LIFE CYCLE ASSESSMENT (LCA) OF A LUNGO CUP OF COFFEE MADE FROM A NESPRESSO ORIGINAL CAPSULE COMPARED WITH OTHER COFFEE SYSTEMS IN EUROPE

In 2018, *Nespresso* commissioned Quantis, a leading consulting firm specialized in sustainability, to perform a life cycle assessment (LCA) of a cup of lungo coffee (110 ml) made from various coffee systems, at home, 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 a lungo cup of coffee prepared using the *Nespresso* Original system in Switzerland compared with three other coffee preparation systems commonly found in the Swiss market: a moka, a drip filter and a full-automat system.

In the framework of this study, a specific scenario has been established for *Nespresso Headquarters* (HQ) in order to adapt the final comparative LCA results to the European market (made of 17 countries of interest). The present document summarizes the LCA adaptation made for the European market; it describes the main assumptions and conclusions applicable to the market.

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

The conclusions of this LCA adaptation for the European market are 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* Original, the drip filter and the moka coffee systems all have a similar carbon footprint, and the full automat system has a higher carbon footprint than the 3 other systems.

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 European 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.

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 Headquarters* commissioned Quantis to carry out an adaptation for the European market of the Life Cycle Assessment (LCA) of a lungo cup of coffee (110 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 Europe?
2) How does it compare to alternative coffee preparation systems used in Europe?

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 European 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 have been peer-reviewed by independent experts from EMPA, Topten International Services and the EPFL. Its results are representative of the year 2019.

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 adaptation?

This study adaptation assesses the life cycle of a lungo cup of coffee (110 ml) prepared and consumed at home, in Europe. The lungo coffee of 110 ml is a very well represented format on the European market and worldwide. The study included the extraction of all raw materials and coffee cultivation through the end-of-life of all components, including packaging. The study is carried out for the *Nespresso* Original coffee preparation system, as well as three other coffee systems commonly found in Europe: drip filter, moka and full automat.
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 household. Some people like to drink coffee in the morning, others in the afternoon and others rather irregularly. In order to achieve comparable results, the study assumes an average drinking habit of 2 cups of lungo coffee per day at home. For all coffee systems compared in the current study, a preparation of a 110 ml lungo cup of coffee was assumed, except for the moka coffee system, for which a volume of 100 ml is considered (moka coffee makers are only available in multiples of 50 ml sizes).

Nespresso

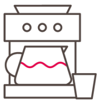
Nespresso Original lungo capsule prepared with one of the three best-seller *Nespresso* machines on the Swiss market that is kept for this adaptation of the study to the European market: ***Nespresso* Inissia**

The *Nespresso* Original system uses portioned coffee to prepare espresso, ristretto or lungo coffees. The coffee ground comes in aluminium 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 a full automat coffee system, with the full automat machine most commonly sold on the Swiss market that is kept for this adaptation; the brand being also well represented in Europe: **Delonghi Ecam 21.117.W/B/SB Magnifica S.**

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.



Drip Filter

Coffee prepared using a drip filter coffee machine, with an average drip filter model with heating plate and glass container following data outlined in the **Draft PEFCR coffee average machine.**

A drip filter machine pours water into a paper filter filled with coffee grounds. The water flows through the ground coffee, dripping into a container placed under the filter. The filter prevents the coffee powder from getting into the coffee.

Moka (Italian) coffee maker

Coffee prepared using a moka coffee maker, on an electric stove: **Moka coffee maker in aluminium (200 ml)**

A moka coffee maker is used to prepare coffee on the stove-top. Water is poured into the boiler. The funnel insert is filled with coffee powder and inserted, after which the machine is screwed together. The boiling water is pressed through the coffee powder, which fills the upper container with coffee.

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

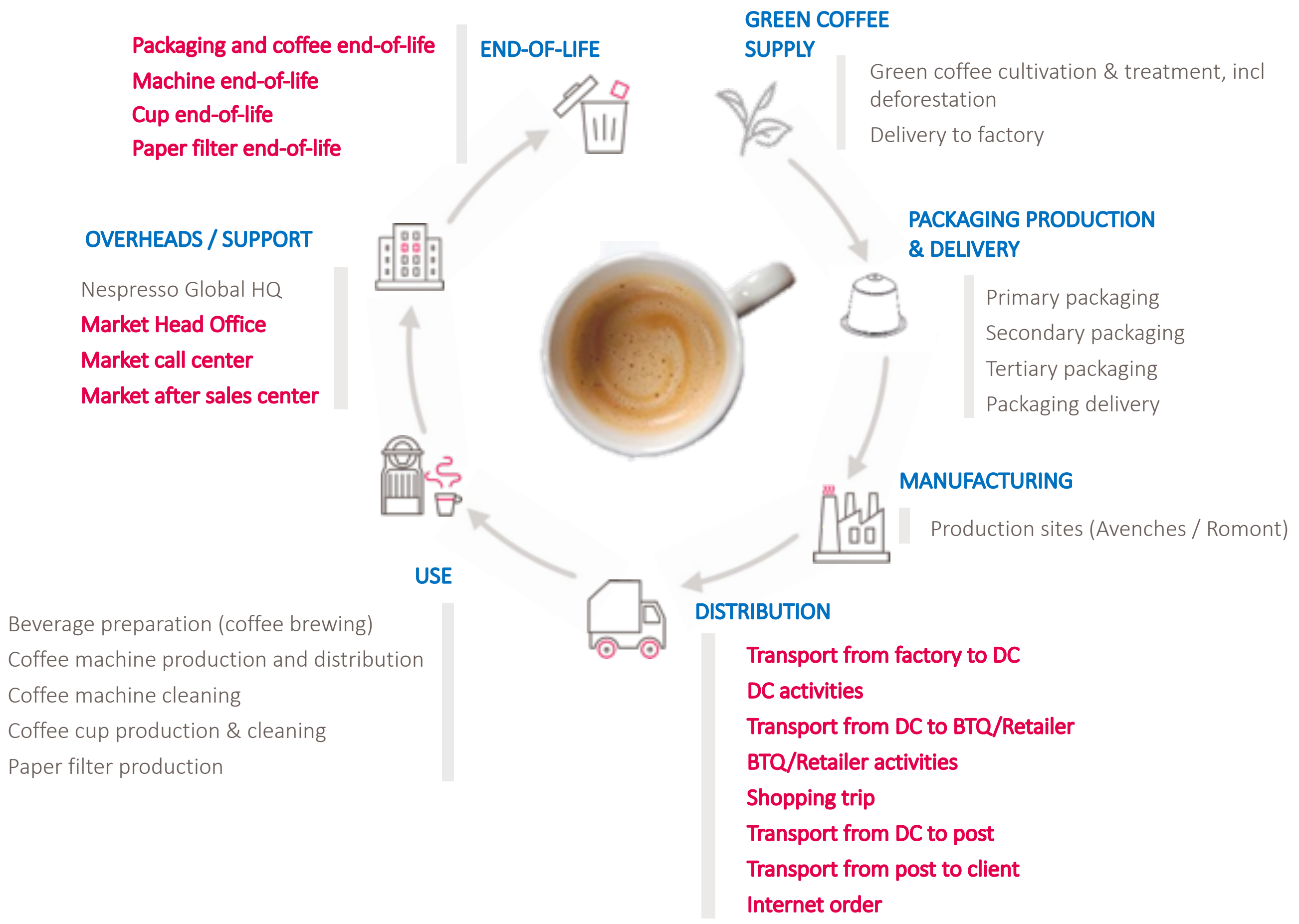


*Figure 1: Life cycle of a lungo cup of coffee (DC: Distribution Center, BTQ: Boutiques, HQ: Head Quarter) – in **red** are the activities adapted for the European market.*

- **Green coffee supply**
  The study analyzes the complete coffee cultivation, including agrochemical use, irrigation, land use change[1], energy and water consumption for coffee cherries processed into green beans and transported to Europe. The same coffee supply is considered for the four coffee systems assessed: a wide variety of coffee is available for moka, full automat and drip filter 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 under consideration.
- **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 aluminium capsule for *Nespresso, the multilayer pouch for other coffee systems*), 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, e.g. in Avenches for *Nespresso*. The same manufacturing process has been considered for all coffee systems. The drip filter and moka use roast and ground coffee, while *Nespresso* and full automat use coffee beans. It can be noted that grinding the beans is negligible in terms of energy consumption.

  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**

  The distribution stage includes the transport routes from production to the point of sale or to the customer. In the case of *Nespresso*, the distribution can be via boutiques, including a shopping trip of the consumer, or via postal delivery.

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

  In the framework of this LCA adaptation, this downstream stage of the life cycle of a cup of coffee remains unchanged for the European market as the average European electricity mix was already used for the baseline study.

- **Overheads/support**

  In this stage, aspects related to the backbone of the company are analyzed, for example, the *Nespresso* headquarters in Lausanne, a weighted average of the European head offices, of the European after sales centers or of the European 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 European market.

- **End-of-Life**

  The final stage covers the collection, sorting and recycling of packaging materials, capsules and coffee grounds. In Europe, municipal wastes are on average 56% incinerated and 44% landfilled (Eurostat data for 2018). Due to the introduction of its own recycling system, *Nespresso* has reached a recycling rate of 38% for the Original capsule in 2019 on the European market. The recycling option is a mix (weighted average) of the options applicable in *Nespresso* European markets: 90% of the recycled capsules are sent to capsule separation and 10% to pyrolysis.

  This means that for 34% of the Original 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 fertilizers; for 56%, the packaging and coffee grounds fraction will be separated with the aluminium going to remelter to produce secondary aluminium and the coffee grounds going to a biodigestion facility, where the biogas produced will be used for heat and power cogeneration and digestate will be used as fertilizers; and for the last 10% of the capsules, they will go to a pyrolysis plant where the aluminium will be recovered while the plastic fraction of the packaging and the coffee grounds will be pyrolyzed and provide energy to the system. The remaining share of the capsules will be incinerated (35%) or landfilled (27%).

  The Original capsule recycling rate is a primary data provided by Nespresso HQ.

Tables summarizing the main data changes from the baseline study to this European market adaptation are presented at the end of this document.

3. Key results

The life cycle assessment of a lungo 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 Original system only,
3.2 is comparing the carbon footprint of the four different systems studied,
3.3 is comparing the four systems studied on other environmental indicators,
3.4 is addressing the impact variability of the results for the four systems studied.

3.1 Carbon footprint performance of the *Nespresso* Original system

A 110 ml cup of *Nespresso* coffee emits about 108 g CO_2-eq on the European market. The carbon footprint of a *Nespresso* lungo is dominated by the use stage (41%) and green coffee supply (32%). Packaging contributes 13% of the greenhouse gas emissions of the *Nespresso* preparation system. Distribution rank fourth (5%) followed by overheads & support (5%) and manufacturing (3%). End-of-life treatment – namely the recycling, incineration or landfilling of the capsules and other packaging items – has a contribution close to 0% (no impacts but no benefits either).

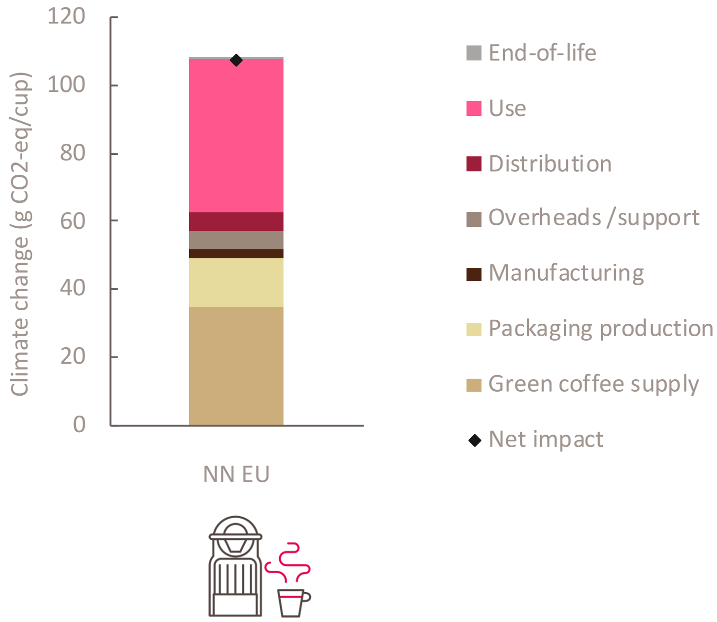


Figure 2: GHG emissions per life cycle stage for a Nespresso lungo (110 ml) cup of coffee on the European market (NN = Nestlé Nespresso)

3.1.1 Green coffee supply

The *Nespresso* coffee capsule contains 6.1 g of ground coffee to make a lungo (110 ml) cup of coffee. Considering the coffee grounds in one lungo *Nespresso* capsule, the green coffee supply accounts for 32% of the total carbon footprint of a cup of *Nespresso* coffee. Fertilizer use (14 g CO_2-eq) and land use change[1] (13 g CO_2-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 CO_2-eq.
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 the fact that these recognized efforts are not taken into account in the current study.

3.1.2 Packaging production and delivery

With 11 g CO_2-eq, the primary packaging, i.e., the capsule, is the main contributor to the packaging production and delivery. The aluminium (1 g) of the *Nespresso* capsule leads to emissions of 9 g CO_2-eq per cup. Recycling aluminium and providing the market with secondary aluminium enables *Nespresso* to contribute to reducing the need to produce more primary aluminium, leading to a net greenhouse gas emissions benefit (included at the end-of-life stage).

The baseline study for the Swiss market assessed in a sensitivity analysis the influence of using aluminium produced with 100% renewable electricity. This showed a reduction of the greenhouse gas emissions of 4 g CO_2-eq per cup of coffee.

Nespresso has started implementing recycled aluminium in Original capsules in 2020, aiming at 80% recycled content in all Original capsules at the end of 2021. Such improvement would lower the greenhouse gas emissions of the system by 1.5 g CO_2-eq per cup of coffee.

3.1.3 Manufacturing

This life cycle stage causes 3% of the carbon footprint (3 g CO_2-eq/cup) of a cup of 110 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 the production center of Avenches, Switzerland (all lungo Original capsules are produced in the Avenches production center, one of the three manufacturing sites of *Nespresso*). The carbon footprint score for this life cycle stage is mostly due to the natural gas consumption, the nitrogen use (to prevent oxidation in the production line) and the packaging losses (treatment of the packaging scraps).

3.1.4 Distribution

5% of the total greenhouse emissions (6 g CO_2-eq/cup) are emitted in the distribution stage (compared to 2 g CO_2-eq in the Swiss study; differences are mainly due to higher distances of transportation, different means of transportation and the energy consumptions in the average boutiques on the European market). For the *Nespresso* capsules on the European market, the distribution can be done either via boutiques (42.8%), via postal delivery (53.6%) or via pick-up points (3.6%). For the three channels, the transport from the manufacturing site in Switzerland to the distribution centers in Europe is considered. Then, for the distribution via boutiques, the transport from the distribution centers to the boutiques was considered, as well as the impacts of boutique themselves (energy, water and paper consumption, IT equipment, employee-related activities such as business travels and commuting) and finally the consumer shopping trip. The postal distribution includes the transport from the distribution centers to the "arrival post", then the postal delivery from the post office to the consumers' home. The electric consumption related to the internet use for the order is also included. For the distribution via pick-up, the transport from the distribution centers to the pick-up points is considered, the shopping trip and the internet order. Most of the carbon footprint for this stage is due to the boutiques activities (energy consumption and to the transport from distribution centers to post (especially the fraction by van) or from factories to distribution centers (by truck), and finally to the distribution centers activities.

3.1.5 Use stage

The largest contributor to the carbon footprint of the use stage of a lungo cup of *Nespresso* coffee is the cup production and washing (27 g CO_2-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 (9 g CO_2-eq). If a consumer's energy supply at home is based on renewable instead of non-renewable electricity, this could lead to a 7 g CO_2-eq decrease in impact per cup in the coffee brewing stage. The machine production, distribution and cleaning of the machine is the least impacting factor (8 g CO_2-eq), since Inissia is relatively light (2.4 kg) and therefore consumes few materials, transport and energy.

3.1.6 Overheads / Support

5% of the total greenhouse gas emissions (5 g CO_2-eq/cup) come from the overheads and support stage (compared to 7 g CO2-eq in the Swiss study; the decrease is mainly due to reduction in business travels or commuting on average in the other European countries, and decrease in the energy consumption of the offices). The overheads for *Nespresso* include the activities related to the global headquarters administrative center, a weighted average of the European head offices, of the European after sales centers and of the European call centers. For each of these elements, the system includes the building, electricity, natural gas, paper and water consumption, the IT equipment, the employees commuting and the business travels. 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 CO_2-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* Original capsules (considered to be 38% recycled, 35% incinerated with energy recovery and 27% landfilled on the average European market) leads to a small greenhouse gas emission net impact of 0.2 g CO_2-eq (compared to a benefit of 5 g CO_2-eq in the Swiss study; differences are mainly due to lower recycling rate of the capsule in Europe and a significant share of the coffee ground going in landfill when the non-recycled fraction is actually fully incinerated with energy recovery in Switzerland).

This could be turned into an environmental benefit if a higher recycling rate of the capsule could be achieved and/or if a higher share of the coffee ground could be diverted from landfilling. A 100% recycling rate would reduce the carbon footprint of the cup of 6 g CO_2-eq.

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

3.2 Carbon footprint performance of the four examined coffee systems

For all coffee systems, impacts on climate change are systematically dominated by the use stage (41% to 50%), especially the cup washing in a dishwasher, and the green coffee supply (32% to 44%). They have a greater impact on the greenhouse gas emissions than packaging, which ranks third (3% to 13%). These three stages represent 87 to 90% of the total greenhouse gas emissions of a 110 ml lungo cup of coffee made and consumed in Europe. The remaining 10 to 13% consist of the end-of-life stage (which varies depending on the considered coffee system), the manufacturing and overheads/support stages as well as distribution.

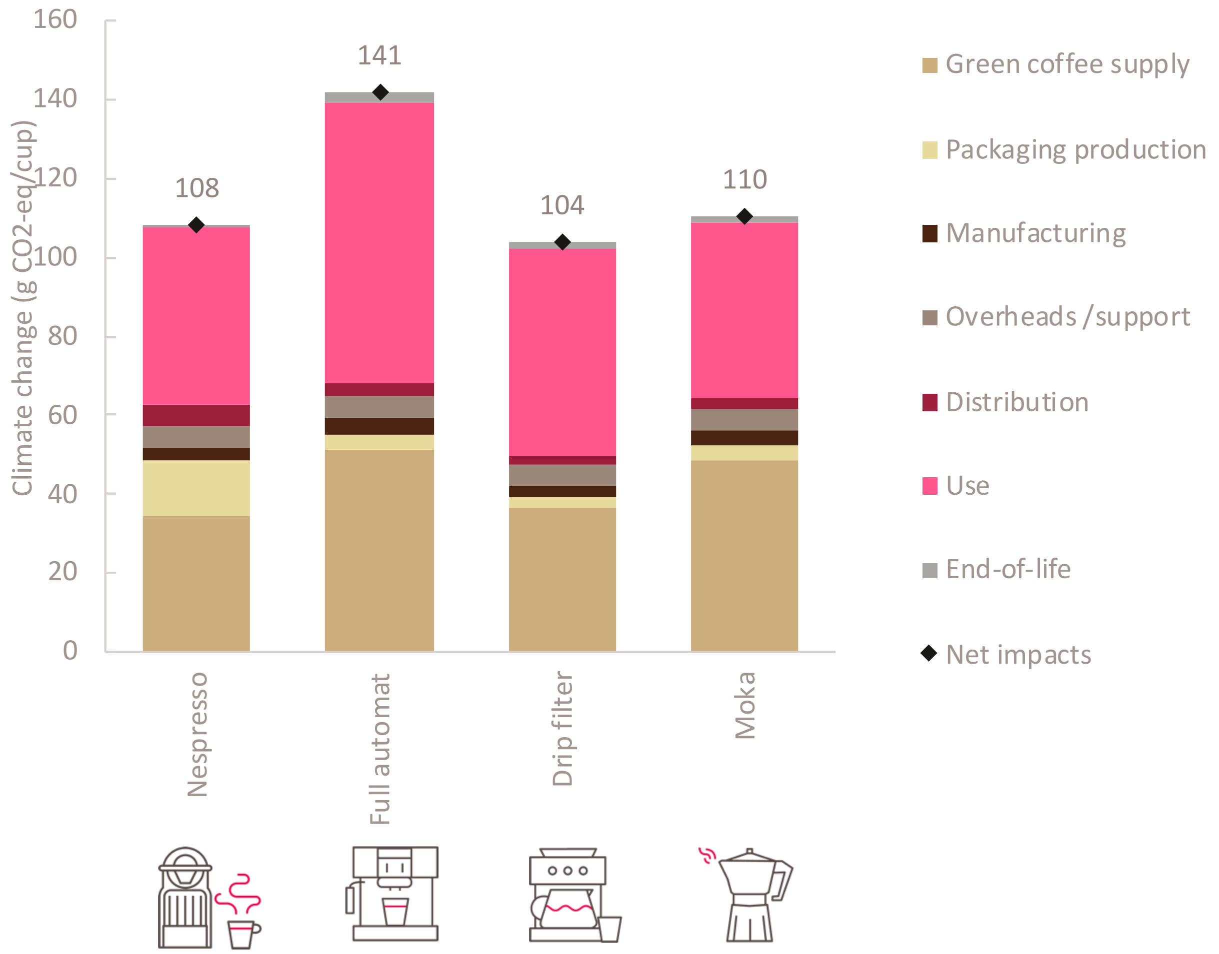


Figure 3: GHG emissions per life cycle stage for the 4 compared coffee systems on the European market.

Based on the studied coffee system carbon footprint, it can be mentioned that *Nespresso*, drip filter and moka coffee systems have similar impacts. The full automat coffee system has the highest carbon footprint of all the systems.

When comparing *Nespresso* to the drip filter coffee system, it appears they have similar environmental impacts (due to uncertainties inherent to the climate change indicator, systems with less than 10% difference can be judged as similar). The drip filter has a slightly higher use stage than the *Nespresso* system due to the paper filter and a higher energy consumption during coffee brewing, and it has a slightly higher impact for the green coffee supply because it is assumed to use more coffee per cup. On the other hand, the *Nespresso* system has a higher packaging contribution.

A cup of coffee prepared with the moka system has also a similar carbon footprint as a cup prepared with the *Nespresso* Original system. Again, the moka system has higher greenhouse gas emissions than the *Nespresso* system regarding the use stage and the coffee supply but this is compensated by the higher carbon footprint of the *Nespresso* packaging.

Finally, the comparison of a cup made from a *Nespresso* Original capsule with a cup prepared in the full automat machine assessed, showed a better performance of the *Nespresso* system regarding greenhouse gas emissions. This better performance is obtained by a lower amount of coffee per cup and a lighter coffee machine for the *Nespresso* system.

3.2.1 Green coffee supply

The cultivation of coffee has the second 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, drip filter and moka 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 (9 g for the full automat, 6.4 g for the drip filter, 8.5 g for the Moka and 6.1 g for the *Nespresso* system). The contributors to this life cycle stage that are described in section 0 above are applicable for all coffee systems as the same green coffee is used for all.

3.2.2 Packaging production and delivery

The coffee pouches (laminate of plastic and aluminium) used for the full automat, drip filter and moka systems are assumed to be the same for all but the amount of coffee per cup varies. The impact of the *Nespresso* coffee system in the packaging stage is higher than for the other three coffee systems (3.5 to 5 times higher). This is mainly due to the amount of aluminium that is needed to produce the capsules, i.e. the primary packaging, as well as a slightly higher weight of primary packaging per cup. While the impacts associated to the secondary and tertiary packaging appear similar for all coffee systems (about 2-3 g CO_2-eq), the difference between the *Nespresso* coffee system and the other systems is largely driven by the primary packaging.

3.2.3 Manufacturing

The Manufacturing stage contributes to 3% of the total greenhouse gas emissions, and it was modelled using the same process for all coffee systems. The same process is considered for all systems due to a lack of data for the full automat, drip filter and moka. Given the wide variety of coffee that can be used for these 3 systems, the manufacturing could vary. However, as *Nespresso* uses 100% renewable electricity for its manufacturing, it was seen as a conservative assumption to consider the same for all systems: this benefits the competitive 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.

3.2.4 Distribution

This stage emits about 2 to 6 g CO_2-eq for all coffee systems. The distribution carbon footprint is driven by the transport to distribution centers and for distribution centers to post, as well as the boutiques activities for the *Nespresso* system, while the transport by truck and the retailer activities explain most of the greenhouse gases emissions for the distribution of the coffee pouch used for the full automat, the drip filter and the moka systems.

3.2.5 The use stage

The use stage has the greatest environmental impact for all examined coffee preparation systems. The cup production and washing has the largest contribution to the use stage carbon footprint (27 to 29 g CO_2-eq-per cup), except for the full automat coffee system where impacts are dominated by the machine production due to its heavy weight (30 g CO_2-eq per cup). Impact caused during brewing represents from 9 to 15 g CO_2-eq per cup, depending on the system considered. For drip filter, the paper filter production and distribution were also included and represent 4 g CO_2-eq per cup. The impact of the water filter production and distribution for the full automat system and the rubber seal production and distribution of the moka coffee system are low.

The use stage of *Nespresso* and moka coffee systems lead to similar greenhouse gas emissions, while the use stages of drip filter and full automat coffee systems are characterized by higher greenhouse gas emissions. Looking specifically at the coffee brewing related aspects, the moka and drip filter coffee systems are more impacting due to their larger energy consumption when they are heated. Varying consumer behavior has further implications on this: for example, brewing with the moka coffee system has an even greater impact if the consumer uses an oversized heating plate, leading to higher energy consumption than necessary. With the drip filter coffee system, energy can be wasted if the consumer uses a non-insulated drip filter pot or keeps it on the warm mode. *Nespresso* machines have an automatic switch-off/standby function, which helps to optimize the energy consumption independent of consumer behavior.

3.2.6 Overheads / Support

The Overheads/support stage contributes to 4 to 5% of the total greenhouse gas emissions, 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 different coffee systems do all lead to net greenhouse gas emission impacts ranging from 0.2 g CO_2-eq (*Nespresso* system) to 2 g CO_2-eq (Drip filter and full automat). This impact is mostly explained by the end-of-life of coffee grounds in landfills which leads to emissions for all coffee systems.

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 70% of the impacts and the use stage has a smaller share.

For all indicators, the drip filter, moka and *Nespresso* systems have a similar performance except for the land use and water withdrawal for which the moka system is slightly less efficient than the two others due to its higher amount of coffee per cup. For all indicators, the full automat system studied has higher impacts than the 3 other systems.

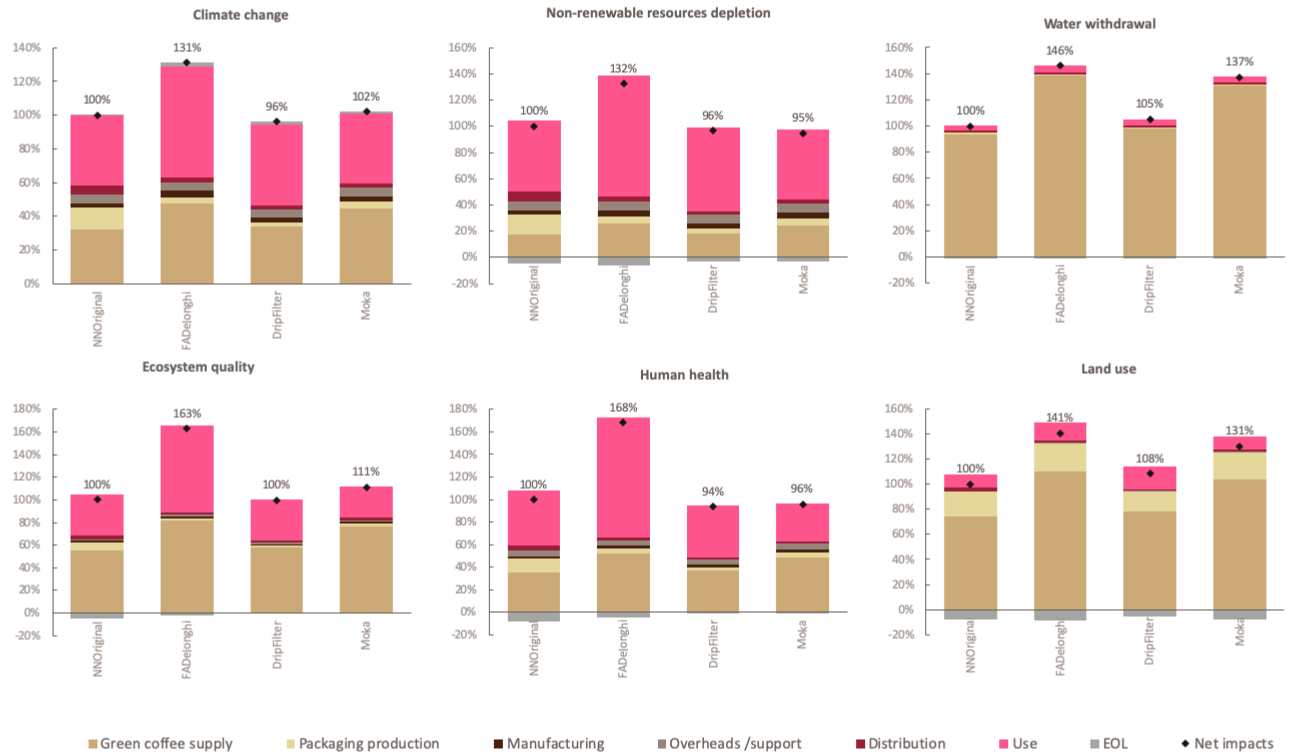


Figure 4: Life cycle stages contribution for the 4 compared coffee systems for all impact indicators on the European market. For each indicator, all coffee systems were normalized with respect to the NN EU coffee system which impact was set at 100%.

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, insulated drip filter pot or not, gas or electric stove for the moka, etc.) or on the recycling rate of capsules (0-100%). Results were combined into a best and a worst combination of criteria. Those analyses showed that, except for the full automat which is more impacting than the *Nespresso* Original coffee system in the context of this study, no coffee system is intrinsically better than another considering the variability each coffee system is subject to. The drip filter and the moka coffee systems can perform better than the *Nespresso* Original coffee system under specific conditions, however the large sensitivity of the drip filter and moka coffee systems to some key consumer-related parameters can quickly make these latters become more impacting than the *Nespresso* Original coffee system in case of inefficient use (coffee wasted, extra R&G coffee use, etc.). Unportioned coffee system performances are therefore much more dependent on consumer behaviour than portioned coffee systems.

Another element tested is the recycling rate of the *Nespresso* capsule: with a 100% recycling rate, the climate change score of the cup of lungo prepared from a *Nespresso* Original capsule would be reduced by 6 g CO_2-eq, while with 0% recycling, it would increase of 4 g CO_2-eq.

4. Conclusion

The holistic view on the life cycle of the four different coffee preparation systems shows that drinking a 110 ml lungo cup of coffee made from a *Nespresso* coffee system in Europe has a similar environmental impact as the same cup of coffee made with a drip filter coffee system or a moka coffee system. On the other hand, preparing a cup of coffee with a full automat preparation system has a higher environmental impact since the machines are heavier and a greater amount of coffee is used.

A large part of the impact on the environment is rooted in the coffee preparation at home (cup production and washing, brewing of the coffee, machine production, distribution and washing), and cultivation of the green coffee. 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 could have a lower impact using a drip filter or a moka than the *Nespresso* Original coffee system under specific conditions, but a less responsible person could prepare a higher impact cup of coffee using the drip filter or moka coffee systems compared with the *Nespresso* Original. Thus, the *Nespresso* coffee system appears 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, 2016[2]). 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 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, drip filter and moka coffee systems, 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, 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 two cups a day, at home in Europe. 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.
- This study adaptation focuses on the European market and the detailed results observed are therefore true only for this specific market.

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

- Although the full automat machine considered correspond to the most sold machine on the Swiss market, producer of this coffee machine is selling internationally and its coffee machines can commonly be encountered on the European market, it does not necessarily mean it is the most sold in Europe. As this report corresponds to an adaptation of the Swiss study to the European 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 CO_2 uptake and release from the coffee (i.e., CO_2 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 European 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, Topten International Services (reviewer)
- François Maréchal, EPFL (reviewer)

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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

Data considered to model Overheads, Distribution and End-of-life is available upon request.

7. Glossary

AAA	The *Nespresso* 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 Organisation 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	Organisation Environmental Footprint
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. 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 their forming for the primary, secondary and tertiary packaging. The primary packaging corresponds to the capsule for the *Nespresso* coffee system and a laminated pouch of 500 g roast and ground coffee for the full automat, drip filter and Moka coffee systems. The secondary packaging corresponds to the sleeve containing 10 capsules for the *Nespresso* and a carton board tray containing several pouches for the full automat, drip filter and Moka coffee systems. The tertiary packaging consists in a corrugated board box, a pallet and an LDPE film for all systems.
PEF / PEFCR	Product Environmental Footprint / Product Environmental Footprint Category Rule
Use	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 drip filter, the paper filter production and distribution are also included.