is of importance for Nespresso as they have targets on this indicator (carbon footprint roadmap). The other indicators assessed are shown then explaining the main trends; and the similarities or dissimilarities compared to climate change are discussed. This does not mean they are less important and the decision and main conclusions are taken considering all indicators. This applies to the baseline results as well as for the sensitivity analyses.

5.1 Climate change

Figure 5-1 presents the greenhouse gas (GHG) emissions for the entire life cycle of an espresso cup of coffee for the NN coffee systems and the other compared coffee systems.

With total GHG emissions of 68 g CO₂-eq per cup, the soluble coffee (useable for the 4 000 cups/year or 10 000 cups/year scenarios) has the lowest impact with respect to climate change.

Regarding the coffee systems suitable for the 4 000 cups/year scenario, the Nespresso Zenius is the best alternative while the two FAuto systems have higher and very similar impacts. The machines used have indeed a similar mass and a very close energy consumption per cup, leading to a negligible difference.

For the coffee systems for the more intense use (10 000 cups/year), the two Nespresso alternatives (Gemini and Momento) are performing the best with about 80 g CO₂-eq/cup each, while the non-efficient FAuto system has the largest impact with about 100 g CO₂-eq. The efficient FAuto system is in between with a score of about 90 g CO₂-eq per cup.

Based on Figure 5-1, it can be seen that for all coffee systems, the coffee supply is the largest GHG emissions contributor – from 38% for soluble coffee to 58% of the total GHG emissions for FAuto efficient for 10 000 cups/year - followed by the use stage – from 26% to 38%. The overheads / support represents the third most important life cycle stage with a contribution ranging from 7% to 10%. Representing 5% to 9% of the total GHG emissions, the packaging production has a higher contribution for the Nespresso systems and the soluble coffee than for the FAuto systems. Finally, the manufacturing, distribution and end-of-life have a lower and similar contribution, except that end-of-life contribution is as a credit.

The green coffee supply, use stage and packaging production stages represent about 90% of the total GHG emissions (and about 80% for soluble) and are further detailed below in Figure 5-2, Figure 5-4 and Figure 5-4, together with details on the end-of-life stage (Figure 5-5) which significantly varies depending on the considered coffee system.

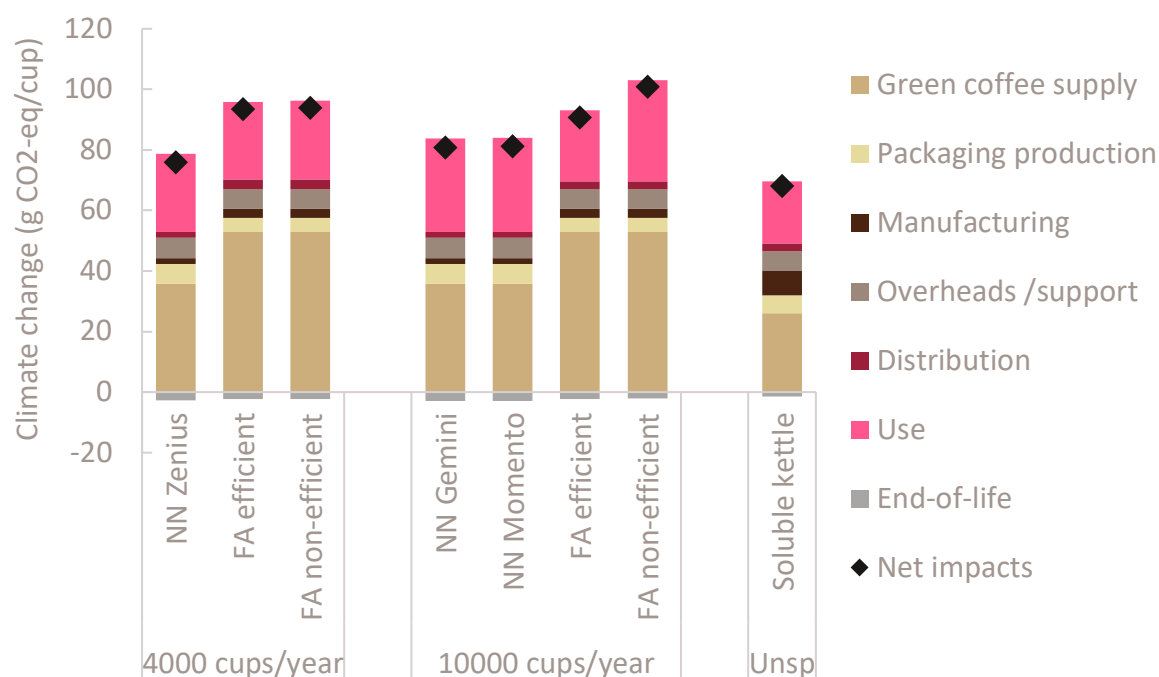


Figure 5-1: GHG emissions per life cycle stage for the compared coffee systems. The three first products correspond to a use scenario of 4 000 cups/year while the 4 next correspond to the use scenario of 10 000 cups/year. The soluble coffee scenario is independent from this use intensity.

5.1.1 Zoom on the green coffee supply stage

The green coffee supply stage represents about 40% to 60% of the total life cycle stage carbon footprint of a cup of espresso. Figure 5-2 represents the contribution of the different emission stages participating in the GHG emissions for the green coffee supply stage. Because all coffee systems were modeled using the same green coffee supply model, no distinction was made with respect to this specific stage and the related coffee cultivation activities. Therefore, only the amount of coffee used per coffee system explains the GHG emission differences observed in Figure 5-1 associated to the green coffee supply.

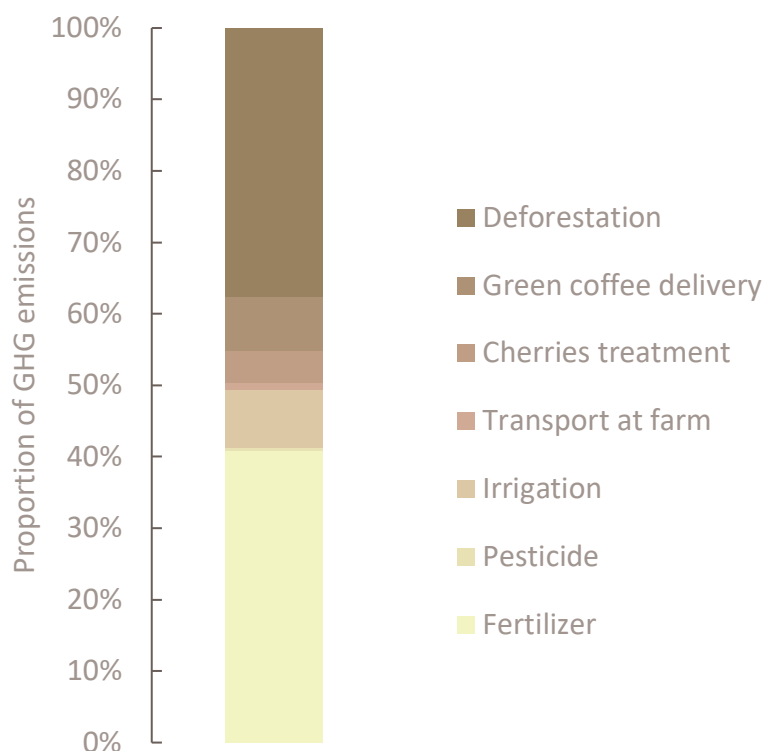


Figure 5-2: Contribution of the different GHG emission stages for the green coffee supply stage.

Based on Figure 5-2 it appears that the fertilizer use and the deforestation are the largest contributors in terms of GHG emissions associated to the green coffee production with contributions of about 40% each. The large contribution of the fertilizer emission stage is largely related to the direct emissions of GHG on field following application (mostly N_2O emissions) as well as the important energy consumption for the fertilizer production. The remaining emissions are mostly related to the combustion of fossil fuels for the field irrigation, the cherries treatment and the coffee delivery from the coffee farm to the manufacturing sites.

5.1.2 Zoom on the packaging production & delivery stage

The packaging production carbon footprint contribution on the total life cycle impacts ranges from about 5% to 9%. Looking at Figure 5-3 it can be seen that the NNCH coffee system has a carbon footprint very close to the one of the soluble coffee system in terms of packaging production (respectively 6.4 and 5.9 g CO_2 -eq/cup). The difference is more important when the capsule is compared to the R&G coffee pouch used for the FAuto coffee system (4.5 g CO_2 -eq/cup).

For Pro capsule and the soluble coffee glass jar, the packaging carbon footprint is dominated by the primary packaging production, mostly the aluminium layer for the Nespresso Pro capsule and the glass jar for the soluble coffee. For the FAuto system, the most important contributor to the packaging production is the tertiary packaging, mainly due to the tray

containing several coffee pouches. The corrugated board box, pallet and LDPE film for transport and the packaging material delivery are much smaller contributors for all packaging types.

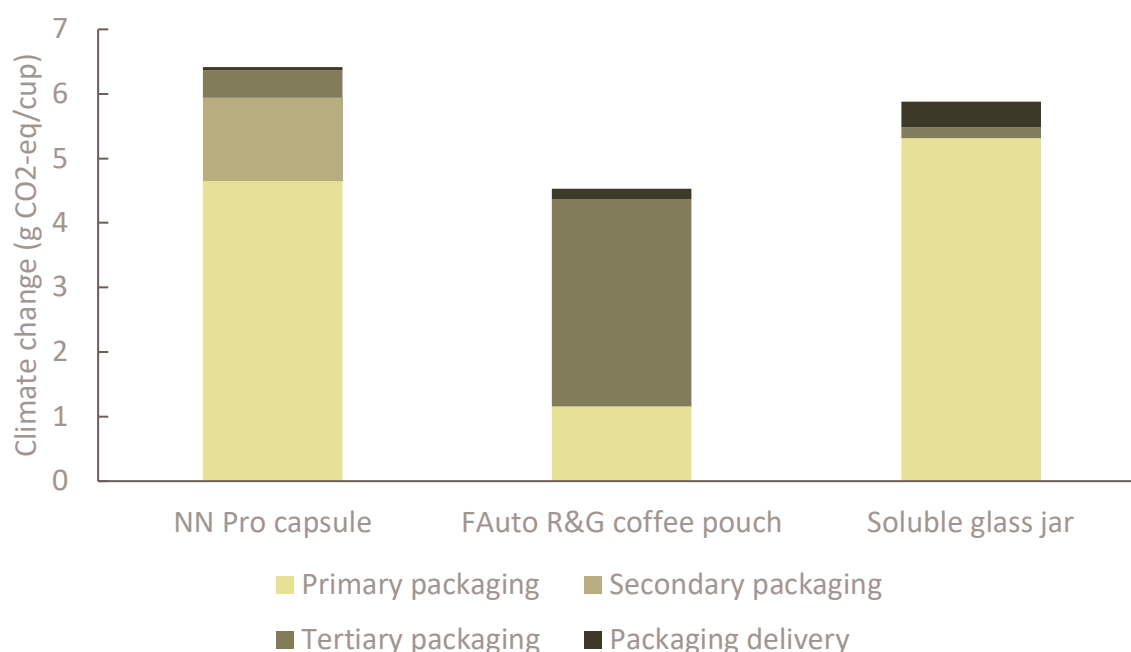


Figure 5-3: GHG emissions for the packaging production & delivery stage for the 3 compared coffee systems: Nespresso Pro capsule, FAuto R&G coffee pouch packed in 1 kg pouch and soluble coffee glass jar packed in a 200 g glass jar. The 3 systems are given per cup of coffee and not per unit of packaging.

Because of the different end-of-life trajectories of the packaging items – Nespresso capsules and the soluble coffee glass jar can be recycled, leading to a GHG emissions benefit, while the R&G coffee pouch cannot be recycled in Switzerland and is therefore incinerated with the plastic combustion leading to an extra GHG emission load – conclusions relative to the packaging performance should not be drawn without considering the packaging end-of-life. In this purpose, Figure 5-5 highlights the end-of-life stage. When combining the packaging production and end-of-life, the net GHG emissions scores are as follows:

- Nespresso: 6.4 g CO₂-eq/cup
- Full automat: 5.3 g CO₂-eq/cup
- Soluble coffee: 4.4 g CO₂-eq/cup

It shows the ranking is different when considering only packaging production and delivery or including also the end-of-life treatment of this packaging. The difference among the 3 packaging types is of 1 to 2 g CO₂-eq/cup (when considering production and end-of-life), what is finally quite low in comparison with the full life cycle carbon footprint.

5.1.3 Zoom on the use stage

The use stage carbon footprint corresponds to the second main contributor to the total life cycle impacts and ranges from about 30% to 40%. Based on Figure 5-4 it appears that the use stage varies quite a lot from a system to another. The soluble coffee system has the lowest use stage GHG emissions (20 g CO₂-eq/cup). The three coffee systems used for the 4 000 cups/year scenario have similar use stage GHG emissions. Finally, regarding the coffee systems for the 10 000 cups/year scenario, the NN Gemini, NN Momento have a similar impact, of 31 g CO₂-eq/cup, while the efficient FAuto machine performs better (23 g CO₂-eq/cup) and the non-efficient FAuto machine has the highest GHG emissions for the use stage, with 34 g CO₂-eq/cup.

The GHG emissions are dominated by the cup production and washing that corresponds to 53% to 87% of the use stage impacts. The machine production and the coffee preparation are the other important contributors, with the coffee preparation contributing more for the machines used for the 10 000 cups/year scenarios than for the less intensive use.

This significant contribution of the cup production and washing (18 g CO₂-eq for all alternatives) is mostly due to the dishwasher electricity requirements to clean up the cup after each use and the allocated part of the dishwasher manufacturing and end-of-life.

The impact of the FAuto water filter replacement has a very small contribution to the overall impact of the use stage.

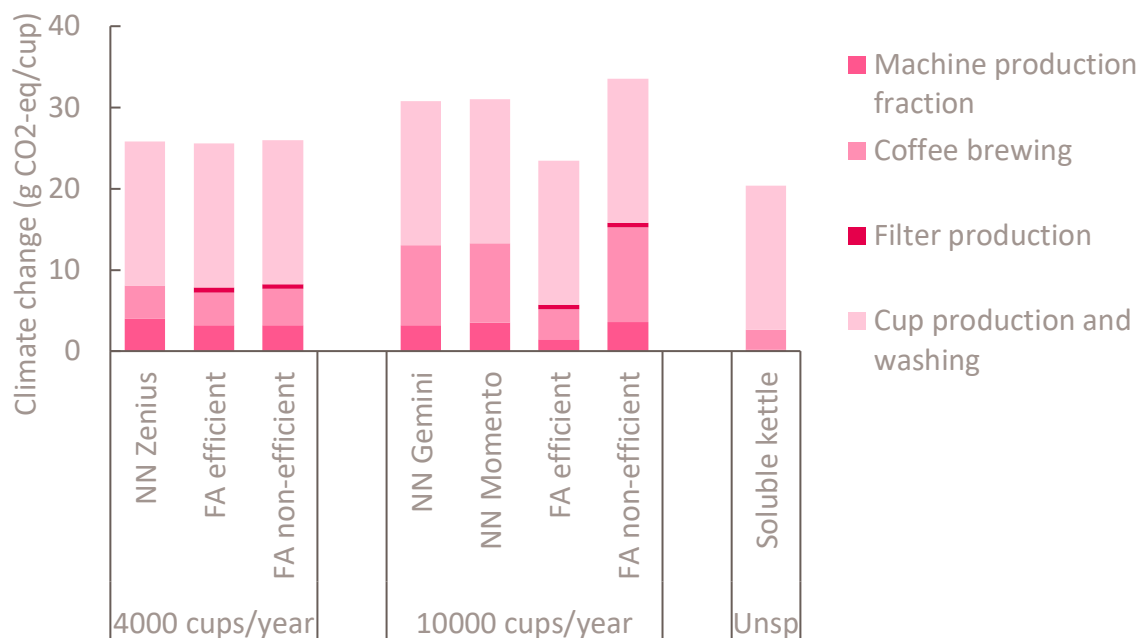


Figure 5-4: GHG emissions for the use stage for the compared coffee systems. The three first products correspond to a use scenario of 4 000 cups/year while the 4 next correspond to the use scenario of 10 000 cups/year. The soluble coffee scenario is independent from this use intensity.

5.1.4 Zoom on the end-of-Life stage

The net impacts of the end-of-life stage represent a credit on the total carbon footprint of a cup of espresso, ranging from -2% to -4%. As presented in Figure 5-5, the end-of-life of the different coffee systems do all lead to a net GHG emission benefit ranging from -2.8 g CO₂-eq (Nespresso) to -1.4 g CO₂-eq (soluble coffee). This general GHG emission benefit is mostly explained by the end-of-life of the coffee grounds which leads to negative GHG emissions for Nespresso and FAuto coffee systems ranging from -3.5 g CO₂-eq (FAuto) to -2.8 g CO₂-eq (NN). This coffee-related benefit is partly compensated by the GHG emissions associated to the end-of-life of the machine, the cup, the water filter and the packaging (1st, 2nd and 3rd packaging), except for the Nespresso coffee systems where the end-of-life of the full packaging further increases the end-of-life benefit.

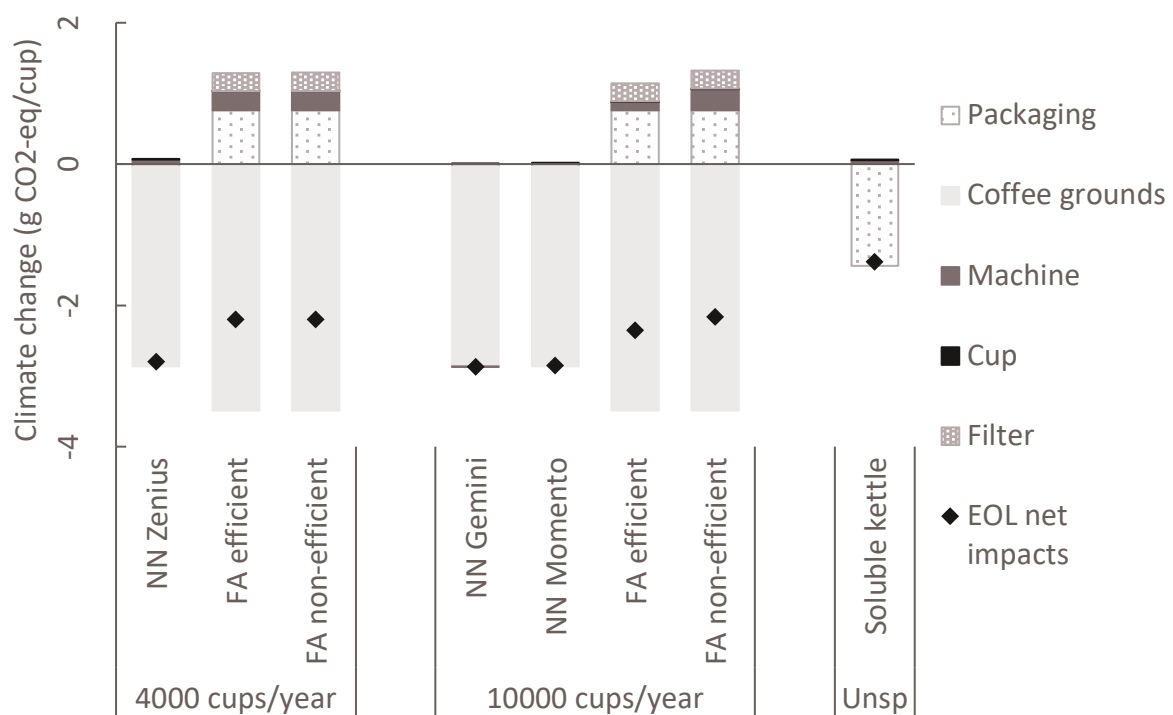


Figure 5-5: GHG emissions for the end-of-life stage for the compared coffee systems. The three first products correspond to a use scenario of 4 000 cups/year while the 4 next correspond to the use scenario of 10 000 cups/year. The soluble coffee scenario is independent from this use intensity.

5.1.5 Discussion on the manufacturing, overheads/support and distribution stages

The manufacturing, overheads/support and distribution stages contribute together to about 10% to 25% of the carbon footprint of a cup of espresso.

The manufacturing contributes to 2-3% of the total GHG emissions for the Nespresso and full automat coffee systems. The same manufacturing was considered for the two systems as no evidence could be found on how a specific coffee system could be more performant than the other with respect to this stage. For this reason, no differentiation was made. On the contrary, regarding the soluble coffee, a generic spray drying process was considered as the processing is obviously different from roasting and grinding. As it is much more energy intensive, its

contribution is higher (12%). The impacts of the manufacturing of R&G coffee are mainly due to the energy consumed for the process (mostly natural gas and diesel), the production and emissions of the carbon dioxide used as protective atmosphere and the packaging wastes (packaging wastes mean that additional packaging has to be produced). For the soluble coffee, the manufacturing impacts are also due to the heat and electricity consumption.

The overheads / support stage contributing together for maximum 10% of the total GHG emissions was modelled using the same processes for all coffee systems assuming the same impact per cup for all, as, again, no evidence could be found on how the other coffee systems could be more or less performant than Nespresso. The GHG emissions related to the overheads / support stage are mainly explained by the services used as e.g., advertising and the car business travels of the market head office.

Regarding the distribution stage, the latter emits about 2-3 g CO₂-eq for all coffee systems (Figure 5-1). The distribution is different for Nespresso that has two distribution channels with postal delivery and distribution with delivery partners and the two others that are assumed to be distributed exclusively with delivery partners. The impacts of the distribution for Nespresso are mostly related to the distribution with delivery partners and the truck transport. For the full automat and the soluble coffee systems, the GHG emissions related to the distribution stage are mostly due to the truck transport.

5.2 Multi-indicators comparison

Environmental impacts regarding all indicators – Human health, Ecosystem quality, Non-renewable resources depletion, Water withdrawal, Land use as well as Climate change – for the different compared coffee systems are presented in Figure 5-6 with Nespresso Zenius being set as 100% of the impact in each in each figure.

5.2.1 Non-renewable resources depletion

Based on Figure 5-6, the Non-renewable resources depletion indicator follows a similar impact trend as the Climate change indicator with a main contribution from the use stage and coffee supply stages. Because there are no impacts related to emissions from fertilizers application and deforestation on this indicator, the green coffee supply contribution is lower than it is for the Climate change indicator. The indicator being driven by substances such as coal, oil, gas, etc. and gold, silver, lead etc., it directly reflects the use of fossil fuels and minerals over the coffee cup life cycle.

The green coffee supply impacts are due to the energy consumed for the coffee cherries treatment and to the energy consumed in the fertilizers production.

For the use stage, the impacts are related to the cup washing (dishwasher use), the coffee brewing and the machine production. For the dishwasher use and the coffee brewing, the Non-renewable resources depletion is due to the electricity consumption (coal, oil, gas and uranium extraction for electricity generation). For the machine production, the impacts are mostly related to the energy consumed to produce the materials (i.e. again coal, oil and gas behind heat and electricity production) but also to the metals and rare earth used for the machine components, as e.g., the gold used in the electronic compounds. Indeed, gold has a quite high characterization factor for the Non-renewable resources depletion as it is a rare metal.

Regarding the ranking of the different coffee systems, the soluble and Nespresso Zenius (for 4 000 cups/year) have similar impacts. Considering the 4 000 cups/year, Nespresso is performing better than the full automat coffee systems. However, for the 10 000 cups/year, the Nespresso Gemini and Momento have the same impact than the efficient full automat and the non-efficient full automat has a worse performance.

5.2.2 Water withdrawal

Based on Figure 5-6, it appears that the Water withdrawal impact is almost entirely driven by the green coffee supply stage. Indeed, 96% to 97% of the Water withdrawal impacts of a cup of espresso are associated to the green coffee supply depending on the coffee system. The green coffee supply water usage is directly related to the water needs for coffee irrigation purposes. The water withdrawal occurring during the use stage - coffee preparation (40 ml), cup washing in dishwasher and machine cleaning – has a much lower contribution and represent only 1 to 3% of the total Water withdrawal impact for all systems.

The water withdrawal being mostly related to the green coffee supply, the coffee systems having less green coffee per cup are performing better: the soluble coffee is the best alternative, followed by the Nespresso systems and finally the full automat systems.

5.2.3 Ecosystem quality

The part of the Figure 5-6 on Ecosystem quality shows that the green coffee supply and the use stages appear as the main contributors with a very low contribution from the other stages.

Most of the impacts of the green coffee supply stage are due to the direct field emissions (ammonia, dinitrogen monoxide, phosphate) resulting from the use of fertilizers. These emissions have acidifying effects (ammonia and dinitrogen monoxide) or eutrophication effects (phosphate) leading to a decrease in the ecosystem quality and therefore to a loss of biodiversity.

The impacts of the use stage are driven by the coffee cup washing and the machine production. For the cup washing, the impact is due to the phosphate emitted during extraction of fossil fuels (mostly lignite tailings emissions) for the production of electricity. For the machine

production, the impacts are due mostly to the metals extraction and emissions of polluting substances located at mines (mainly phosphate emissions from tailings related to gold extraction – gold is used in integrated circuits, i.e., electronic parts of the machines).

The trends observed for climate change in terms of the best or worst performing coffee systems can be observed for the ecosystem quality too: the soluble coffee system has the best performance while the full automat coffee systems have higher impacts than the Nespresso systems, both for the 4 000 cups/year and the 10 000 cups/year.

5.2.1 Human health

Looking at Figure 5-6, it appears that the life cycle stages contribution for the Human health follow similar trends than for the Climate change with the use and green coffee supply stages being the largest contributors.

The impacts for the green coffee supply are driven by the ammonia emitted in the cultivation area due to the N fertilizers applied. The second contributor for this stage is the emission of particulate matter (<2.5 µm) that is related mainly to fossil fuels burning and therefore to the energy consumption, either direct energy use at farm for cherries treatment and irrigation or indirect energy consumption for the fertilizers production. Particulate matter (<2.5 µm) and ammonia affect human health due to their effect on the respiratory system.

Impacts on use stage are mostly related to the manufacturing of the coffee machine, the manufacturing of the dishwasher as well as the cleaning of the coffee cup. The machine production impacts are related mostly to the electronic parts: their production consumes a lot of energy (fossil fuels burned, i.e., particulate matters emissions and respiratory effects) and specific metals, e.g., gold, which production emits heavy metals at mine (in the case of gold, arsenic emissions from the tailings).

The trends observed for the climate change in terms of ranking of the different scenarios are similar for human health: the soluble coffee is the best performing system, followed by the Nespresso systems (both for 4 000 cups and 10 000 cups/year) and the full automat are the scenarios having the higher impacts. The difference between Nespresso and full automat is more marked for the 4 000 cups/year coffee systems than for the 10 000 cups/year coffee systems.

5.2.2 Land use

Looking at Figure 5-6, it appears that the stages which contribute the most to the Land use indicator are in order of contribution the green coffee supply, the packaging production & delivery and the use stage, except for the soluble coffee for which the use stage is slightly larger than the packaging production & delivery.

The large contribution of the green coffee supply stage is associated to the use of land for the green coffee cultivation itself. The contribution of the packaging production & delivery stage is largely explained by the use of land for forests which deliver the wood fibers necessary for the production of the cardboard packaging. The use stage impacts are due to the electricity consumed by the dishwasher and the coffee machine (part of cogeneration based on wood chips, i.e., forest land use) and to the soap used by the dishwasher (made from soybean oil, i.e., use of agricultural land).

As the Land use indicator is highly driven by the green coffee cultivation, the impacts are directly proportional to the amount of coffee being used for each of the coffee system assessed, with the soluble coffee system performing the best and the full automat systems having the higher impact.

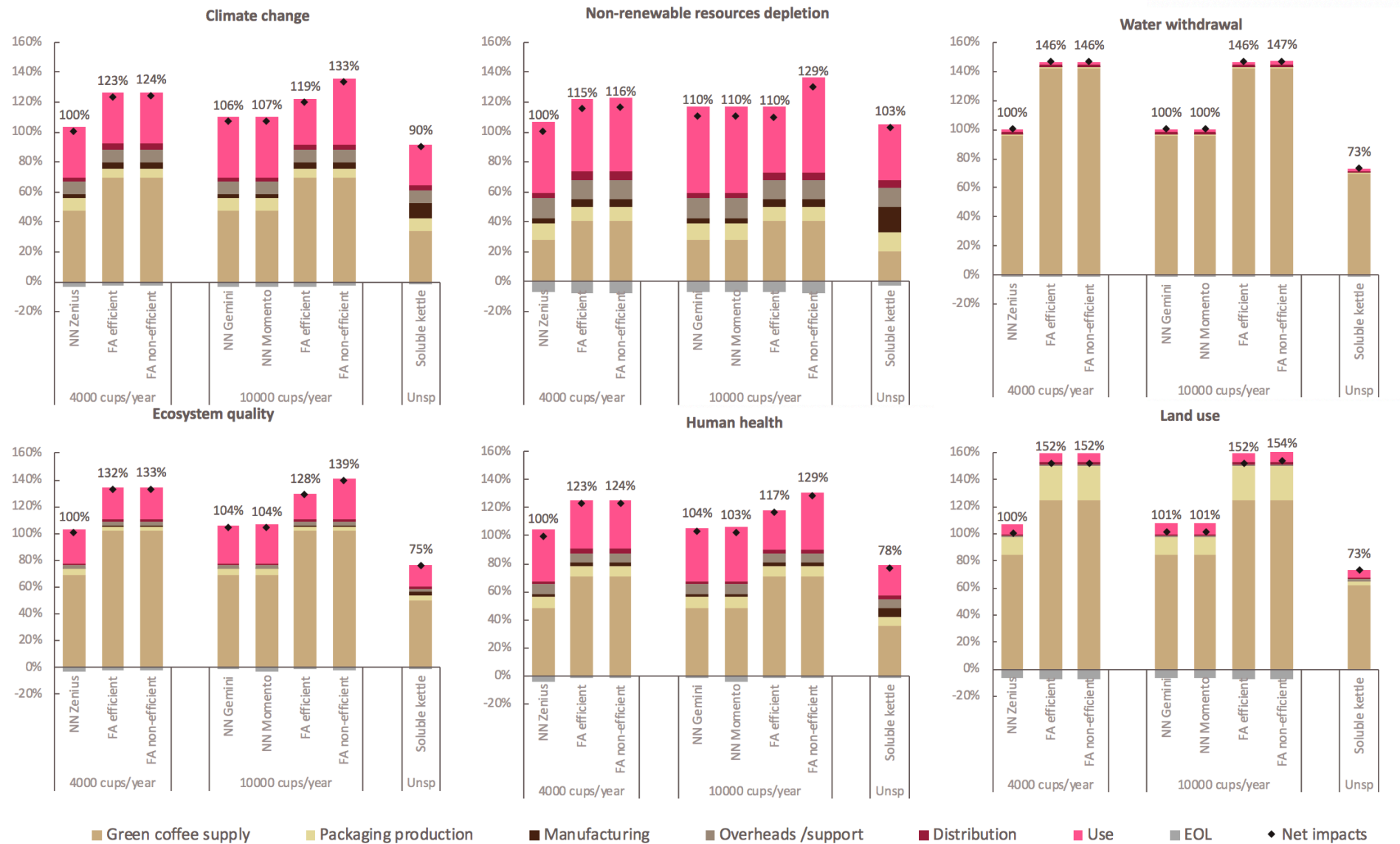


Figure 5-6: Life cycle stages contribution for the compared coffee systems for all impact indicators. For each indicator, all coffee systems were normalized with respect to the NN Zenius coffee system which impact was set at 100%.

5.3 Sensitivity analyses

The following section presents the results of the different conducted sensitivity analyses that were presented in section 4.5. A first section presents the sensitivity analyses for which a data point has been varied one by one. A second section presents the combination of the parameters variation into best and worst case scenarios and a third section shows the results obtained when using another life cycle impact assessment method.

5.3.1 Parameters variation

Table 5-1 presents the variation of the total greenhouse gas emissions for the systems concerned by the different sensitivity analyses performed. Overall, it appears that some sensitivity analyses increase the scores, up to more than 253% and others are decreasing the Climate change impact, up to -30%.

Table 5-1: Sensitivity analyses scores for the Climate change indicator. The scores are in g CO₂-eq/cup of espresso. When the score is reduced with the parameter tested, the score is in green and when it is increased, it is in pink. The baseline score is provided in the first row for comparison.

	4000 cups/year			10000 cups/year				Soluble kettle
	NN Zenius	FA efficient	FA non-efficient	NN Gemini	NN Momento	FA efficient	FA non-efficient	
Baseline	75.9	93.5	93.9	80.9	81.1	90.6	100.9	68.2
Amount of coffee: low	75.3	73.2	73.7	80.3	80.5	70.6	80.8	47.6
Amount of coffee: high	77.1	127	128	82.0	82.3	124	134	88.7
Coffee preparation electricity consumption: high				81.5	81.7	91.2	101	
Coffee preparation electricity consumption: low		92.4		75.6	76.1			67.7
Renewable electricity for coffee preparation	72.3	89.9	90.0	72.1	72.4	87.3	90.5	66.0
Machine lifetime: short	78.6	95.8	96.2	83.0	83.4	91.7	103	
Machine lifetime: long	75.3	92.9	93.3	80.3	80.5	90.4	100	
Packaging recycling rates: 100%	73.5	93.5	93.9	78.4	78.6	90.6	101	68.0
Packaging recycling rates: 0%		93.5	93.9			90.6	101	70.3
Portioned packaging for soluble								68.3
Coffee grounds management: methanization		91.7	92.1			88.8	99.1	
Amount of boiled water: high	75.9	93.5	93.9	80.9	81.1	90.6	100.9	72
trip		92.9	93.4			91	101	69
Use scenario. 100 cups/day	73.5	91.4	91.8	73.9	73.9	88.4	92.3	
Green coffee supply: low impacting coffee	68.1	81.9	82.3	73.0	73.2	79.1	89.3	62.4
Green coffee supply: high impacting coffee	170	232	232	175	175	229	239	136
Electricity mix: CH	65.9	83.7	83.8	66.2	66.5	81.1	85.1	57.9

The green coffee supply having a high influence on the overall score, reduce the amount of coffee per cup or using a less impacting coffee are actions that have the higher potential to reduce the GHG emissions. This is clearly shown by the analysis on the amount of coffee that shows a potential reduction of the carbon footprint of a cup of espresso up to 30% (for the soluble system).

The use stage is the other major contributor to the GHG emissions of a cup of espresso. The sensitivity analyses performed regarding this stage are related to the energy consumption – less efficient brewing electricity consumption for Nespresso and FAuto system (“coffee preparation electricity consumption high” in Table 5-1), A++ machine for the FAuto system for 4 000 cups/year scenario, no cup heating function for Nespresso Gemini and Momento or more efficient kettle for soluble (“coffee preparation electricity consumption low” in Table 5-1) – but also to the machine lifetime or on these two elements together with the more intensive use scenario. The analysis having the higher influence on the final score is this latter with a reduction up to 9%. The A++ FAuto machine use for the FAuto system for 4 000 cups/year showed a reduction of only 1% compared to the efficient machine considered in this study that is already quite efficient. The exclusion of 75% of the energy losses for the Nespresso Gemini and Momento to estimate the exclusion of the cup heating would lead to a reduction of 6 to 7% of the impacts. This would need to be confirmed by measurements of the machine energy consumption without the cup heating function. For the soluble coffee system, the analysis testing the influence of boiling 100 ml water instead of 40 ml shows an increase of 6% of the GHG emissions compared to the baseline. If focusing only on the variation of this parameter (amount of water boiled) for the soluble coffee system, the consumer would have to boil 3 to 5 times the amount of water needed (120 to 200 ml) to reach the impact of a Nespresso coffee.

The sensitivity analyses influencing the end-of-life (high or low recycling rate for Nespresso Pro capsules, cardboard and glass) have a bigger influence on the Nespresso scenarios because change in the recycling rate is high (22% in the baseline and 100% in the good recycling rate) and the capsule contribution in the end-of-life is higher than e.g., the cardboard boxes or the glass jar. For the FAuto systems, the good management of the coffee grounds with 100% sent to a biogas facility lead to a reduction of 2% of the GHG emissions.

The sensitivity analysis on the packaging for the soluble coffee, i.e., considering portioned small pouches of soluble coffee (“sticks”), shows very similar results as with the glass jar packaging.

Finally, the analyses on the distribution for the FAuto and soluble coffee systems show that if some consumers opt for a distribution via a retailer and including a shopping trip (following default data from PEF method), their carbon footprint would stay similar. The change is invisible for the FAuto scenarios and the increase is of 2% for the soluble coffee system. Another quick side calculation regarding distribution has been made to check the influence of refining the modelling of the product ordering by internet. It showed that per order, the impact could be underestimated by a factor 5 (9 g instead of about 1.6 g CO₂-eq/order). However, per cup of coffee, this leads to a negligible amount (0.02 g CO₂-eq/cup), given the amount cup equivalents delivered per order.

The sensitivity analysis considering the Swiss electricity mix instead of the ENTSO-E shows a reduction of about 10 g CO₂-eq/cup of espresso for the 4 000 cups/year coffee systems and

for the soluble coffee and from 10 to 15 g CO₂-eq/cup of espresso for the 10 000 cups/year systems. This represents a reduction of about 10% to 20% depending on the coffee system.

Looking at other indicators (see

Appendix B - Sensitivity analyses results for Non-renewable resources depletion, Water withdrawal, Ecosystem quality, Human health and Land Use), it appears that all reductions and increases observed through the Climate change indicator are also leading to respective impact reduction and increase for the other indicators. The breadth of the variation differs from an indicator to another.

5.3.2 Best and worst cases analysis

The sensitivity analyses have been consolidated to generate a best and a worst case scenario for each coffee system. These best and worst case scenarios are not absolute best and worst cases but correspond to the best and worst combination of the parameters tested in sensitivity analyses. The use of the electricity mix and the more intensive coffee consumption (100 cups/day) corresponding to methodological or scope variation, they are excluded from the best and worst case but shown next to them. The best and worst cases are called “BestCombi” and “WorstCombi” in the report.

Figure 5-7 presents the BestCombi and WorstCombi scenarios for each coffee system and for all indicators. It appears that the variation ranges are much larger for the unportioned FAuto and soluble coffee systems in comparison to the portioned Nespresso Pro coffee system. Based on the Climate change indicator, this variation range varies from 12 g CO₂-eq (15%) for the NN Zenius coffee system to 60-69 g CO₂-eq (65 to 68%) for the various FAuto coffee systems. The difference is of 53 g CO₂-eq/cup for the soluble coffee system, corresponding to 78% of the baseline score

Comparing the coffee systems for 4 000 cups/year, i.e., the Nespresso Zenius, the FAuto efficient and FAuto non-efficient coffee systems as well as the soluble coffee system, the following observations can be noticed:

- For all impact indicators, the variation range between the BestCombi and WorstCombi is much larger for the FAuto and the soluble than for the NN Zenius.
- The variation ranges of the FAuto and soluble coffee systems encompass the variation range of the NN Zenius coffee system for all indicators. Therefore, under the specific scenarios tested in the sensitivity analyses, the FAuto and soluble coffee systems can have lower or larger impact than the NN Zenius coffee system.
- For all indicators and all systems, the use of the Swiss electricity mix for all operation in Switzerland leads to a reduction but the ranking remains the same.
- A more intensive consumption (100 cups/day) shows a reduction for all systems except for the soluble coffee system (analysis not performed). The reduction varies slightly from a system to another but the general ranking remains the same.

Comparing the coffee systems for 10 000 cups/year, i.e., the Nespresso Gemini, Nespresso Momento, the FAuto efficient, the FAuto non-efficient as well as the soluble coffee system, it can be observed that:

- For all impact indicators, the variation range between the BestCombi and WorstCombi is much larger for the efficient and non-efficient FAuto and the soluble than for the NN Gemini and Momento.
- The variation ranges of the FAuto and soluble coffee systems encompass the variation range of the NN coffee systems for all indicators. Therefore, under the specific scenarios tested in the sensitivity analyses, the efficient and non-efficient FAuto and the soluble coffee systems can have lower or larger impact than the NN Gemini and Momento coffee system.
- For all indicators and all systems, the use of the Swiss electricity mix leads to a reduction. The ranking between the systems remains the same.
- A more intensive consumption (100 cups/day) shows a reduction for all systems except for the soluble coffee system (analysis not performed). The reduction varies from a system to another and is more important for the NN Gemini and Momento and the non-efficient FAuto than for the efficient FAuto that already has a low impacting machine (low mass and low energy consumption). The general ranking remains the same even if the difference between scenarios is smaller.

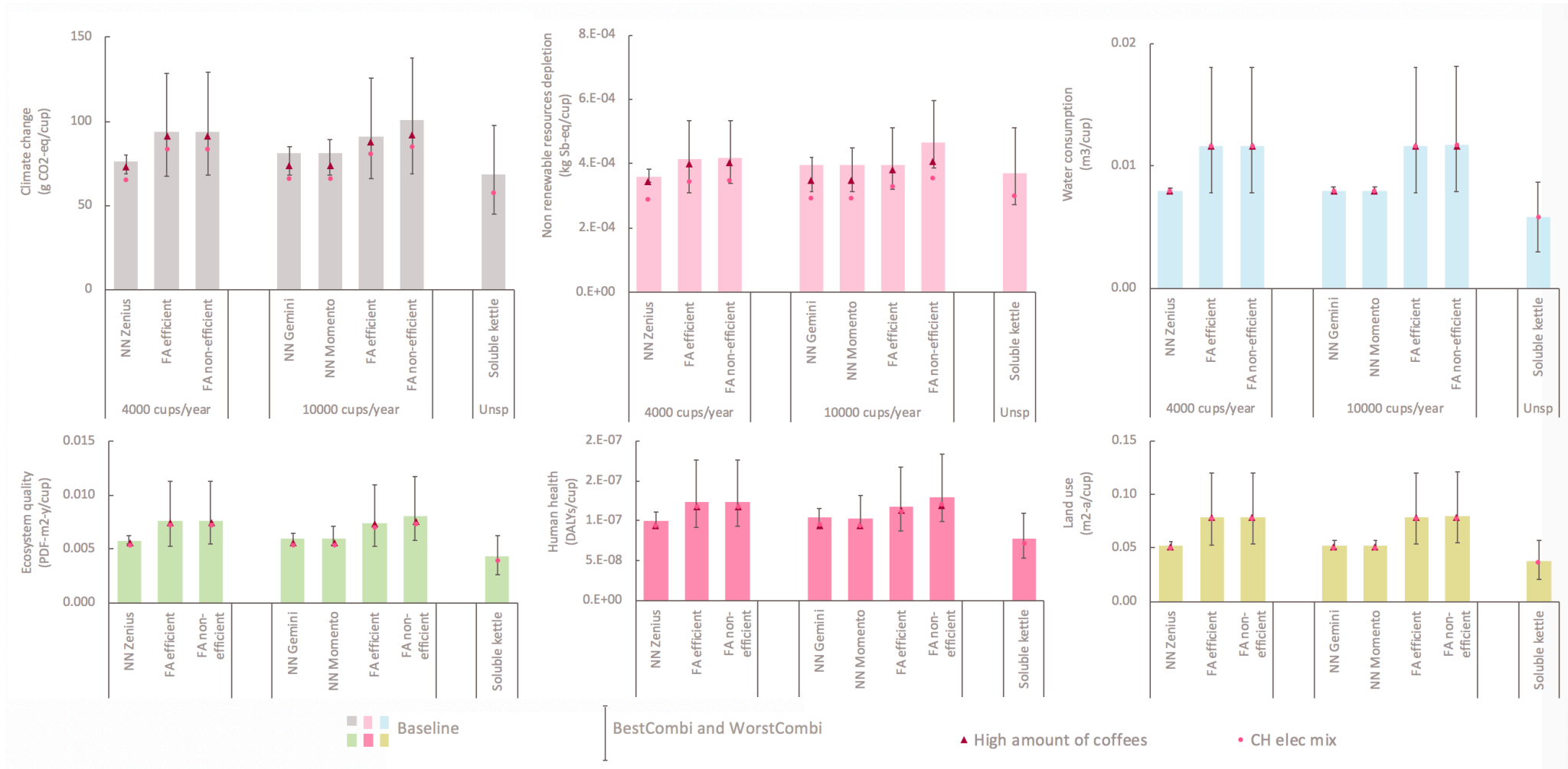


Figure 5-7: Baseline, BestCombi and WorstCombi scenarios for all coffee systems and all indicators. While the bars illustrate the impact of the coffee system baseline, the error bar represents the impact reached with the BestCombi and WorstCombi scenarios. The more intensive consumption scenario (considering 100 cups/day for all systems, i.e., 26 000 cups/year) and the scenario applying the Swiss electricity mix are shown with respectively the small purple triangle and the pink circle.

5.3.2.1 LCIA method

The impact scores have been calculated with another LCIA method, here the EF method (official method of the PEF and recommended by the European Commission). They are presented in the Table 5-2 and Table 5-3 below.

Considering the use scenario of 4 000 cups/year (Table 5-2), the soluble coffee is the less impacting and the FAuto scenarios have a higher impact as it was shown with the indicators of the Nestlé method. Considering the indicators that can be found in both methods as climate change, non-renewable resources depletion, water consumption and land use, the ranking of the different coffee systems is similar to what was obtained with the indicators of the Nestlé method. A different trend can be observed for the non-renewable resources minerals and metals, mostly in relation to the machine composition (electronic components dominate this indicator). The Nespresso machines contain a higher quantity of electronic components based on the data considered (generic data for the FAuto), leading to a higher impact for this indicator. It is not the case for the Nestlé non-renewable resources depletion because this latter also includes the fossil fuels consumption and therefore metals or plastics have also an important contribution for the machine production and machine contribution itself a lower contribution (because of green coffee and use stage energy consumption).

Table 5-2: Impact scores calculated with the Nestlé method and the EF method for the coffee systems for 4 000 cups/year, i.e., Nespresso Zenius, efficient and non-efficient full automat and the soluble coffee.

Nestlé method				
	NN Zenius	FA efficient	FA non-efficient	Soluble kettle
Climate change	100%	123%	124%	90%
Non renewable resources depletion	100%	115%	116%	103%
Water consumption WSI	100%	146%	146%	73%
Ecosystem quality	100%	132%	133%	75%
Human health	100%	123%	124%	78%
Land use	100%	152%	152%	73%

EF Method				
	NN Zenius	FA efficient	FA non-efficient	Soluble kettle
Climate change	100%	123%	123%	90%
Ozone depletion	100%	115%	116%	101%
Ionising radiation	100%	107%	109%	95%
Photochemical ozone formation	100%	130%	130%	84%
Particulate matter	100%	131%	131%	85%
Human toxicity, non-cancer	100%	144%	145%	73%
Human toxicity, cancer	100%	132%	132%	72%
Acidification	100%	137%	137%	79%
Eutrophication, freshwater	100%	114%	114%	61%
Eutrophication, marine	100%	141%	141%	77%
Eutrophication, terrestrial	100%	143%	143%	76%
Ecotoxicity, freshwater	100%	143%	143%	73%
Land use	100%	158%	159%	76%
Resource use, fossils	100%	113%	114%	104%
Resource use, minerals and metals	100%	79%	79%	37%
Water use	100%	130%	130%	74%

For the use scenario of 10 000 cups/year (Table 5-3), the scores obtained with the EF method show similar trend as for the 4 000 cups/year, i.e., soluble coffee being the less impacting and FAuto system being higher than the Nespresso systems. The difference observed between the different coffee systems for 10 000 cups/year scenarios are similar to the ones observed with the Nestlé indicators. A different trend can be observed for the EF method for other indicators such as ionizing radiation and freshwater eutrophication. The ionizing radiations are embedded in human health endpoint indicator in the Nestlé method, but they have a low contribution to the overall human health endpoint compared to e.g., the particulate matter. For the freshwater eutrophication, it is embedded in ecosystem quality in the Nestlé method, but it represents only one of the midpoints contributing to the ecosystem quality endpoint. This explains why the trends observed for human health and ecosystem quality are different from these two EF method midpoints. When aggregated to show the damage on human health and ecosystem quality, the inverse effect of ionizing radiation and freshwater eutrophication is compensated by the other midpoints.

The fossil resource use indicator shows also the efficient FAuto being slightly better but the difference (5%) is small and therefore the system can be seen as similar to Nespresso and

soluble systems. It has been identified that the peat is included as fossil resources in the EF method but not in the Nestlé method. Composting of coffee pulp at the green coffee farm considers that it avoids a small amount of peat (brings same soil structuring effect) and this effect is therefore showing a benefit with the EF method only.

Table 5-3: Impact scores calculated with the Nestlé method and the EF method for the coffee systems for 10 000 cups/year, i.e., Nespresso Gemini and Momento, efficient and non-efficient full automat and the soluble coffee.

Nestlé method

	NN Gemini	NN Momento	FA efficient	FA non-efficient	Soluble kettle
Climate change	100%	100%	112%	125%	84%
Non renewable resources depletion	100%	100%	100%	117%	93%
Water consumption WSI	100%	100%	146%	146%	73%
Ecosystem quality	100%	99%	123%	133%	72%
Human health	100%	99%	112%	124%	75%
Land use	100%	100%	150%	152%	72%

EF Method

	NN Gemini	NN Momento	FA efficient	FA non-efficient	Soluble kettle
Climate change	100%	100%	112%	124%	84%
Ozone depletion	100%	100%	107%	116%	97%
Ionising radiation	100%	100%	84%	112%	78%
Photochemical ozone formation	100%	100%	121%	130%	81%
Particulate matter	100%	100%	129%	132%	84%
Human toxicity, non-cancer	100%	100%	144%	145%	73%
Human toxicity, cancer	100%	99%	128%	132%	71%
Acidification	100%	99%	131%	136%	76%
Eutrophication, freshwater	100%	97%	92%	118%	57%
Eutrophication, marine	100%	100%	139%	141%	77%
Eutrophication, terrestrial	100%	100%	141%	143%	75%
Ecotoxicity, freshwater	100%	100%	142%	144%	73%
Land use	100%	100%	149%	157%	72%
Resource use, fossils	100%	100%	95%	115%	92%
Resource use, minerals and metals	100%	124%	84%	110%	50%
Water use	100%	100%	123%	131%	71%

5.4 Study limitations

It is important to understand how this study was conducted so that its results and conclusions are applied appropriately. The following limitations should be considered along with the context described in earlier sections of this report when interpreting the information presented in this work:

- This study focuses on the Swiss market and the results observed are therefore true only for this specific market. One important parameter that influences the results is that in Switzerland the wastes that are trashed are 100% incinerated (landfilling of municipal solid wastes is forbidden) and also that there is no littering (or very small quantities). Having landfilling would increase some of the impacts, e.g., coffee grounds or other bio-based materials in landfills would emit methane and therefore would have higher

impacts than when incinerated, leading to a higher difference between e.g., recycling scenarios and trash scenarios.

- The green coffee cultivation is assessed following the PEF CR for coffee and the same coffee is applied for all systems. In reality, if one of the systems is sourcing from completely different origins, this could lead to differences of production, less or more deforestation impacts or lower or higher delivery distance. The Nespresso AAA coffee from Nespresso is also not considered in the current study while it could influence the coffee impacts. As the cultivation system of the coffee from the other systems studied is unknown, it seemed better not to differentiate the systems for this stage. The conclusions of this study are therefore only true when the same coffee is used for all the coffee systems assessed.
- The conclusions of this study are robust for the Climate change indicator. For the other indicators, these conclusions are less robust as they are more uncertain. This is inherent to the state of knowledge regarding the modelling of these indicators and to all impact assessment methods: the radiative forcing effect of greenhouse gases is better known than, e.g., the movements of a polluting substance in the different environmental compartment, its intake and exact toxic effect.
- The Nespresso coffee systems are modelled with a bit more details and granularity because primary data were available for this model. As one of the purposes of the study was to understand better the impacts of the Nespresso coffee systems, it was decided to keep all available data on this system, even if it was not possible to find as detailed data for the compared systems. This is also the rationale that led to include life cycle stage having the same impacts for all systems, e.g., the overheads or the cup washing. The different level of granularity in the data for the competitive systems is balanced by the number of sensitivity analyses.
- The soluble coffee system assessed in the current study is not necessarily the most appropriate type of soluble coffee for business. Soluble coffee prepared in a vending machine or soluble coffee packaged in portioned packaging would be more appropriate. However, the objective to have soluble coffee in the study was to position the Nespresso and full automat systems compared to this soluble alternative known as efficient in terms of environmental impacts. The portioned packaging is also tested in sensitivity analysis.
- Biogenic CO₂ uptake and release by coffee is not included. However, it is accepted that all the coffee will be (almost) entirely degraded at end-of-life for composting, methanization and incineration and therefore that the balance is neutral for these end-of-life routes.
- In the baseline scenarios, the incineration with energy recovery leads to credits related to the avoided conventional energy produced. For the heat, natural gas is assumed to

be avoided as proxy for the default heat used. This could be refined with a more detailed heat mix representing the Swiss average heat mix.

- Some aspects are not well covered in the model for the compost and digestate spread on fields as, e.g., carbon storage, agricultural yield increase, erosion decrease and services to the ecosystems. This means that the benefits related to composting and methanization could be higher than what is shown in this study.
- Renewable electricity is considered for the manufacturing of the coffee at Nespresso factories. To consider renewable electricity for the factories, the study should remove the renewable fraction from the average grid mix that is used for non-certified electricity consumption. This was not done as the renewable fraction is still small in the average European electricity mix. All experts are not fully aligned on the electricity mix choice issue. Some challenge the idea of considering renewable electricity mix for activities as long as not 100% of the electricity consumed in a country is not renewable. For this study, the choice was made to consider renewable electricity as less impacting to show the effort made by Nespresso through its purchase of certified renewable electricity: an increase in the demand of renewable electricity pushes in the right direction. For this, it is required that purchasing this electricity certifies that an additional renewable electricity is produced thanks to the certification. Finally, the same manufacturing process is considered for Nespresso and full automat and therefore renewable electricity is also considered for the full automat. This assumption is judged as a conservative approach as its implications remain equitable for all systems considered.
- Some life cycle stages are common to all coffee systems leading to a smaller difference among the systems (e.g., overheads/support, cup production and washing). In a pure comparative study, these common elements could have been excluded to focus on the differences. However, one objective of the study being to have also a better idea of the main contributors to the impacts of a cup of coffee, these elements are included in the assessment. It also avoids concluding one system is much better than the other while in reality, when considering the full life cycle, it is only slightly different.
- Unlike environmental risk assessment conducted in a regulatory context, which uses a conservative approach, LCA seeks to provide the best possible estimate (Udo de Haes et al. 2002). In other words, the LCIA tries to represent the most probable case in that the models (of transport and fate of contaminants in the environment and of toxic effects on biological receptors) do not attempt to maximize exposure and environmental damage.
- LCIA methodologies do not and cannot characterize the wide array of emissions released to soil, air and water from processes. However, it does characterize the most well-known pollutants and in doing such, provides the best estimate to evaluate environmental impact.

- Finally, LCIA results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins or risks.

These limitations of the LCIA results do not challenge the main conclusions relative to the defined goal and scope of the study as the results still allow the identification of the key environmental parameters and key differences among scenarios.

When this study is communicated to stakeholders, the magnitude and nature of the limitations should be communicated at the same time.

6 Discussion and conclusion

For all coffee systems and all indicators, impacts are systematically dominated by the green coffee supply and the use stage (respectively 20% to 98% and 15% to 53% depending on the coffee system and indicator), except for the Land use and for the Water withdrawal for which the use stage is small and the impacts are almost completely driven by the green coffee supply (81% to 97% depending on the coffee system and indicator considered). Because the same green coffee supply process is used for all coffee systems, only the amount of coffee per cup does influence the comparison among the coffee systems. Among the most important parameters influencing the use stage, the electricity consumption for coffee preparation as well as the weight of the coffee machine can be highlighted.

The packaging production represents the third or the fourth contributor to overall impact depending on the indicator considered. The Nespresso packaging system is more impacting than the full automat packaging system for all indicators assessed except for Water withdrawal and Land use. It has a similar impact as the one of the soluble coffee system, except for Water withdrawal and Land use for which it has a much higher impact. The carbon footprint of the packaging is dominated by the primary packaging for the Nespresso (Pro capsule) and the soluble coffee system (glass jar) while the secondary packaging is the main contributor for the full automat packaging stage (cardboard tray). To compare the different packaging items, it is important to consider their production and delivery, but also their end-of-life treatment. Consider the sum of these two elements reduces slightly the differences between the Nespresso and the full automat coffee systems (1 g CO₂-eq more for Nespresso) and increases the difference when compared to the soluble coffee system (2 g CO₂-eq more for Nespresso).

Key finding #1 - Coffee system contributors

Based on the studied coffee system impacts at baseline, it can be mentioned that for all systems, the most impacting life cycle stages are the coffee supply and the use stage. The

packaging production contribution is only the third or the fourth contributor to the impacts for all indicators and all systems assessed.

Based on the evaluation of the baseline scenarios, it appears that drinking an espresso cup of coffee made from a Nespresso Pro system have higher impacts than a same cup made from a soluble coffee system. The full automat coffee systems tested in this study appear as the most impacting coffee system. The full automat emits about 20% more GHG emissions than the Nespresso Pro for the 4 000 cups/year scenarios, and from 10% to than 25% GHG emissions than Nespresso Pro for the 10 000 cups/year scenarios. The use stage is quite similar for the Nespresso Zenius and the two full automat systems that are compared with it for the 4 000 cups/year scenario. This means that for this consumption intensity, most of the difference between the coffee systems is explained by the amount of green coffee used per cup. For the 10 000 cups/year scenarios, the efficient full automat has lower use stage GHG emissions than the Nespresso Gemini and Momento, mainly due to its lower energy consumption for the coffee preparation (lower electricity losses for ready-to-use, stand by, etc.), but also because the machine is quite light. The lower use stage GHG emissions compensate partly the higher amount of coffee per cup but is not sufficient to completely compensate it. The non-efficient full automat for 10 000 cups/year has the highest use stage, mostly due to its high energy consumption. In addition to the higher amount of R&G coffee consumed per cup for the full automat systems, it leads this system to the highest carbon footprint. For the 10 000 cups/year consumption intensity, the ranking of the different systems is therefore explained mostly by the amount of green coffee needed per cup and the machine mass and electricity consumption during the use stage.

The soluble coffee correspond to both the lowest amount of green coffee consumed per cup and the lowest energy consumption for coffee preparation leading to the lowest impacting of all coffee systems compared in this study for most of the indicators assessed (only non-renewable resources consumption gives a different trend where soluble coffee has similar impacts to the Nespresso Zenius, the two of them being the most efficient).

The difference of the systems in terms of packaging are quite small. The Nespresso systems packaging emits about 2 g CO₂-eq/cup more than the full automat systems packaging. This equals to a difference of having 0.5 g more R&G coffee per cup. This means that if a full automat has 0.5 g more R&G coffee per cup, it compensates its lower impact for the packaging.

Key finding #2 – Comparison of the different coffee systems

When comparing the systems, it appears the soluble coffee is the lowest or among the lowest impacting coffee system assessed. Its low amount of green coffee per cup and low electricity consumption for the use stage explain this good position.

The full automat coffee systems have the highest baseline impacts for all indicators assessed. This is particularly marked for the indicators that are mostly influenced by coffee supply. This shows the differentiation between the Nespresso and full automat scenario is mostly driven by the amount of green coffee needed per cup, even if the use stage of some of the full automat systems is more efficient than the Nespresso use stage.

The assessment of the baseline models shows that Nespresso systems have a higher impact than the soluble coffee but a lower impact than the full automat systems.

Considering the conducted sensitivity analyses, the Nespresso systems show the lowest variability while both full automat and soluble coffee systems have a much larger range. While testing the influence of the parameters selected, it has been observed that the controlled amount of coffee as well as the more standardized coffee machines characterizing the Nespresso portioned coffee systems lead to much lower possible impact variations than the unportioned coffee systems (full automat is considered as unportioned here as the amount of coffee can be defined by the user). Comparing Nespresso to full automat systems, it is only the fixed amount of coffee that explains the lower variability of the Nespresso system as the use-related parameters are also quite stable for the full automat. Comparing Nespresso to the soluble coffee system, the large variation of the use stage parameters together with the variation of the soluble coffee amount per cup explain the large impact variation.

With the Nespresso coffee systems variation range being encompassed by the full automat ranges and the soluble coffee range, the Nespresso systems can have similar impact to the full automat or soluble coffee systems under specific conditions. Because of this significant larger variation of unportioned coffee systems, the soluble and full automat coffee systems, which might be more performant than portioned coffee system under certain circumstances (e.g. lower amount of coffee per cup) can quickly become more impacting if not efficiently used. In other words, an eco-friendly consumer could have lower impacts using a soluble or full automat than the Nespresso Pro coffee system under specific conditions, but someone being not careful about its environmental footprint could prepare a less impacting coffee with the Nespresso system than with the soluble or full automat coffee system.

A responsible consumer using a soluble coffee, boiling the right amount of water in an efficient kettle, recycling its packaging and using a limited amount of soluble coffee per cup can save up to 23 g CO₂-eq per coffee cup compared to another responsible consumer using a Nespresso coffee machine without turning on the cup heater, recycling all the packaging (capsule and cardboard) and keeping the machine on the long term. On the contrary, a non-responsible consumer of soluble coffee, boiling too much water, using a less efficient kettle, not recycling the packaging wastes and using 3 g soluble per cup would emit 8 to 13 g CO₂-eq more per cup of espresso than a non-responsible consumer using the Nespresso system (changing the

machine quickly, using the cup-heater mode, not recycling the capsules and selecting the type of capsules with the highest amount of coffee inside). If focusing only on the variation of the amount of water boiled for the soluble coffee system, the consumer would have to boil 3 to 5 times the amount of water needed (120 to 200 ml) to reach the carbon footprint of a Nespresso coffee.

A responsible consumer using an efficient full automat machine, keeping it on the long term and selecting a low amount of coffee per cup (6 g, same as for Nespresso Pro) and sending its coffee grounds to a biogas facility has a similar impact than the responsible consumer using the Nespresso system as described above. On the contrary, a non-responsible full automat consumer, choosing a highly dosed coffee, a non-efficient machine and changing it after only 6 years and not recycling the packaging wastes will emit about 35 to 50 g CO₂-eq more than the non-responsible Nespresso consumer described above.

Consumer behaviour is therefore key.

Key finding #3 – Overall assessment of the coffee system impact variability

Considering the sensitivity analyses performed, no coffee system is intrinsically better than another considering the variability each coffee system is subject to. Indeed, a responsible consumer behaviour for the full automat and the soluble systems could lead to similar or lower impacts than the Nespresso coffee system, while a non-responsible consumer behaviour for the full automat and soluble systems will lead to higher impact than Nespresso. The Nespresso system being more framed as a portioned system, its variability is much lower than the variability for the two other systems assessed. Unportioned coffee system performances are much more dependent on consumer behaviour than portioned coffee systems.

Nespresso impacts are for all systems mostly due to the green coffee supply and the use stage. Working on these two stages is therefore a priority to reduce Nespresso system impacts. One idea could be to work on the improvement the coffee extraction to be able to reduce more the coffee amount in capsule or at least reduce the heavier espresso capsules from 6.3 to 6 g. Reducing from 6.3 g to 6 g represents a reduction of a bit less than 2 g CO₂-eq per cup of espresso (but it has to be noted that the weighted average of coffee per cup is 6.1 g for the espresso Pro capsules, i.e., not 100% of the cups can be reduced). Then of course continue working on the coffee cultivation step together with the farmers to ensure keeping the same yield with less fertilizers and pesticides use, renewable energy consumption for the cherries treatment and ensuring a good coffee pulp management. These aspects are partly explored through the AAA program.

Regarding the use stage, the impacts are related to both the machine mass, its composition and its electric consumption. Ensure having light machines with a low amount of electronic

components would help reduce the impact. Indeed, the electronic component represents a high contributor to the machine production. It has to be highlighted here that the latest machine model (Momento) does not go in the right direction as it is slightly heavier than the Gemini machine (1 more kg) and it has a large touchable screen and a presence detector, i.e., more electronic than in the previous machine. Another element that could be further assessed is the machine maintenance and repair. Ensuring the machines are well maintained and easily repairable can help keeping them on a longer term. Keeping a machine for 12 years instead of 6 years saves 3 g CO₂-eq per cup of espresso (the lifetime considered in the baseline is 10 years). Regarding the electricity use, the cup heating option seems to correspond to up to 75% of the ready-to-use energy consumption according to a VDE expert (Institute that made the energy consumption measurements for the Nespresso machines). It could be explored if it corresponds to an option often used by the consumers and if not, it could be considered to remove this option from most of the machines, and maybe keep it only for the machines used in restaurant. Not using the cup heating mode could reduce the carbon footprint of about 5 g CO₂-eq/cup of espresso for the Gemini and the Momento machines.

The packaging is not a major contributor but is an element highly visible for the consumer. As the aluminium is the most impacting element of the capsule packaging, exploring the potential use of secondary aluminium or ASI-certified aluminium (produced with renewable electricity) could lead to an impact reduction.

Finally, an additional option to reduce the overall environmental impact of a cup of coffee would be to use renewable electricity at the use stage (for example by providing pre-purchased credits of renewable energy when purchasing each capsule (e.g. 0.2 cts./cup)). It would enable to gain 4 to 9 g CO₂-eq in the brewing stage respectively for the Zenius and the Gemini or Momento systems.

Key finding #4 – Improvement potential of the Nespresso Pro coffee system

Testing the influence of several parameters on the impacts of the Nespresso Pro coffee system, it appears that changing some key parameters could clearly help reducing the impacts and especially the GHG emissions. While using for example renewable instead of non-renewable electricity over the coffee brewing stage at consumer could lead to a 4 to 9 g CO₂-eq decrease per cup of espresso, excluding to cup-heating mode could represent a reduction of 5 g CO₂-eq per cup. Other pathways could be to reduce the amount of R&G coffee used per capsule, ensuring the machine is well maintained to prolong its lifetime or work on the aluminium supply for the capsules packaging.

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8 Appendices

8.1 Appendix A – Circular Footprint Formula

Figure 8-1 (European Commission, 2017) presents the circular footprint formula with its three distinct components: material (production and recycling), energy (recovery) and disposal, which add-up to the total impacts of a given material. Table 8-1 details the notation used in the formula.

The two parameters in the formula are:

- A: Allocation factor of burdens and credits between supplier and user of recycled materials. This is a key parameter that enables a refined tuning between 100/0 and 0/100.

If A is large (e.g., 0.8), the credits are mostly given to the system that uses recycled (secondary) material. Conversely, a small A (e.g., 0.2) will mostly give credits to the system providing recyclable material for use in the next system.

- B: Allocation factor of burdens and credits between supplier and user of energy recovery processes. Currently set to 0 by default, so full impacts and credits are allocated to the system generating the waste. This implies that the use of electricity and heat from MSWI plants is “free of charge”. This could be changed if it was decided for policy reasons.

These factors are material- and application-specific.

$$\text{Material} \quad (1 - R_1) \times E_V + R_1 \times \left(A \times E_{\text{recycled}} + (1 - A) \times E_V \times \frac{Q_{\text{Sin}}}{Q_p} \right) + (1 - A) \times R_2 \times \left(E_{\text{recyclingEoL}} - E_V^* \times \frac{Q_{\text{Sout}}}{Q_p} \right)$$

$$\text{Energy} \quad (1 - B) R_3 \times (E_{ER} - LHV \times X_{ER,heat} \times E_{SE,heat} - LHV \times X_{ER,elec} \times E_{SE,elec})$$

$$\text{Disposal} \quad (1 - R_2 - R_3) \times E_D$$

Figure 8-1: Circular Footprint Formula.

Table 8-1: Notations and formulas used in the Circular footprint formula.

Signs

A	Allocation factor of burdens and credits between supplier and user of recycled materials.
B	Allocation factor of energy recovery processes: it applies both to burdens and credits.
Q_{Sin}	Quality of the secondary material used as input.
Q_{Sout}	Quality of the recycled material outgoing the system at the point of substitution.
Q_p	Quality of the primary material, i.e. quality of the virgin material.
R_1	Proportion of secondary material in the input.
R_2	Proportion of the material in the product that will be recycled (or reused) in a subsequent system. R_2 shall therefore take into account the inefficiencies in the collection and recycling (or reuse) processes. R_2 shall be measured at the output of the recycling plant.
R_3	Proportion of the material in the product that is used for energy recovery at EoL.
E_{recycled}	Specific emissions and resources consumed arising from the recycling process of the recycled (reused) material, including collection, sorting and transportation process.
$E_{\text{recyclingEoL}}$	Specific emissions and resources consumed arising from the recycling process at EoL, including collection, sorting and transportation process.
E_V	Specific emissions and resources consumed arising from the acquisition and pre-processing of virgin material.
E_V^*	Specific emissions and resources consumed arising from the acquisition and pre-processing of virgin material assumed to be substituted by recyclable materials.
E_{ER}	Specific emissions and resources consumed arising from the energy recovery process (e.g., incineration with energy recovery, landfill with energy recovery, etc.).
$E_{SE,heat}$ $E_{SE,elec}$	Specific emissions and resources consumed that would have arisen from the specific substituted energy source, heat ⁴ and electricity ⁵ respectively.
E_D	Specific emissions and resources consumed arising from disposal of waste material at the EoL of the analysed product, without energy recovery.
$X_{ER,elec}$ $X_{ER,heat}$	Efficiency of the energy recovery process for heat and electricity respectively.
LHV	Lower Heating Value of the material in the product that is used for energy recovery.

The values used for the different parameters are the default values as specified in the Annex C of the PEF method (European Commission, 2019).

⁴ By default, the substituted heat is natural gas boiler.

⁵ By default, the substituted electricity mix is the European one, medium voltage.

The B factor equals to 0 as default (European Commission, 2017).

The A factor varies depending on the material considered (European Commission, 2017):

- 0.2 for steel, aluminium, copper, and other metals
- 0.2 for paper and cardboard as used in this study (but e.g., 0.5 for tissue paper, not used in the current study)
- 0.2 for glass
- 0.5 for plastics
- 0.8 for wood

8.2 Appendix B - Sensitivity analyses results for Non-renewable resources depletion, Water withdrawal, Ecosystem quality, Human health and Land Use

Table 8-2: sensitivity analyses for the non-renewable resources depletion indicator. The scores are in kg Sb-eq per cup of espresso. When the score is reduced with the parameter tested, the score is in green and when it is increased, it is in pink. The baseline score is provided in the first row for comparison.

	4000 cups/year			10000 cups/year				Soluble kettle
	NN Zenius	FA efficient	FA non-efficient	NN Gemini	NN Momento	FA efficient	FA non-efficient	
Baseline	3.6E-04	4.1E-04	4.2E-04	4.0E-04	4.0E-04	4.0E-04	4.7E-04	3.7E-04
Amount of coffee: low	3.6E-04	3.5E-04	3.5E-04	4.0E-04	4.0E-04	3.3E-04	4.0E-04	2.8E-04
Amount of coffee: high	3.6E-04	5.2E-04	5.3E-04	4.0E-04	4.0E-04	5.0E-04	5.7E-04	4.6E-04
Coffee preparation electricity consumption: high				4.0E-04	4.0E-04	4.0E-04	4.7E-04	
Coffee preparation electricity consumption: low		4.1E-04		3.6E-04	3.6E-04			3.7E-04
Renewable electricity for coffee preparation	3.4E-04	3.9E-04	3.9E-04	3.4E-04	3.4E-04	3.7E-04	3.9E-04	3.5E-04
Machine lifetime: short	3.8E-04	4.3E-04	4.3E-04	4.1E-04	4.1E-04	4.0E-04	4.8E-04	
Machine lifetime: long	3.6E-04	4.1E-04	4.1E-04	3.9E-04	3.9E-04	3.9E-04	4.6E-04	
Packaging recycling rates: 0%	3.6E-04	4.1E-04	4.2E-04	4.0E-04	4.0E-04	4.0E-04	4.7E-04	3.8E-04
Packaging recycling rates: 100%	3.5E-04	4.1E-04	4.2E-04	3.8E-04	3.8E-04	4.0E-04	4.7E-04	3.7E-04
Portioned packaging for soluble								3.6E-04
Coffee grounds management: methanization		4.0E-04	4.0E-04			3.8E-04	4.5E-04	
Amount of boiled water: high	3.6E-04	4.1E-04	4.2E-04	4.0E-04	4.0E-04	4.0E-04	4.7E-04	4.0E-04
Distribution: retailer & shopping trip		4.1E-04	4.1E-04			4.0E-04	4.7E-04	3.8E-04
Use scenario. 100 cups/day	3.4E-04	4.0E-04	4.0E-04	3.5E-04	3.5E-04	3.8E-04	4.1E-04	
Electricity mix: CH	2.9E-04	3.5E-04	3.5E-04	2.9E-04	2.9E-04	3.3E-04	3.6E-04	3.0E-04

Table 8-3: sensitivity analyses for the water withdrawal. The scores are in m3 per cup of espresso. When the score is reduced with the parameter tested, the score is in green and when it is increased, it is in pink. The baseline score is provided in the first row for comparison.

	4000 cups/year			10000 cups/year				Soluble kettle
	NN Zenius	FA efficient	FA non-efficient	NN Gemini	NN Momento	FA efficient	FA non-efficient	
Baseline	0.0080	0.0117	0.0117	0.0080	0.0080	0.0117	0.0117	0.0058
Amount of coffee: low	0.0078	0.0078	0.0078	0.0079	0.0079	0.0078	0.0079	0.0030
Amount of coffee: high	0.0082	0.0180	0.0180	0.0082	0.0082	0.0180	0.0181	0.0087
Coffee preparation electricity consumption: high				0.0080	0.0080	0.0117	0.0117	
Coffee preparation electricity consumption: low		0.0117		0.0080	0.0080			0.0058
Renewable electricity for coffee preparation	0.0080	0.0116	0.0116	0.0080	0.0080	0.0116	0.0116	0.0058
Machine lifetime: short	0.0080	0.0117	0.0117	0.0080	0.0080	0.0117	0.0117	
Machine lifetime: long	0.0080	0.0117	0.0117	0.0080	0.0080	0.0117	0.0117	
Packaging recycling rates: 0%	0.0080	0.0117	0.0117	0.0080	0.0080	0.0117	0.0117	0.0058
Packaging recycling rates: 100%	0.0080	0.0117	0.0117	0.0080	0.0080	0.0117	0.0117	0.0058
Portioned packaging for soluble								0.0058
Coffee grounds management: methanization		0.0117	0.0117			0.0117	0.0117	
Amount of boiled water: high	0.0080	0.0117	0.0117	0.0080	0.0080	0.0117	0.0117	0.0058
Distribution: retailer & shopping trip		0.0117	0.0117			0.0117	0.0117	0.0058
Use scenario. 100 cups/day	0.0080	0.0117	0.0117	0.0080	0.0080	0.0117	0.0117	
Electricity mix: CH	0.0080	0.0117	0.0117	0.0080	0.0080	0.0117	0.0117	0.0058

Table 8-4: sensitivity analyses for the ecosystem quality. The scores are in PDF-m2-y per cup of espresso. When the score is reduced with the parameter tested, the score is in green and when it is increased, it is in pink. The baseline score is provided in the first row for comparison.

	4000 cups/year			10000 cups/year				Soluble kettle
	NN Zenius	FA efficient	FA non-efficient	NN Gemini	NN Momento	FA efficient	FA non-efficient	
Baseline	0.00576	0.00763	0.00766	0.00602	0.00598	0.00740	0.00801	0.00435
Amount of coffee: low	0.00570	0.00558	0.00560	0.00596	0.00591	0.00535	0.00596	0.00269
Amount of coffee: high	0.00590	0.01106	0.01108	0.00616	0.00611	0.01082	0.01143	0.00601
Coffee preparation electricity consumption: high				0.00605	0.00601	0.00743	0.00804	
Coffee preparation electricity consumption: low		0.00758		0.00578	0.00575			0.00433
Renewable electricity for coffee preparation	0.00560	0.00747	0.00748	0.00564	0.00559	0.00725	0.00755	0.00425
Machine lifetime: short	0.00603	0.00788	0.00790	0.00629	0.00621	0.00751	0.00828	
Machine lifetime: long	0.00570	0.00757	0.00759	0.00596	0.00592	0.00737	0.00794	
Packaging recycling rates: 0%	0.00579	0.00763	0.00766	0.00605	0.00601	0.00740	0.00801	0.00439
Packaging recycling rates: 100%	0.00566	0.00763	0.00766	0.00591	0.00587	0.00740	0.00801	0.00435
Portioned packaging for soluble								0.00431
Coffee grounds management: methanization		0.00753	0.00755			0.00730	0.00791	
Amount of boiled water: high	0.00576	0.00763	0.00766	0.00602	0.00598	0.00740	0.00801	0.00453
Distribution: retailer & shopping trip		0.00765	0.00767			0.00744	0.00805	0.00440
Use scenario. 100 cups/day	0.00552	0.00742	0.00744	0.00555	0.00553	0.00724	0.00748	
Electricity mix: CH	0.00529	0.00717	0.00718	0.00533	0.00529	0.00695	0.00726	0.00387

Table 8-5: sensitivity analyses for the human health. The scores are in DALY per cup of espresso. When the score is reduced with the parameter tested, the score is in green and when it is increased, it is in pink. The baseline score is provided in the first row for comparison.

	4000 cups/year			10000 cups/year				Soluble kettle
	NN Zenius	FA efficient	FA non-efficient	NN Gemini	NN Momento	FA efficient	FA non-efficient	
Baseline	1.00E-07	1.24E-07	1.24E-07	1.04E-07	1.03E-07	1.17E-07	1.30E-07	7.79E-08
Amount of coffee: low	9.96E-08	9.60E-08	9.64E-08	1.04E-07	1.02E-07	8.98E-08	1.02E-07	5.35E-08
Amount of coffee: high	1.02E-07	1.70E-07	1.70E-07	1.06E-07	1.05E-07	1.63E-07	1.76E-07	1.02E-07
Coffee preparation electricity consumption: high				1.05E-07	1.03E-07	1.18E-07	1.30E-07	
Coffee preparation electricity consumption: low		1.23E-07		1.01E-07	9.95E-08			7.75E-08
Renewable electricity for coffee preparation	9.85E-08	1.22E-07	1.22E-07	9.98E-08	9.84E-08	1.15E-07	1.24E-07	7.67E-08
Machine lifetime: short	1.08E-07	1.31E-07	1.31E-07	1.12E-07	1.10E-07	1.20E-07	1.37E-07	
Machine lifetime: long	9.85E-08	1.22E-07	1.22E-07	1.03E-07	1.01E-07	1.16E-07	1.28E-07	
Packaging recycling rates: 0%	1.02E-07	1.24E-07	1.24E-07	1.06E-07	1.04E-07	1.17E-07	1.30E-07	8.00E-08
Packaging recycling rates: 100%	9.63E-08	1.24E-07	1.24E-07	1.00E-07	9.89E-08	1.17E-07	1.30E-07	7.77E-08
Portioned packaging for soluble								7.75E-08
Coffee grounds management: methanization		1.22E-07	1.22E-07			1.16E-07	1.28E-07	
Amount of boiled water: high	1.00E-07	1.24E-07	1.24E-07	1.04E-07	1.03E-07	1.17E-07	1.30E-07	8.09E-08
Distribution: retailer & shopping trip		1.23E-07	1.24E-07			1.17E-07	1.30E-07	7.87E-08
Use scenario. 100 cups/day	9.36E-08	1.18E-07	1.18E-07	9.39E-08	9.34E-08	1.14E-07	1.18E-07	
Electricity mix: CH	9.41E-08	1.17E-07	1.18E-07	9.52E-08	9.39E-08	1.11E-07	1.20E-07	7.15E-08

Table 8-6: sensitivity analyses for the land use. The scores are in m2-y per cup of espresso. When the score is reduced with the parameter tested, the score is in green and when it is increased, it is in pink. The baseline score is provided in the first row for comparison.

	4000 cups/year			10000 cups/year				Soluble kettle
	NN Zenius	FA efficient	FA non-efficient	NN Gemini	NN Momento	FA efficient	FA non-efficient	
Baseline	0.0517	0.0786	0.0787	0.0524	0.0524	0.0784	0.0797	0.0377
Amount of coffee: low	0.0509	0.0538	0.0539	0.0517	0.0517	0.0536	0.0549	0.0207
Amount of coffee: high	0.0531	0.1199	0.1200	0.0539	0.0539	0.1197	0.1210	0.0547
Coffee preparation electricity consumption: high				0.0525	0.0525	0.0785	0.0797	
Coffee preparation electricity consumption: low		0.0785		0.0517	0.0517			0.0376
Renewable electricity for coffee preparation	0.0511	0.0781	0.0781	0.0511	0.0511	0.0779	0.0781	0.0374
Machine lifetime: short	0.0518	0.0788	0.0788	0.0526	0.0526	0.0785	0.0798	
Machine lifetime: long	0.0516	0.0786	0.0786	0.0524	0.0524	0.0784	0.0796	
Packaging recycling rates: 0%	0.0547	0.0786	0.0787	0.0555	0.0554	0.0784	0.0797	0.0379
Packaging recycling rates: 100%	0.0509	0.0786	0.0787	0.0516	0.0516	0.0784	0.0797	0.0377
Portioned packaging for soluble								0.0395
Coffee grounds management: methanization		0.0784	0.0785			0.0782	0.0795	
Amount of boiled water: high	0.0517	0.0786	0.0787	0.0524	0.0524	0.0784	0.0797	0.0382
Distribution: retailer & shopping trip		0.0788	0.0788			0.0786	0.0798	0.0378
Use scenario. 100 cups/day	0.0515	0.0785	0.0785	0.0516	0.0516	0.0782	0.0787	
Electricity mix: CH	0.0503	0.0773	0.0773	0.0504	0.0505	0.0771	0.0775	0.0363

9.15 Singaporean market adaptation

LIFE CYCLE ASSESSMENT (LCA) OF AN ESPRESSO CUP OF COFFEE MADE FROM A NESPRESSO PROFESSIONAL CAPSULE COMPARED WITH OTHER COFFEE SYSTEMS IN A SINGAPOREAN CONTEXT

In 2019, *Nespresso* commissioned Quantis, a leading consulting firm specialized in sustainability, to perform a life cycle assessment (LCA) of a cup of espresso coffee (40 ml) made from various coffee systems, in a business environment, in Switzerland. This study examined the life cycle of a cup of coffee from the extraction and processing of all raw materials through the end-of-life of all components, including packaging (a cradle-to-grave approach). The study assessed the impact of an espresso cup of coffee prepared using the *Nespresso* Professional system in Switzerland compared with two other coffee preparation systems: the full-automat system (considering one efficient system and one non-efficient system) and the soluble with kettle coffee system.

Two use scenarios have been tested: a case of a business consuming 4 000 cups per year and machine, and a case with a higher coffee consumption of 10 000 cups per year and machine. The type of machine used for these different use intensities is different, both for *Nespresso* (recommending a machine called Zenius for the 4 000 cups/year and the machines Gemini or Memento for the more intensive use of 10 000 cups/year) and for the full automat machines.

For the full automat machines, given the wide range of available machines on the market, two different alternatives have been chosen among machines widely sold on the Swiss market, one representing an efficient machine and one a non-efficient and this for the two use intensities of 4 000 and 10 000 cups per year. The soluble coffee system remains the same whatever the number of cups prepared per year.

In the framework of this study, a specific scenario has been established for *Nespresso HQ* in order to adapt the final comparative LCA results to the Singaporean market.

The present document summarizes the LCA adaptation made for the Singaporean market; it describes the main assumptions and conclusions applicable to the market.

The results show that for all coffee systems, impacts are dominated by both the green coffee supply – which encompasses coffee production in the country of origin and its transportation to the manufacturing sites of *Nespresso* – and by the use stage, i.e. the preparation of the coffee in the office.

The conclusions of this LCA adaptation for the Singaporean market are partly in line with the main conclusions of the baseline study for the Swiss market: considering the scenarios studied for the different coffee systems, the *Nespresso* Professional system has similar carbon footprint than the full automat systems assessed (except when a very efficient full automat is used, in this case the impact of *Nespresso* system is higher) but a higher carbon footprint than the soluble coffee.

To follow the requirements of the International Organization for Standardization (ISO) 14040/ 14044 standards for a comparative assertion and public disclosure, this LCA adaptation for the Singaporean market of *Nespresso* as well as the baseline comparative LCA study have been peer-reviewed by three independent experts.

1. Background and context

Over 30 years ago, *Nespresso* revolutionized coffee culture with its invention of a compact portioned coffee system for easy at-home use. Then 10 years later, *Nespresso* revolutionized coffee culture in business environment with the creation of the Professional capsule and associated machines.

Today people are increasingly concerned with the environmental impact of portioned coffee capsules. More and more, people question the use of resources in the production process and the impacts of the capsule packaging after usage. With the evolution of the brand and product range over the last three decades, *Nespresso* has taken various steps to improve its environmental performance. Among other initiatives, *Nespresso* introduced its own recycling system in 1991 and worked to improve the energy efficiency of its machines.

To identify key focus areas to further improve its environmental performance, *Nespresso* Singapore commissioned Quantis, an international sustainability consultancy, to carry out an adaptation for the Singaporean market of the Life Cycle Assessment (LCA) of an espresso cup of coffee (40 ml) made and consumed in Switzerland. The current adaptation aims to respond to two key questions:

- 1) What is the impact of the *Nespresso* preparation system on the environment in Singapore?
- 2) How does it compare to other coffee preparation systems commonly used in Singapore?

1.1 1.1. Life Cycle Assessment (LCA) – what is it?

In order to assess the impact of a product on the environment, its entire life cycle must be considered. This is because the environmental impact of a product goes beyond the use or consumption of that product. The life cycle of a product is defined by the production, distribution, use and end-of-life (usually disposal) stages. The life cycle assessment quantifies the environmental impacts related to all the raw materials used to manufacture, distribute, use and treat the product at the end of its life. The life cycle assessment considers various indicators to assess different environmental impacts such as carbon footprint, water footprint, or impacts on biodiversity.

Using the life cycle assessment methodology, it is also possible to compare different products, considering the same unit of reference for all systems compared and all life cycle stages. One product may perform worse at a stage visible to the consumer, but at another stage it may perform significantly better for the environment than comparable products, often leading to unexpected conclusions.

The present LCA adaptation to Singaporean market and the initial LCA report conform to the International Organization for Standardization (ISO) 14040/ 14044 standards for a comparative assertion and public disclosure and has been peer-reviewed by independent experts from the Swiss Federal Laboratories of Materials, Science and Technology (EMPA), Töpten International Services and the Swiss Federal Institute of Technology in Lausanne (EPFL). Its results are representative of the year 2019-2020.

It is important to note that LCA does not quantify the exact impacts of a product or service due to data availability and modelling challenges. However, LCA allows a scientifically based estimation of the environmental impacts a system might cause over its typical life cycle, by quantifying (within the current scientific limitations) the likely emissions produced and resources consumed.

2. What is the scope of the study?

This study assessed the life cycle of an espresso cup of coffee (40 ml) prepared and consumed in a business environment, in Singapore. The study included the extraction of all raw materials and coffee cultivation through the end-of-life of all components, including packaging. The study was done for the *Nespresso* Professional coffee preparation system, as well as two other coffee systems: full automat and soluble coffee. Due to a lack of data availability related to green coffee cultivation and delivery for all systems, the coffee systems are being compared considering the same green coffee cultivation and delivery - partly based on primary data from *Nespresso* and also following data outlined in the Draft PEFCR coffee.

Coffee is consumed differently in every business environment. In order to achieve comparable results, the study assumes two frequencies of coffee consumption: 4 000 cups/year-machine and 10 000 cups/year-machine. For all coffee systems compared in the current study, a preparation of a 40 ml espresso cup of coffee was assumed.



Nespresso

Nespresso Professional espresso capsule prepared with the three *Nespresso* machines suitable for the following scenarios:

- 4 000 cups/year frequency: **Nespresso Zenius**
- 10 000 cups/year frequency: **Nespresso Gemini CS200** and **Nespresso Momento 100**

The *Nespresso* Professional system uses portioned coffee to prepare espresso. The roast and ground coffee comes in laminated “pods” capsules that are inserted in the machine. Water under high pressure is pumped through the capsules, and the brewed coffee flows through a funnel into the coffee cup.



Full Automat

Coffee prepared using full automat coffee system, one efficient system and one non-efficient system from energy consumption standpoint have been initially selected among the three most sold machines on the Swiss market, for both frequencies of coffee consumption. Producers of these coffee machines are selling internationally and their coffee machines can be found worldwide. The machines selected do not include milk refrigeration compartment as black coffee is assessed.

- 4 000 cups/year frequency:
 - o Efficient system: **Jura ENA MICRO 1**
 - o Non-efficient system: **Delonghi Magnifica ECAM 350.75.SB.**
- 10 000 cups/year frequency:
 - o Efficient system: **Jura WE6**
 - o Non-efficient system: **Franke A200 MS EC**

A full automat coffee system can produce various types of coffee fully automatically according to the espresso method. The machine grinds the coffee beans according to the desired grinding degree and weighs them according to the selected product. The heated water is pressed under pressure through the coffee powder.



Soluble Coffee

Coffee prepared using soluble coffee with an average electric kettle following data outlined in the **Draft PEFCR coffee**.

A spoon of soluble coffee taken from a soluble coffee glass jar and poured in an espresso cup. The sufficient amount of water is heated using the electric kettle and is then poured in the espresso cup as well.

To determine the environmental impact of the *Nespresso* preparation system, fully automatic machines, and soluble coffee, the study considers different stages of the coffee product life cycle.



Figure 1: Life cycle of an espresso cup of coffee (DC: distribution center, HQ: Headquarter, HO: head office) – in red are the activities adapted for the Singaporean market.

■ Green coffee supply

The study analyzes the complete coffee cultivation, including agrochemical use, irrigation, land use change¹, energy and water consumption for coffee cherries processed into green beans and transported to Europe. The same coffee supply is considered for the three coffee systems assessed: a wide variety of coffee is available for the full automat and soluble coffee systems (that can have higher or lower impacts than the *Nespresso* coffee), and therefore it has been decided not to differentiate the coffee systems on the type of coffee but only on the quantity.

In the framework of this LCA adaptation, this upstream stage of the life cycle of a cup of coffee remains unchanged regardless of the market considered.

■ Packaging production and delivery

To calculate the impact of the packaging material, the environmental impact of the materials from which the coffee packaging or capsules are made is considered. This includes the primary packaging (e.g. the laminated capsule for *Nespresso*, the multilayer pouch for full automat coffee systems and the glass jar for the soluble coffee), the secondary or outer packaging (e.g. sleeves), and the tertiary packaging used for the delivery (e.g. Europallet or large cardboard boxes).

¹ Land use change includes every change in the use of a land. It can be a change from e.g., grassland to an arable crop, from an arable crop to another arable crop or to a perennial, or from a primary or secondary forest to arable or perennial crop (i.e., deforestation). Deforestation is the permanent destruction of forests in order to make the land available for other uses. This is the main contributor to the impacts from land use change. The amount of land transformed over the last 20 years for the different countries of coffee origin and from forest or grassland to perennial cropland (coffee cultivation) is based on FAOstat data and taken from the direct land use change assessment tool developed for GHG protocol by Blonk Consultants. It corresponds to statistical land use change per crop and per country and not to specific farming practices.

In the framework of this LCA adaptation, this upstream stage of the life cycle of a cup of coffee remains unchanged regardless of the market under consideration.

- **Manufacturing**

The examination includes all steps of further coffee processing such as roasting and grinding in the production sites of Orbe, Avenches and Romont for *Nespresso*. The same manufacturing process has been considered for the full automat and *Nespresso* systems, even if the full automat uses coffee beans and *Nespresso* roast and ground coffee. It has been confirmed by coffee experts that the grinding has a negligible contribution in terms of energy consumption compared to the roasting. The soluble coffee manufacturing is based on secondary data from the World Food LCA Database.

In the framework of this LCA adaptation, this upstream stage of the life cycle of a cup of coffee remains unchanged regardless of the market under consideration.

- **Distribution**

Includes the transport routes from production to the customer. In the case of *Nespresso*, the distribution can be via postal delivery or other delivery partners. For the full automat and soluble coffee, a similar distribution via post or delivery partners is considered.

In the framework of this LCA adaptation, this stage of the life cycle of a cup of coffee has been modified in order to consider distribution distances and transportation means across the Singaporean market.

- **Use**

The study examines the environmental impact of various aspects: In addition to the energy and water involved in brewing coffee, it also examines the complete production of machines with all the necessary materials, delivery, cleaning and disposal, as well as the cup production and washing in a dishwasher. All coffee systems need a cup to be produced and washed when drinking a cup of coffee.

In the framework of this LCA adaptation, this downstream stage of the life cycle of a cup of coffee is adapted (applying the Singaporean electricity mix for all the use stage activities (machine or kettle use, dishwasher use).

- **Overheads/support**

In this stage, aspects related to the backbone of the company are analyzed, for example, the *Nespresso* headquarters in Lausanne, the Singaporean head offices, the Singaporean after sales centers or the Singaporean call centers. The data for this step is known only for *Nespresso* but similar life cycle stages exist for the other coffee systems. Therefore, the same impacts for overheads/support per cup of coffee is considered for all coffee systems.

In the framework of this LCA adaptation, this stage of the life cycle of a cup of coffee has been modified in order to consider overheads activities applicable for the Singaporean market.

- **End-of-Life**

The final stage covers the collection, sorting and recycling of packaging materials, capsules and coffee grounds. In Singapore, municipal wastes are on average 94% incinerated and 6% landfilled (<https://unstats.un.org/unsd/environment/wastetreatment.htm>). Thanks to the introduction of its own recycling system, *Nespresso* has reached a recycling rate of 34% for the Professional capsule in 2020 on the Singaporean market.

- This means that for 34% of the Professional capsules, after separation from the coffee grounds fraction, the packaging part will be sent to a remelter to produce secondary aluminium and the coffee ground will be sent to a composting facility, where it will create compost that will ultimately substitute mineral fertilizer. The remaining share of the capsules will be incinerated (62%) or landfilled (4%).

The Professional capsule recycling rate is a primary data provided by Nespresso Singapore.

Tables summarizing the main data changes from the baseline study to this Singaporean market adaptation are presented at the end of this executive summary.

3. Key results

The life cycle assessment of an espresso cup of coffee studies the contribution of the life cycle stages for various environmental impacts: carbon footprint, non-renewable resources consumption, land use (i.e. how much land is needed for cultivation or for buildings to process the coffee), impacts on ecosystem quality (measuring the effects on biodiversity), human health impacts (measuring the indirect effect on human health from the whole coffee system) and finally, water consumption (throughout the whole lifecycle, not just in the use phase). A detailed interpretation of the carbon footprint indicators is performed hereafter as this indicator is well known and understood, and it is of importance for Nespresso as they have targets on this indicator. The conclusions for the others indicators are in line with the conclusions for carbon footprint.

This chapter 3 of Key results is divided in four sub-chapters:

- 3.1 is detailing the carbon footprint of the Nespresso Professional system only.
- 3.2 is comparing the carbon footprint of the three different systems studied
- 3.3 is comparing the three systems studied on other environmental indicators
- 3.4 is addressing the impact variability of the results for the three systems studied

3.1 Carbon footprint of the *Nespresso* Professional system

A 40 ml cup of *Nespresso* coffee emits from 98 to 103 g CO₂-eq on the Singaporean market (depending on the use intensity considered: 4 000 cups/year or 10 000 cups/year). The carbon footprint of a *Nespresso* espresso is dominated by the green coffee supply (35% to 36% depending on the *Nespresso* machine considered), the use stage (25% to 29% depending on the machine used) and the distribution (23% to 24% depending on the machine used). Overheads & support contributes to 7% of the greenhouse gas emissions of the *Nespresso* preparation system, similar to the packaging production (6 to 7%). The manufacturing follow with 2%. End-of-life treatment – namely the recycling, incineration or landfilling of the capsules and other packaging items – represents a benefit (-1%) thanks to the high recycling rate and the incineration with energy recovery.

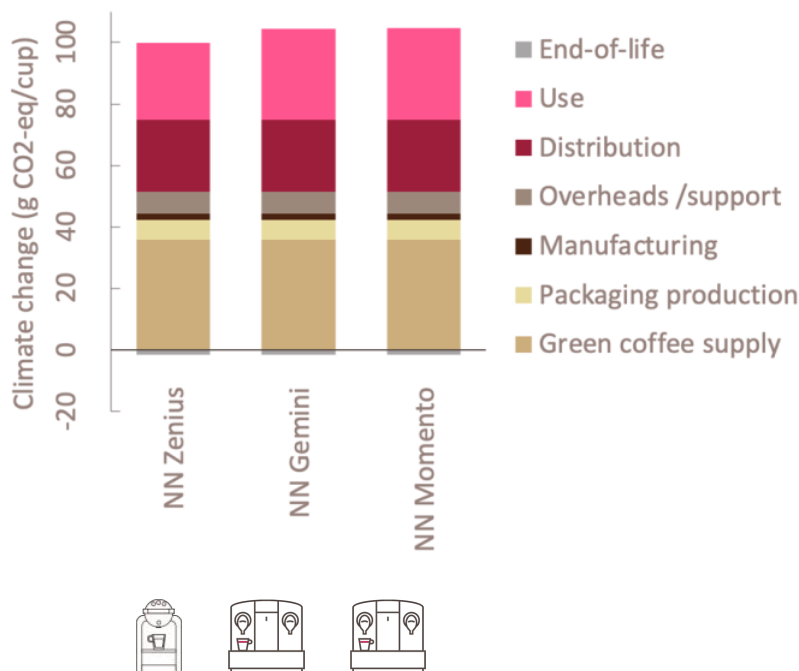


Figure 2: GHG emissions per life cycle stage for a Nespresso espresso (40 ml) cup of coffee on the Singaporean market (NN = Nestlé Nespresso)

3.1.1 Green coffee supply

The *Nespresso* coffee capsule contains in average 6.1 g of ground coffee to make an espresso (40 ml) cup of coffee. Considering the coffee grounds in one espresso *Nespresso* capsule, the green coffee supply accounts for 35% to 36% of the total carbon footprint of a cup of *Nespresso* coffee (36 g CO₂-eq/cup). Fertilizer use (14 g CO₂-eq) and land use change¹ (13 g CO₂-eq) are the largest contributors of greenhouse gas emissions to the green coffee supply. The remaining emissions are mostly related to the combustion of fossil fuels for field irrigation, the treatment and delivery of coffee cherries from the farms to the processing sites, and the processing itself. The delivery to the factories in Switzerland represents 3 g CO₂-eq of the carbon footprint for this stage.

The work on coffee sourced through the AAA Sustainability Quality Program should continue and also focus on fertilizers and pesticides use reduction keeping the same yield, use of renewable energy for coffee cherries processing, good coffee pulp management options, etc. despite these recognized efforts are not taken into account in the current study.

3.1.2 Packaging production and delivery

With 4.7 g CO₂-eq, the laminated capsule (0.52 g) is the main contributor to the packaging production and delivery. The contribution of the secondary (sleeves) and tertiary packaging (large corrugated board box, pallet and film) represents 1.7 g CO₂-eq.

The baseline study for the Swiss market assessed in a sensitivity analysis the influence of using aluminium produced using 100% renewable electricity. This showed a reduction of the greenhouse gas emission of the system of approx. 1.4 g CO₂-eq per cup of coffee.

3.1.3 Manufacturing

This life cycle stage causes 2% of the carbon footprint (2 g CO₂-eq/cup) of a cup of 40 ml *Nespresso* and includes the energy, water, gases, building, machinery that are needed for the processing of green coffee into roast and ground coffee. The wastes generated and their treatment were also considered. The data correspond to a weighted average of the production centers of *Nespresso* in Orbe, Avenches and Romont, in Switzerland. The carbon footprint score for this life cycle stage is mostly due to the natural gas consumption, the carbon dioxide use (to prevent oxidation in the production line) and the packaging losses (packaging scraps need to be treated but require an additional material input to compensate the losses).

3.1.4 Distribution

23% to 24% of the total greenhouse emissions (23 g CO₂-eq) are emitted in the distribution stage (compared to 2 g CO₂-eq in the Swiss study; differences are mainly due to higher distances and different means of transportations on the Singaporean market). For the *Nespresso* Professional capsules, the distribution is done 100% via postal delivery. The transport from the manufacturing sites in Switzerland to the distribution centers in Singapore is considered. Then, the postal distribution includes the transport from the distribution center to the post office, then the postal delivery from the post office to the consumers' location. The electric consumption related to the internet use for the order is also included. Most of the carbon footprint for this stage is due to the transport from factory to distribution centers (long distance from Switzerland to Singapore and some transport by plane), to the distribution centers activities (energy consumption and paper).

3.1.5 Use stage

The second contributor to the carbon footprint of an espresso cup of *Nespresso* coffee is the use stage, more precisely the cup production and washing (17 g CO₂-eq). This is mostly due to the dishwasher electricity requirements to clean the cup after each use and the allocated part of the dishwasher manufacturing and end-

of-life. The second highest impact on climate change in the use stage for the *Nespresso* coffee system is the coffee brewing (4 to 9 g CO₂-eq depending on the *Nespresso* machine). The machine production and distribution are the least impacting factors (3 to 4 g CO₂-eq depending on the *Nespresso* machine). If a consumer's energy supply in the office environment is based on renewable instead of non-renewable electricity, this could lead to a decrease in impact per cup of 3 to 8 g CO₂-eq for the coffee brewing depending on the type of *Nespresso* machine used.

3.1.6 Overheads / Support

7% of the total greenhouse gas emissions (7 g CO₂-eq/cup) come from the overheads and support stage, depending on the *Nespresso* system considered. The overheads for *Nespresso* include the activities related to the global headquarters administrative center, a weighted average of the Singaporean head offices, of the Singaporean after sales centers and of the Singaporean call centers. For each of these elements, the system includes the building, electricity and other energy consumption, paper and water consumption, the IT equipment, the employees commuting and the business travels. Most of the greenhouse gas emissions are explained by the global HQ activities (services purchase), to the market head office activities (energy and paper consumption) and to the after sales activities (business travels and energy consumption). For the global headquarters, the impacts related to various services (mostly advertising) are assessed through their economic value and a database linking costs to environmental impacts (these services are responsible for 3 g CO₂-eq/cup).

3.1.7 End-of-life

The end-of-life is a sum of various contribution inducing impacts (e.g. landfilling of coffee ground that ultimately lead to some release of methane in the atmosphere) or benefits (e.g. recycling of aluminium which finally avoid primary aluminium production).

The end-of-life of the *Nespresso* Professional capsules (considered to be 34% recycled, 62% incinerated with energy recovery and 4% landfilled on the Singaporean market) leads to a greenhouse gas emission net benefit of 1 g CO₂-eq (compared to a benefit of 3 g CO₂-eq in the Swiss study; differences are mainly due to the share being landfilled while the non-recycled fraction is actually fully incinerated with energy recovery in Switzerland).

As the recycling rate is quite high and the incineration with energy recovery is not a bad option for the Pro capsule, a 100% recycling rate would not improve the environmental performance.

The end-of-life treatment of the secondary and tertiary packaging, of the machine and the cup has only a very small contribution to the end-of-life greenhouse gas emissions.

3.2 Carbon footprint of the three examined coffee systems

For all coffee systems, impacts on climate change are systematically dominated by the green coffee supply (35% to 59%) and the use stage (25% to 32%), especially the cup washing in a dishwasher. They have a greater impact on the greenhouse gas emissions than distribution, which ranks third (2% to 24%) and overheads, which ranks fourth (7% to 10%). These four stages represent from 79% to 95% of the total greenhouse gas emissions of a 40 ml espresso cup of coffee made and consumed in a Singaporean context. The remaining 5% to 21% consists of the packaging production (5% to 9%), the manufacturing (2% to 12%) and the end-of-life stage (-2% to 0%).

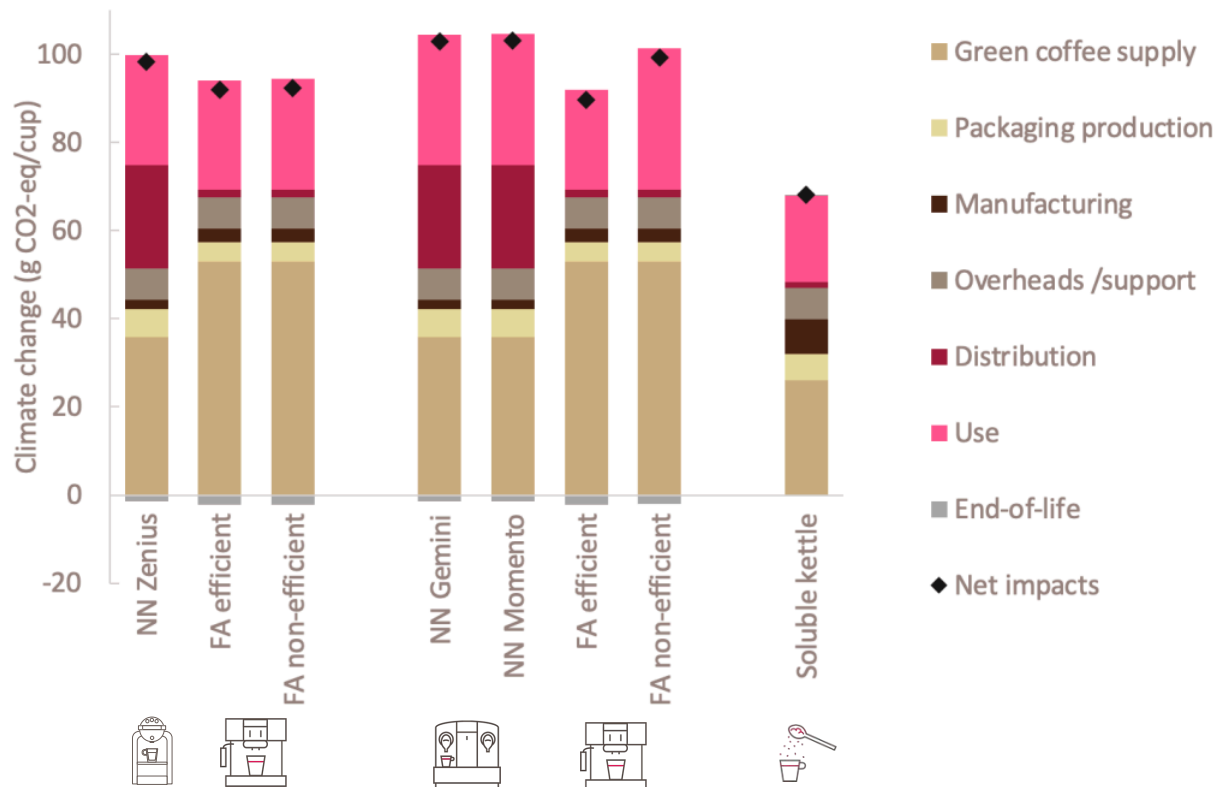


Figure 3: GHG emissions per life cycle stage for the compared coffee systems on the Singaporean market. The three first systems correspond to a use scenario of 4 000 cups/year while the 4 next correspond to the use scenario of 10 000 cups/year. The soluble coffee scenario is independent from this use intensity

Based on the studied coffee system carbon footprint, it can be mentioned that *Nespresso* system has similar impacts as full automat systems (except when a very efficient full automat is used, in this case the impacts of *Nespresso* system are higher) but higher impacts than the soluble coffee system.

When comparing *Nespresso* to the full automat coffee systems, *Nespresso* performs better regarding the green coffee supply and the manufacturing (because a lower amount of coffee has to be roasted and ground per cup of coffee) and it has similar, better or worst performance for the use stage depending on the efficiency of the full automat it is compared with. Regarding the packaging or the distribution, *Nespresso* has a higher carbon footprint than the full automat system. The two systems have the same carbon footprint for the overheads/support and the end-of-life.

Nespresso has a higher carbon footprint than the soluble coffee, mainly explained by the higher amount of green coffee needed per cup of coffee, and the higher use stage impacts (capsules machines are more impacting to produce than kettles and the *Nespresso* machine energy consumption for coffee preparation is higher than the use of a kettle). The carbon footprint of the *Nespresso* packaging is also slightly higher than for

the soluble coffee packaging. The distribution for the *Nespresso* system has higher greenhouse gas emissions than for the soluble coffee. On the contrary, the manufacturing impacts on climate change are higher for the soluble coffee due to the higher level of transformation of the product.

3.2.1 Green coffee supply

The cultivation of coffee has the greatest influence on the greenhouse gas emissions. All coffee systems were examined using the same green coffee supply and deforestation model for better comparability across systems despite a lack of comparative data from other companies (full automat and soluble coffee can use a wide variety of coffee, in terms of origin, farming practices, and cherries treatment). The differences observed among the systems are related to the amount of coffee used per cup only: the full automat having the highest amount of coffee beans per cup (9 g) has the highest carbon footprint, while the soluble coffee that needs the lowest amount of green coffee per cup has the lowest carbon footprint for this stage. The contributors to this life cycle stage that are described in section 3.1.1 above are applicable for all coffee system as the same green coffee is used for all.

3.2.2 Packaging production and delivery

The coffee pouches (laminated of plastic and aluminium) used for the full automat system, and the glass jar with PP cap used for the soluble coffee system have been modelled according to recommendations from the draft PEFCR for coffee. The impact of the *Nespresso* coffee system in the packaging stage is slightly higher than for the other two coffee systems. The difference for packaging production among the 3 packaging types is of 0.5 to 2 g CO₂-eq/cup, which is finally quite low in comparison with the full life cycle carbon footprint.

3.2.3 Manufacturing

The Manufacturing stage contributes to 2% to 3% (2 to 3 g CO₂-eq/cup) of the total greenhouse gas emissions for the *Nespresso* and full automat systems while it reaches 12% (8 g CO₂-eq/cup) for the soluble, due to the higher contribution of processing green coffee beans into soluble coffee. The same process is considered for *Nespresso* and full automat due to a lack of data for the full automat. Given the wide variety of coffee that can be used for this system, the manufacturing could vary. *Nespresso* uses 100% renewable electricity for its manufacturing, it was seen as a conservative assumption to consider the same for the 2 systems: this benefits the full automat systems as their manufacturing does not necessarily use renewable electricity in reality, but it is a safer approach in the context of this study that compares the environmental impacts of *Nespresso* with other coffee systems. The manufacturing impacts are calculated per kg of coffee and therefore the systems have a higher or lower manufacturing impact depending on the amount of coffee used per serving.

The soluble coffee manufacturing was based on a different processing as the transformation of green coffee into spray dried coffee consumes much more energy than roasting. This leads to a higher contribution of the manufacturing stage for the soluble coffee compared to the *Nespresso* and full automat systems.

3.2.4 Distribution

This stage emits 1 to 2g CO₂-eq for the soluble and full automat system whereas for *Nespresso* this stage emits about 23 g CO₂-eq. The higher impact for *Nespresso* distribution is mainly explained by the fact that the *Nespresso* capsules are transported from the factories in Switzerland up to Singapore (and partly by plane) while the other coffee products are assumed to be manufactured in the country (each country produces roasted coffee beans that can be used in full automat or soluble coffee). For soluble coffee, the amount of coffee per cup is low compared to *Nespresso* system and therefore the amount of product to be distributed is much lower.

3.2.5 The use stage

The use stage has the second greatest greenhouse gas emissions for all examined coffee preparation systems. The cup production and washing has the largest contribution to the use stage carbon footprint (17 g CO₂-eq). Impact caused during brewing typically represents about 2 g CO₂-eq (for the soluble coffee) to 11 g CO₂-eq (for the less efficient full automat machine), while the contribution of the machine production ranges from less than 1 g CO₂-eq (kettle for the soluble coffee) to 1 to 4 g CO₂-eq for the full automat or *Nespresso* machines. The impact of the water filter production and distribution for the full automat system is low (less than 1 g CO₂-eq).

The use stage of *Nespresso* and full automat coffee systems lead to similar greenhouse gas emissions for the low intensity use (4 000 cups/year). For the more intense use (10 000 cups/year), the efficient full automat machine performs better than *Nespresso* while the less efficient full automat machine has a similar impact. The soluble coffee use stage has the lowest use stage impact among coffee systems assessed.

3.2.6 Overheads / Support

The Overheads/support stage contributes to 7% to 10% of the total greenhouse gas emissions (7 g CO₂-eq) and it was modelled using the same process for all coffee systems.

Regarding the overheads/support, no evidence could be found on how a specific coffee system could perform better than another and therefore no differentiation could be made based on this stage.

3.2.7 End-of-life

The end-of-life of the *Nespresso* and full automat coffee systems greenhouse gas emissions is inducing a net benefit for all systems ranging from 1 to 2 g CO₂-eq. The end-of-life for the soluble coffee system leads to no greenhouse gas emissions: the balance between benefits (mostly related to glass jar recycling) and impacts (e.g., due to landfilling of cardboard) reaches 0.

3.3 Comparing the *Nespresso* preparation system with other systems for other indicators

Considering the other indicators assessed (non-renewable resources depletion, water withdrawal, ecosystem quality, human health and land use), the main contributors to the impacts of a cup of coffee are the same as for the climate change: the green coffee supply and the use stage are the most important contributors, except for the water withdrawal and the land use for which the green coffee supply covers more than 81% of the impacts and the use stage has a smaller share.

For all indicators, the soluble coffee is the best-performing system compared to *Nespresso* system. For the 4 000 cups per year scenarios, the *Nespresso* Zenius systems has a similar performance as the full automat, for all indicators except for non-renewable resources depletion for which it has higher impacts and for land use and water withdrawal for which it has a lower impact.

Regarding the 10 000 cups per year scenarios, *Nespresso* system has a similar performance than the efficient full automat for ecosystem quality and human health, a better performance for the water withdrawal and land use and a worse performance for climate change and non-renewable resources depletion. When compared with the non-efficient full automat machine, *Nespresso* system is better regarding water withdrawal and land use (thanks to the lower amount of coffee per cup), it has similar performance for climate change, ecosystem quality and human health and it has higher impacts regarding the non-renewable resources depletion.

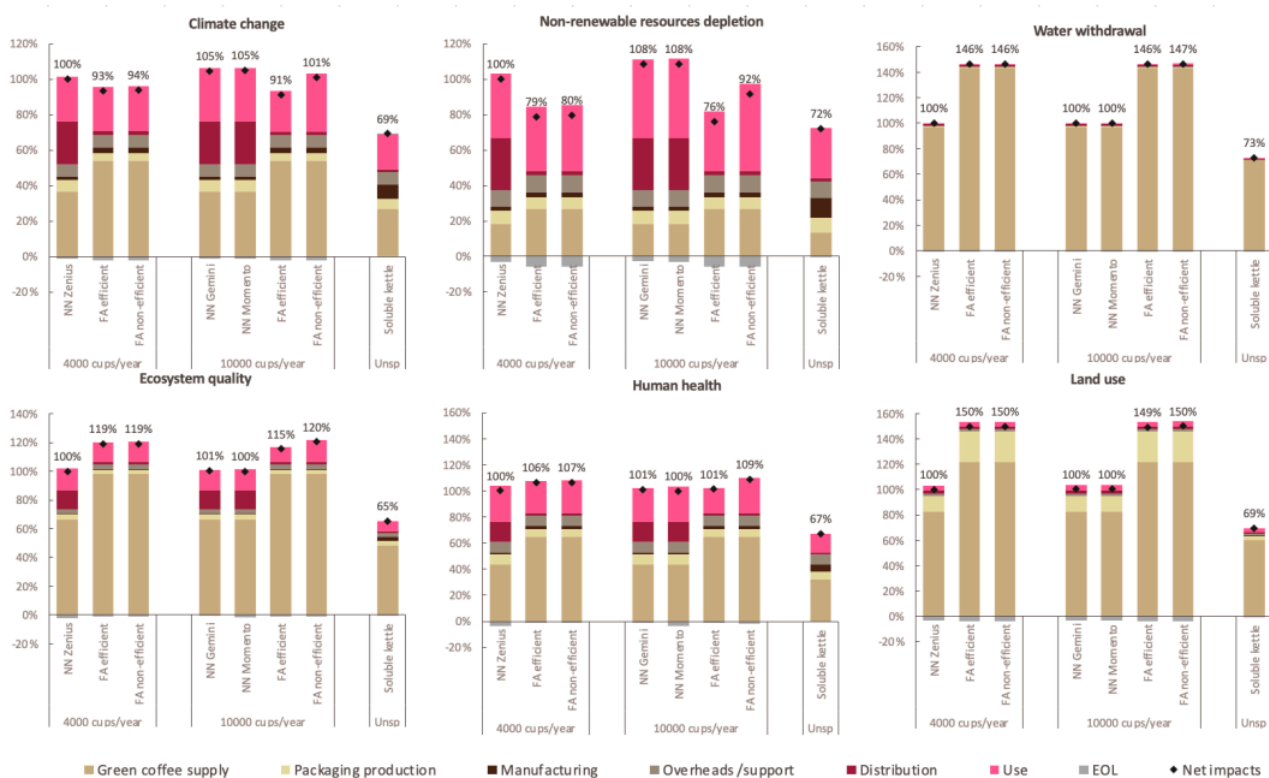


Figure 4: Life cycle stages contribution for the compared coffee systems for all impact indicators on the Singaporean market. For each indicator, all coffee systems were normalized with respect to the NN Zenius coffee system which impact was set at 100%. Each indicator has a different uncertainty level, thus the needed percentage difference between two coffee systems to state that one system is better/worse/similar than the other varies from one indicator to another. For instance, the uncertainty level for ecosystem quality and human health is much higher than for climate change and non-renewable resources depletion.

3.4 Assessing impact variability through sensitivity analyses

For the baseline study, several sensitivity analyses have been performed for all systems according to ISO requirements. Analyses were performed on e.g., the amount of coffee used (higher or lower amount per cup),

on the energy consumption for preparation (machine efficiency, amount of water boiled, etc.) or on the recycling rate of capsules (0-100%). A responsible consumer behavior for the full automat and the soluble systems could lead to similar or lower impacts than the *Nespresso* coffee system, while a non-responsible consumer behavior for the full automat and soluble systems will lead to higher impacts than *Nespresso*. The *Nespresso* system being more framed as a portioned system, its variability is much lower than the variability for the two other systems: portioned coffee system performances are much less dependent on consumer behavior than unportioned coffee systems.

Another element tested is the recycling rate of the Nespresso capsule: because both incineration with energy recovery and recycling are good options regarding climate change for the Pro capsule, the difference with a 0% recycling rate or 100% is negligible (less than - 1 g CO₂-eq).

4. Conclusion

The holistic view on the life cycle of the three different coffee preparation systems shows that drinking a 40 ml espresso cup of coffee made from a *Nespresso* coffee system in a Singaporean context has similar impact for 3 out of the 6 environmental indicators assessed than the same cup of coffee made with full automat systems for a low intensity use (4 000 cups/y) while it has a better or worse performance for the other indicators. Considering the more intense use scenario (10 000 cups/y), *Nespresso* coffee system has a similar performance compared to the full automat (efficient and non-efficient) on 2 of the indicators, a lower impact for 2 other indicators, a higher impact for 1 indicator and a higher or similar impact for the remaining indicator. The differentiation between *Nespresso* and full automat scenario is mostly driven by the amount of green coffee needed per cup.

Nespresso has a higher impact than the same cup of coffee made with soluble coffee. The low amount of green coffee per cup and the low electricity consumption for the use stage for the soluble coffee explain this good position.

A large part of the impact on the environment is rooted in the cultivation of green coffee and the coffee preparation in the office (cup production and washing, brewing of the coffee, machine production, distribution and washing). The environmental impact of coffee consumption increases significantly when consumers do not dose exactly, throw out left-over coffee, or use machines irresponsibly. Unportioned coffee system performances are much more dependent on consumer behavior than portioned coffee systems. In other words, a more responsible consumer has a similar or lower impact using a full automat or soluble coffee than the *Nespresso* Professional coffee system, but a less responsible person could prepare a higher impact cup of coffee using the full automat or soluble coffee systems compared with the *Nespresso* Professional. Thus, the *Nespresso* coffee system could be seen as a safeguard and stable solution against an environmental un-responsible use.

5. About the methodology and data used

The study worked with a variety of data sources. In addition to publicly accessible databases and studies, expert judgments and measurements from Quantis, primary data were available from *Nespresso* itself, especially for the *Nespresso* preparation system. For the alternative systems, on the other hand, publicly accessible data had to be used. Furthermore, the study did not investigate the environmental impact of different coffee varieties, growing regions or cultivation types.

Data for all systems were based on calculations for a standardized coffee that is average in European comparison. One major source of secondary data was the draft Product Environmental Footprint Category Rule (PEFCR) for the coffee sector. Product Environmental Footprint (PEF) is a European initiative to establish rules on how to perform LCA in various sectors, among others the coffee sector. This pilot on coffee stopped during the process but a draft document has been established and it contains a lot of useful data (PEF coffee Technical Secretariat, 2016²). The pilot stopped because no consensus was found about the labelling/comparison part, not because of the data. This draft document, including the part on data it contains, has been validated by the European Commission and the coffee stakeholders.

The electricity mix used for all activities occurring in Europe, including Switzerland, is the ENTSO-E mix (European Network of Transmission System Operators for Electricity), representing the average electricity mix consumed in Western Europe through the highly interconnected electric grid. For the activities happening in a Singaporean context (i.e. activities of the downstream life cycle stages of a cup of coffee), the Singaporean electricity mix has been used. For green coffee cultivation and treatment, the electricity consumed is based on the electricity mix from the different coffee production countries.

The packaging production for the *Nespresso* coffee system is based on primary data from *Nespresso*. For the full automat systems and soluble coffee, the packaging data come from the PEFCR study for coffee for the composition and on own measurement for the mass.

In this work, environmental impacts are assessed through six indicators corresponding to midpoint and endpoint level indicators and they are aligned with international guidance on life cycle assessment: greenhouse gas emissions (climate change), non-renewable resources depletion, land use, impact on ecosystem quality, water withdrawal, and human health.

Quantis compiled the data for each coffee system and evaluated them for the respective environmental impacts according to defined formulas. This was based on the consumer ritual, i.e. the consumption of 4 000 cups/year or 10 000 cups/year in a business environment, in a Singaporean context. This assumption and data basis formed the basis for all statements and comparisons made in the study. If variables such as different types of coffee, machine types or consumer behavior are changed, this can lead to different results.

It is important to note that LCA does not exactly quantify the real impacts of a product or service due to data availability and modelling challenges. For the current assessment, the following limitations should be considered:

- The *Nespresso* coffee system is modelled with more details and granularity because primary data were available for this model. As one of the purposes of the study was to understand better the impacts of the *Nespresso* coffee system, it was decided to keep all available data on this system, even if it was not possible to find as detailed data for the comparative systems. This is also the rationale that led to include life cycle stages with the same impacts for all systems, e.g., the overheads or the cup washing.

² <https://webgate.ec.europa.eu/fpfis/wikis/pages/viewpage.action?spaceKey=EUENVFP&title=Stakeholder+workspace%3A+PEFCR+pilot+Coffee>

- This study adaptation focuses on the Singaporean market and the detailed results observed are therefore true only for this specific market.
- Although the type of full automat machine considered correspond to most sold machines on the Swiss market, producers of these coffee machines are selling internationally and their coffee machines can be encountered worldwide, it does not necessarily mean they are the most sold worldwide. As this report corresponds to an adaptation of the Swiss study to the Singaporean market, it was not meant to integrate new machines.
- The green coffee cultivation is assessed following the PEFCR for coffee and the same coffee is applied for all systems. If one of the systems is sourcing from completely different origins, or from farms with completely different practices, this could lead to differences of production, less or more land use change impacts, or lower or higher delivery distances.
- Biogenic CO₂ uptake and release from the coffee (i.e., CO₂ that is consumed by the coffee plant while growing and released at the end-of-life when coffee grounds decompose or are incinerated) has not been included. Indeed, it is accepted that all the coffee will be almost entirely degraded at end-of-life leading to a nearly neutral balance

These limitations of the LCA results do not challenge the main conclusions relative to the defined goal and scope of the study, as the results still allow the identification of the key environmental parameters and key differences among scenarios.

The baseline study and adaptation to Singaporean market is compliant with ISO 14040/14044 standards and its methodology, database and results have been critically examined by the following three independent experts, who found the results to be clear and transparent:

- Roland Hischier, EMPA (reviewer and chairman of the panel)
- Hélène Rochat, Tipten International Services (reviewer)
- François Maréchal, EPFL (reviewer)

Date: December 2021

This report has been prepared by the Lausanne office of Quantis. Please direct all questions regarding this report to Quantis Lausanne. www.quantis-intl.com

6. Data

This section details the data that are different from the original study made for the Swiss market, i.e., for the overheads/support, the distribution, the use stage and the end-of-life. All other data can be found in the original ISO report for the Swiss market.

For all tables, data in pink have been collected by Nespresso Singapore. Data in orange correspond to average data from 31 other Nespresso markets (used when data was missing for the Singaporean market). Data in italic are the same as in the Swiss original study. Data in blue are data from literature and data in grey correspond to assumptions.

6.1 Overheads/support

Table 1: Data considered to model the Overheads stage of all the compared coffee systems. Annual material and energy used data have been divided by the total amount of capsule sold over the year in order to obtain data per cup.

	All systems
Global HQ overheads	No change compared to the Swiss study
Market head office	Data per cup: 0.93 Wh electricity, (of which 0% renewable mix), 37 ml water, 137 mg paper, 1 pers-m by car and 4.4 pers-m by public transport for the employees commuting, no car and plane for business travels, IT equipment as well as paper wastes and wastewater are also included.
Call centers	Data per cup: (data from previous markets adjusted considering the number of employees, full-time equivalent (FTE)) 9 FTE 0.24 Wh electricity (of which 6% renewable mix), 0.05 Wh natural gas, 5 ml water, 1 mg paper, 0.5 pers-m by car and 0.6 pers-m by public transport for the employees commuting, 0.03 pers-m by car and 0.1 pers-m by plane for business travels, IT equipment as well as paper wastes and wastewater are also included.
After sales centers	Data per cup: (data from previous markets adjusted considering the FTE) 8 FTE 0.67 Wh electricity (of which 2% renewable mix), 1.72 Wh natural gas, 0.2 Wh other fuels, 21 ml water, 11 mg paper, 0.4 pers-m by car and 0.3 pers-m by public transport for the employees commuting, 1.3 pers-m by car and 0.1 pers-m by plane for business travels, IT equipment as well as paper wastes and wastewater are also included.

6.2 Distribution

Table 2: Data considered to model the Distribution stage of all the compared coffee systems.

	Nespresso Professional	Full automat	Soluble
Factories to distribution center	<p>Factories to distribution center: 1 distribution center (DC) in Singapore. The transport from factories to DC is modelled with 12'267 km by ship, 104 km by truck, 499 km by train and 2'115 km by plane.</p> <p>Distribution center activities (per cup): 1.16 Wh electricity (of which 0% renewable mix), 2 ml water, 89 mg paper, 0 pers-m by car and 1.35 pers-m by public transport for the employees commuting, no car and plane for business travels, IT equipment as well as paper wastes and wastewater are also included.</p>	<p>Factories to distribution center: 1'200 km with >32 t truck according to PEF/OEF default data from PEF method 2019</p> <p>Distribution center activities (per cup): 2.9 mm² building, 2.9 mm² parking, 0.09 Wh electricity, 0.29 Wh natural gas, 0.04 ml water use.</p>	<p>Distribution center activities (per cup): 2.8 mm² building, 2.8 mm² parking, 0.08 Wh electricity, 0.28 Wh natural gas, 0.03 ml water use.</p>
Distribution via post	<p>Distribution via post is applied to 100% of the Professional capsules sold.</p> <p>DC to arrival post: 25 km, 100% by diesel van.</p> <p>Postal delivery: 30 km by van for 150 parcels delivered. 1 parcel assumed for the 4 000 cups/year systems and 2 parcels per order for the 10 000 cups/year (to take into account the higher volume occupied). 1 parcel = 400 capsules</p> <p>Internet order: 2 minutes of a computer and network use (100 W) for an order of capsules</p>	<p>Distribution center to customer via delivery partners: 155 km, 84% by 7.5-16 t truck, 13% by van, 3% by 3.5-7-5 t trucks. 1 parcel assumed for the 4 000 cups/year systems and 2 parcels per order for the 10 000 cups/year (to take into account the higher volume occupied). 1 parcel = 4 pouches of 1 kg R&G coffee or 4 glass jars of 200 g soluble coffee</p> <p>Internet order: 2 minutes of a computer and network use (100 W) for an order of 8 kg (8 pouches of 1 kg)</p>	

6.3 End-of-life

Table 3: End-of-life data considered for the compared coffee systems.

	Nespresso Professional	Full automat	Soluble
Common data	<p>Wastes collection (for all wastes except capsules recycled): assumed to be a 30 km truck transport (municipal collection). A plastic bag is also considered for all wastes except for the cardboard, the machines that are recycled and the pallets: 6.7 g PP per kg waste according to the PEF method.</p> <p>Recycled capsules collection: There are 2 different collection options. In Singapore, 61% of the capsules are collected via <i>recycling at home</i> and 39% via <i>other collection point</i>. The recycling at home is assumed to correspond to the same transport as for the postal delivery (see section 6.2) while the collection via other collection point is modelled considering the same assumption as for the shopping trip (see section 6.2).</p> <p>Energy recovery from incinerator is assumed to be the same as for European average, i.e., 31% as heat and 10% as electricity (based on PEF EOL default data (PEF-OEF_EOL DefaultData_V1.2_uploaded.xlsx) 2015 document provided by the EU commission).</p>		
Primary packaging and coffee grounds	<p>The capsules are 34% recycled, 62% incinerated and 4% landfilled (municipal solid waste fate in Singapore is 94% incineration and 6% landfilling for the non-recycled fraction according to UNSTATS 2011 (https://unstats.un.org/unsd/environment/wastetreatment.htm)).</p> <p>Capsule separation for recycling: 399 Wh electricity (of which 0 % renewable mix) and 0.09 L water per kg input material.</p> <p>Aluminium recycling: at remelter, the PET, PP and glue layers burn during the remelting process while the aluminium is remelted into secondary aluminium. This avoids the use of primary aluminium (wrought alloy). The remelting yield considered is of 60%.</p> <p>Coffee grounds: the coffee grounds is 100% sent to a composting facility and is then used as fertilizer.</p> <p>Incineration: the coffee grounds lower heating value is 7 MJ/kg</p>	<p>The laminated pouch is 100% trashed: there is no recycling option existing for this kind of packaging.</p> <p>The coffee grounds go 50% to trash (i.e., 47% to incineration, 3% landfilling), 25% to compost and 25% to a biodigester according to PEF method default treatment for food wastes.</p> <p>Composting: The model corresponds to industrial composting. The handling of the compost, the direct emissions (CH₄, NH₃, CO₂ and N₂O) and infrastructures are considered as well as the benefits related to the compost use, i.e., mineral fertilizers production avoided, improvement of yield and peat use avoided. This is based on Quantis internal database.</p> <p>Biodigestion: the biodigestion is based on the Henniez plant and data from Nespresso Switzerland.</p> <p>Incineration: the coffee grounds lower heating value is 7 MJ/kg</p>	<p>Recycling: the glass jar is assumed to be partly recycled (11%, https://www.nea.gov.sg/our-services/waste-management/waste-statistics-and-overall-recycling), while the cap and wad are trashed (i.e., 94% incinerated, 6% landfilled). The paper label goes to glass recycling with the glass and is incinerated/landfilled once separated from the glass stream.</p> <p>Incineration and landfilling: packaging items are collected with the municipal solid wastes and then go to incineration with energy recovery or landfilling.</p> <p>There are no coffee grounds at the end-of-life for soluble coffee system.</p>
Secondary packaging	<p>Sleeve treatment: 38% recycling (https://www.nea.gov.sg/our-services/waste-management/waste-statistics-and-overall-recycling) and 58% incineration and 4% landfilling</p>	<p>Tray/box treatment: see sleeve treatment</p> <p>LDPE film treatment: assumed 100% trashed, i.e., 94% incinerated and 6% landfilled</p>	
Tertiary packaging	<p>Tertiary box treatment: : see sleeve treatment</p> <p>Wooden pallet and LDPE film are assumed 100% trashed, i.e., 94% incinerated and 6% landfilled</p>		
Machine	<p>Machine treatment: for all types of machines, it is considered they are dismantled and then the metallic parts are assumed to be 100% recycled while the plastic parts are 100% incinerated. The dismantling is assessed through a generic dataset for electric waste shredding.</p>		
Cup	<p>The cup is sent to an inert material landfill according to the draft PEFCR coffee.</p>		

7. Glossary

AAA	The <i>Nespresso</i> AAA Sustainable Quality™ Program was launched in 2003 with the NGO the Rainforest Alliance. It is based on internationally recognized social and environmental sustainability criteria. It fosters long term relationships with farmers, embeds sustainable practices on farms and the surrounding landscapes, and improves the yield and quality of harvests. At the same time, it contributes to improve the livelihoods of farmers and their communities.
ASI	Aluminium Stewardship Initiative
Carbon footprint	The carbon footprint is a measure of the potential impact on climate change. It takes into account the capacity of a greenhouse gas to influence radiative forces, expressed in terms of a reference substance and specified time horizon (100 years). The impact metric is expressed in kg CO ₂ -eq.
Biogenic CO ₂	Plants photosynthesis consumes CO ₂ . When released, e.g., when the plant is composted or incinerated, this CO ₂ is specified as biogenic CO ₂ . As the quantity released has been before pumped by the plant, the balance is considered to be neutral. This is true only when the carbon is released as CO ₂ , but not when it is released as methane that has a higher global warming potential than CO ₂ .
Distribution	The distribution life cycle stage covers the transportation of the production from the manufacturing site to the consumer.
End of life	The end-of-life stage includes the collection and treatment of the different packaging items, the coffee grounds, the machine and the cup.
ENTSO-E	European Network of Transmission System Operators for Electricity
Green coffee supply	The study analyzes the complete coffee cultivation, including agrochemical use, irrigation, possible deforestation, energy and water consumption for coffee cherries processed into green beans and transport to Europe.
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
LCIA	Life Cycle Impact Assessment
Manufacturing	The manufacturing stage includes the energy, water, gases, building, machinery that are needed for the processing of green coffee into roast and ground coffee. The wastes generated and their treatment are also considered.
Net impact	The net impacts is the sum of impacts and credits.
NN	Nestlé Nespresso
OEF	Organization Environmental Footprint
Overheads/support	The overheads for <i>Nespresso</i> include the activities related to the global headquarter administrative center, the market head office, the market after sales centers and the market call center. The same data are considered for the Overheads/support for all coffee systems studied.
Packaging production & delivery	The packaging production includes the production of the materials and the forming steps for primary, secondary and tertiary packaging. The primary packaging corresponds to the capsule for the <i>Nespresso</i> coffee system, a laminated pouch of 500 g roast and ground coffee for the full automat systems and a 242 g glass jar for the soluble coffee. The secondary packaging corresponds to the sleeve containing 50 capsules for the <i>Nespresso</i> and none for the full automat systems and soluble coffee. The tertiary packaging consists in a corrugated board box, a pallet and an LDPE film for all systems.
PEFCR	Product Environmental Footprint Category Rule
PEF	Product Environmental Footprint
Use	The use stage includes the machine production fraction, the cup production, the coffee brewing (machine use), the machine cleaning and the cup washing.