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GREENChainSAW4Life

Project n° LIFE18 CCM/IT/001193

"GREEN energy and smart forest supply CHAIN as driverS for A mountain action plan toWards climate change"

Deliverable number DL.C3.4

Fossil based goods and services Carbon Fluxes base-line report

Action Number and Title	*C3 Resources Consumption Model and Carbon Fluxes Baseline*
Task	*C3.4 Measuring current carbon fluxes*
Starting Date	*M1*
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Due Date of Delivery	*31/03/2021*
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Author(s)	*Manuel Lai (IRIS), Paolo Albertino (IRIS), Mara Bartolini (IRIS)*
Version	*1.0*

Abstract

The partners involved in the WP will measure carbon fluxes with a Life Cycle Assessment approach, taking into account the Agribalyse and ELC (European Life Cycle) databases. The report is carried out by determining the emission factors of local and non-local biomass fuels by comparing them with the factors of fossil origin. Starting from the data and analyzes present in Deliverables C3.2, considering the local energy consumption collected and validated, it is possible to evaluate the environmental impact that the local biomass supply systems affect the project area. The deliverable determines the emission factors of the entire process: biomass cutting (local and non-local), chipping, transport, production of electrical and thermal energy (on-grid and off-grid scenario). Two main methodologies are used to determine the final value: IPCC GWP 20a and ILCD 2011+ Midpoint.

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This document has been produced in the context of the GREENChainSAW4Life Project by Mara Bartolini (IRIS), Paolo Albertino (IRIS), and Manuel Lai (IRIS).
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Emission factor, Life Cycle assessment LCA, Local biomass, GHG emission, Energy Database, Biomass energy, Bio-materials, Cogeneration, Energy efficiency, Green retrofit, Energy community

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1. INTRODUCTION

1.1. OBJECTIVES AND SCOPE OF THE DOCUMENT

The deliverable determines the emission factors of the entire process: biomass cutting (local and non-local), chipping, transport, production of electrical and thermal energy (on-grid and off-grid scenario). Two main methodologies are used to determine the final value: IPCC GWP 20a and ILCD 2011+ Midpoint. The LCA is a procedure used to identify the environmental emission factors of a product (such as mass or energy generated by a system). In our case the product selected are:

- mass of chip;
- thermal and electric energy of a cogeneration system (OFF-GRID);
- thermal energy of a small combustion system (ON-GRID).

All the parameters thus identified are applied to local consumption already identified in Deliverable 3.2. Finally, we are comparing the values with ones used for DL 3.2 estimation.

Following the analysis of the current levels of consumption and emissions from traditional energy sources, we intend to carry out a study on possible renewable sources of production that are not very widespread in the area. Precisely, having estimated the innovative production process, we intend to calculate the emission value that new technologies would bring to the territory without changing the estimated level of consumption.

The results presented are elaborated according to 4-steps-approach presented in Figure 1 below.

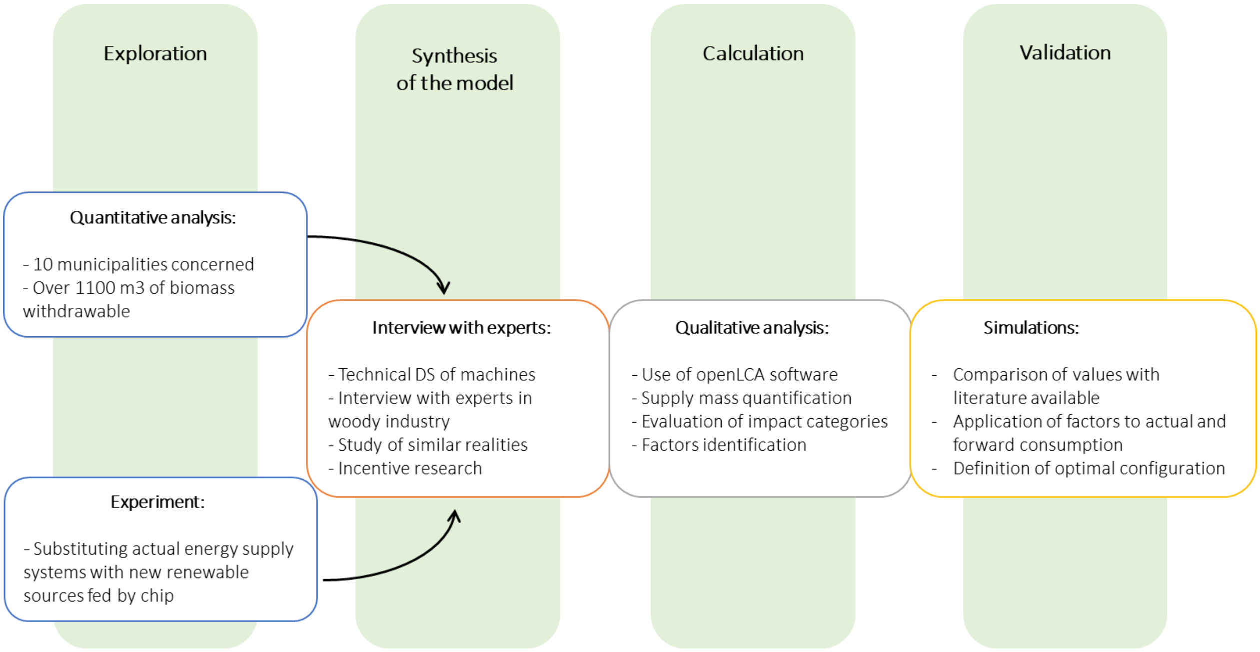

Figure 1 - Method of analysis applied in the document. The approach is deterministic with the purpose to prescribe the most objective result useful for the project itself.

The four steps are:

- Exploration → examination of the contest and of the opportunities. We examined 10 municipalities and their forestry availability.
- Synthesis of the model → detection of model and real parameter to implement. This phase is dominant in the execution because most of the data collected are referred to local habits.
- Calculation→ develop the data into a dedicated software. The software selected is openLCA which already presents database to review.
- Validation→ the final output of factors is correlated to the territory according actual and simulated scenarios-

This method wants to highlight the data collection procedure and estimations.

The final purpose of present work is the realization of the territorial SECAP (DL C4.2) with new parameter and leading local environmental policy to promote more efficient technologies.

1.2. STRUCTURE OF THE DELIVERABLE

The document will be divided into four phases:

- **REPORT OF LCA METHOD:** The first section contains a description of methodology necessary for life cycle assessment (LCA), used to determine the environmental loads associated with a process or activity. Then we move on to the presentation of the openLCA software which was used for the creation of the product life cycle model, as well as for the evaluation of potential environmental impacts.
- **REPORT OF IMPACT ASSESSMENT**: The second section presents two methods used for the assessment of these impacts: IPCC 2013 GWP 20a and ILCD 2011+ Method, considering the main differences and the environmental assumption those methods require.
- **ANALYSIS OF PHASES:** This part is the core of the document due to is functional role in the assessment input. Here, we are going to describe the technical process of getting chipped biomass, electrical and HVAC energy. All result coming out from openLCA are strongly related to this hypothesis.
- **CONCLUSION:** In the final part of the report the sum is drawn to define clearly what is the most affordable technologies in terms of sustainability. Other arguments and considerations are exposed.

The document avails itself of a research method whose logical characterization is summarized in Figure 2.

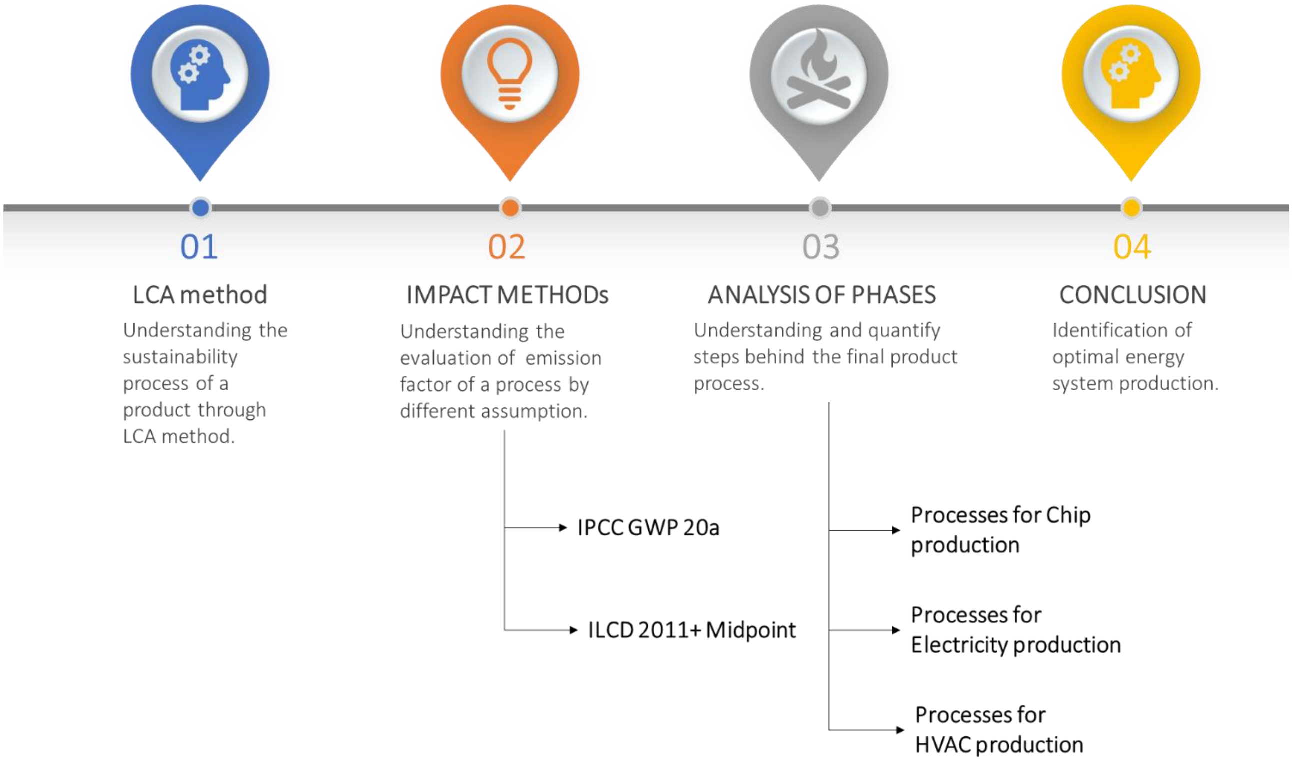

Figure 2 – Schematic summary of the structure of Deliverable 3.4

2. LCA METHODOLOGY AND CALCULATION

2.1. LCA METHODOLOGY [1]

A correct estimation of environmental impacts can be carried out through a Life Cycle Assessment (LCA). This methodology allows to determine and quantify the concrete and potential energy and environmental loads present in the various phases of the bioenergy production and consumption cycle, considered related and interdependent. The LCA therefore quantifies the environmental effects of flows in and out of the production system using appropriate impact indicators.

This technique, applied in the field of renewable energies, makes it possible to compare the environmental profile of the various bioenergy with that of fossil energies that perform similar functions. This comparison provides useful pointers for the choice of technologies that best integrate with the concept of sustainable development.

In order to contain carbon dioxide emissions, it is therefore essential to minimize the use of fossil energy within the entire process of transforming biomass into energy. Through research and the use of the best technologies, it is possible to gradually reduce all polluting emissions during the bioenergy generation process. The LCA reveal ecological weaknesses of processes and give basis to suggest actions.

The method offers many possibilities for use:

- the assessment of the environmental impact of different products with the same function;
- the identification, within the production cycle, of the moments in which the most significant impacts are recorded, from which the main paths to possible improvements can be indicated, intervening on the choice of materials, technologies and packaging;
- support for the design of new products;
- the reporting of strategic directions for development, which allow savings, both for the company and for the consumer;
- proof that it has achieved a reduced environmental impact for the purpose of awarding the Community Ecolabel;
- the pursuit of marketing strategies in relation to the possession of the Ecolabel;
- obtaining energy savings;
- support in the choice of clean-up procedures;
- support in the choice of the most effective and suitable solutions for waste treatment;
- the objective basis of information and work for the preparation of environmental regulations.

The LCA is not only a means of protecting the environment, but it can also become an important tool for strengthening competitive dynamics as well as for reducing and controlling costs.

On the other hand, each evaluation technique necessarily has limitations, which it is essential to know and take into account during the analysis process, in particular:

- the models used for inventory analysis or to assess environmental impacts are limited by the assumptions implicitly contained in it;
- the accuracy of an LCA study may be limited by the accessibility or availability of relevant or high-quality information;
- the lack of a spatial and temporal dimension in the inventory of data used for impact assessment introduces uncertainty about impact outcomes;
- it is not possible to have an absolute and complete representation of any effect on the environment as it is based on a scientific model which is a simplification of a true physical system.

In general, information obtained through an LCA study should be used as part of a much more comprehensive decision-making process and used to understand global or general exchanges. Comparing the results of different LCA studies is only possible if the assumptions and context of each study are the same. For reasons of transparency, these assumptions should be explicitly stated.

As a result of the LCA's limitations, there was a need for standardization. To this end, in June 1993, the Organization of International for Standardization (ISO), has established the Technical Committee 207 with the aim of developing international standards and rules for environmental management. Currently, the international regulatory reference for the development of LCA studies is represented by the following standards of the ISO 14040 series (in Italy transposed as UNI):

- UNI EN ISO 14040:2006 "Environmental Management – Life Cycle Assessment – Principles and Framework", which provides in a general framework the practices, applications and limitations of the LCA, and is intended for a wide range of potential users and stakeholders, even with limited knowledge of life cycle assessment;
- UNI EN ISO 14044:2006 "Environmental Management – Lifecycle Assessment – Requirements and Guidelines", which has been developed for the preparation, management and critical review of the life cycle and represents the main support for the application practice of an LCA study. In addition, in order to provide support to the standards of the UNI EN ISO 14040 series, the following two technical reports are available:
- ISO / TR 14047:2003 “Environmental management – Life cycle impact assessment – Examples of application of ISO 14042”
- ISO /TR 14049: 2000 “Environmental management – Life cycle assessment – Examples of application of ISO 14041 to goal and scope definition and inventory analysis”

The technical specification ISO / TS 14048:2002 "Environmental management – Life cycle assessment – Data documentation format" is also available, which aims to provide the requirements and structure related to the format of the data, used for the documentation and exchange of these during the inventory phase, as well as during the evaluation of the life cycle itself.

According to the ISO standards of the 14040 series, an LCA study consists of the following phases (specifically described in the following paragraphs):

1) Definition of goals and objectives, to define the objective → the intended application and the functional unit of the study;

2) Inventory → to provide a detailed description of the input materials and output of fuels and waste solids, liquids and gases into and out of a system of product;
3) Impact assessment → focused on the potential environmental impacts of a product system;
4) Interpretation and improvement → to obtain conclusions and recommendations;

A schematic representation of four phases of the LCA study is given in Figure 3,4 and 5.

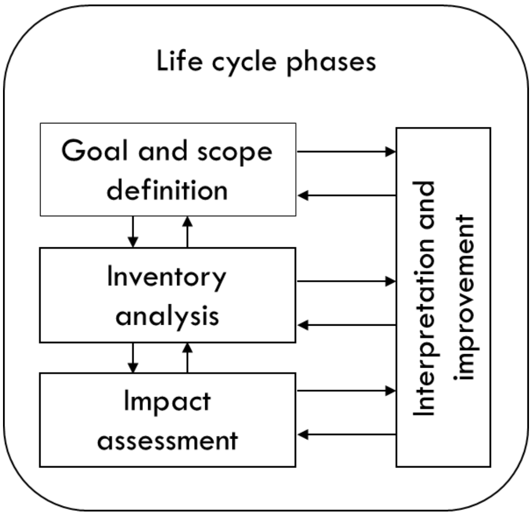

Figure 2- LCA phases

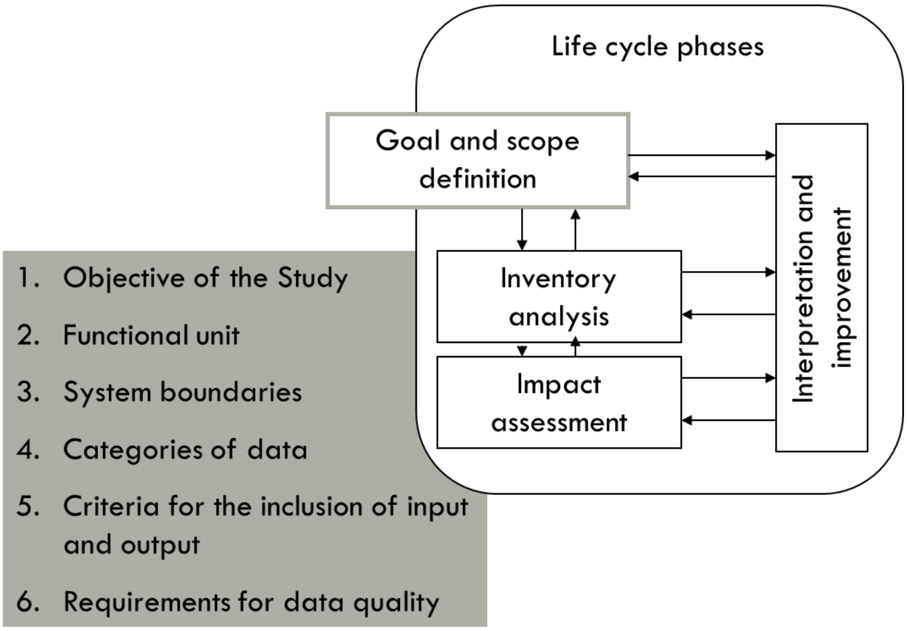

Figure 3 – Upper part there is the simple exposition of all LCA phases needed; downside there is the unpacked steps for define the first phase.

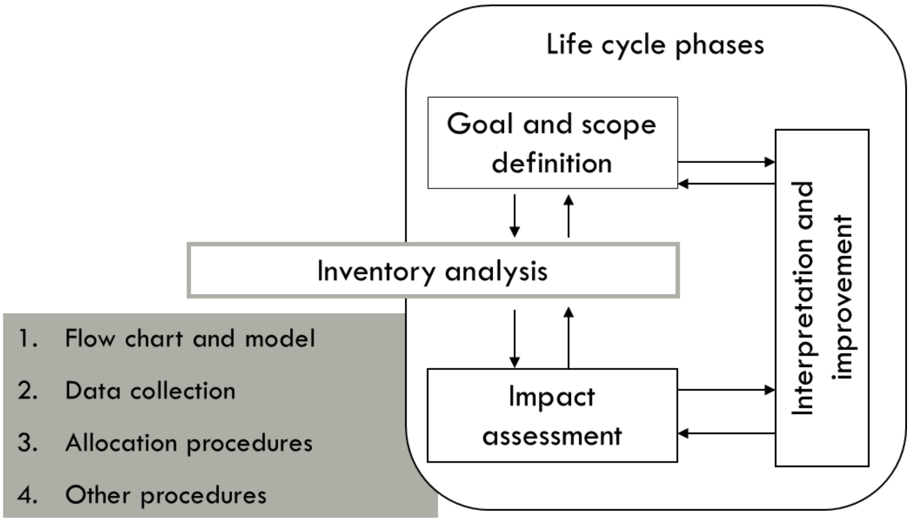

Figure 4 - The inventory analysis is the one which provides the quantification of inputs and outputs and their organization in a model for a given system/product throughout the life cycle.

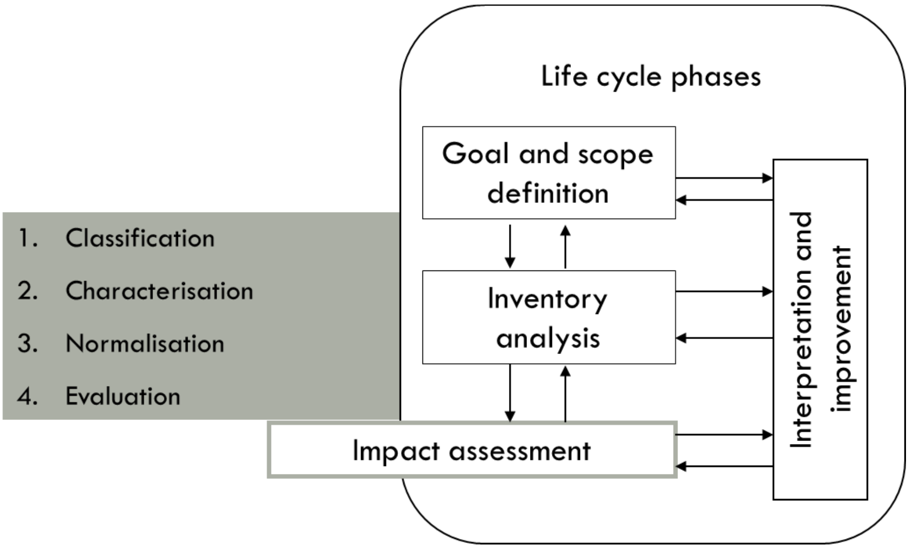

Figure 5 - The Impact Assessment is the third phase of an LCA. The goal of an LCIA is the evaluation of the inventory results in order to understand the environmental effects, defined as impact categories, associated to the system. For each category of impact, proper indicators are defined in order to quantitatively interpret the inventory results.

2.1.1. THE FUNCTIONAL UNIT

The starting point of analysis is the definition of the functional unit. The functional unit must be representative of a quantifiable and objectively detectable performance of a product and/or process, in order to allow comparability of the results of the LCA.
The choice of such a unit is arbitrary and depends essentially on the purpose for which the subsystems and the global system were designed and can be understood as an index of the performance performed by the system. Its definition is therefore fundamental to the success of the study.

This unit was also created because the units of measurement normally used, such as a mass, number of pieces, volume, etc. are not always adequate to represent the (energy and environmental) performance of a production process, but also because equal results of a study expressed according to different functional units can lead to completely different conclusions.

2.1.2. THE BOUNDARIES OF THE SYSTEM.

Boundaries determine the process units to be included in the LCA and their interrelationships; it is often useful to represent them through a flowchart.

To determine the boundaries of research these are defined with great care and attention. This definition follows a detailed description of the system under consideration and the construction of the flow chart, carried out in order to plan the collection of data and information, thus outlining the field of action.

A first delimitation of boundaries will take place in the context of the research of physical environments and production processes that it is considered for analysis. It will then be possible to exclude components which prove to be of no importance or for which it is too expensive to obtain detailed information, or to include others which were not initially given adequate importance.

It is understood, however, that the choice of the boundary of the analysis must be adequately justified and always indicated in the study.

It is now possible to reiterate that each LCA contains simplifications and limitations to make it manageable compared to an LCA of the entire global system that will never be reproducible in its entirety. Therefore, the initial objective of an LCA is to retrace backwards all the production chains of the system investigated up to the extraction of raw materials in the most complete way possible and estimate the error that is made by neglecting some process units. The ISO is very clear in this regard: "the criteria adopted in establishing the boundaries of the system must be identified and justified within the scope of the study".

The reference period is also a constraint in the choice of the boundaries of the analysis. The data can also represent an average system operation situation, or the best available techniques (BAT).

2.1.3. INVENTORY ANALYSIS

It is undoubtedly the most delicate and time-consuming phase of an LCA, as it is the information base on which the next steps are grafted.

Following the ISO 14041, it is precisely at this stage that they are "[...] identified and quantified the flows in and out of a system - product, throughout its life [...]". The consumption of resources (raw materials, recycled products and water), energy (thermal and electrical) and emissions into air, water and soil will be identified and determined. At the end of the day, the structure will take on the appearance of a real environmental balance sheet.

The process of conducting inventory analysis is iterative. As the collected data becomes more in-depth and the system is better known, new requirements or limitations can be identified, which may also lead to changes in data collection procedures, so that the objectives of the study are still met.

The inventory can be divided into four modules:

1. Process flow-chart: the process flowchart consists of a graphical and qualitative representation of all relevant phases and processes involved in the life cycle of the analyzed system;

2. Data collection: the collection of data requires a very high commitment, in terms of time and resources, due to the considerable amount of information, often difficult to find, necessary to characterize all phases of the production process.

The data collected can be divided into three categories:

- primary data, coming from direct surveys;
- secondary data, obtained both from the literature, such as databases of specific software (BUWAL, CETIOM, CBS, IVAM) and technical manuals, as well as from other studies and engineering calculations;
- tertiary data, from estimates and similar operations, data on laboratory tests, environmental statistics and average values.

When collecting the dataset, it is necessary to check that these are concrete and consistent: a simple evaluation method is to budget for each process, taking into account that the amount of inputs must be equal to the release of outputs.

In addition to the impacts related to the process, data concerning:

- impacts and consumption related to the electricity imported into the system: it is necessary to clarify what is the reference context (Regional, National, Community) to proceed with the evaluation of the mixing of fuels that contribute to the production of the exploited electric kW, the overall efficiency of the system and its impacts on the environment;
- impacts and consumption related to the transport system: the products can be transported by different means, each of which corresponds to a certain impact per unit of product transported.

3. System boundaries: at this stage we define:

- the boundary between the system studied and the environment; the load on the environment, represented by all extractions and inputs that take place throughout the entire life cycle, must also be specified;
- the boundary between the processes considered relevant and those irrelevant: at this stage the extension of the study is decided, establishing what should be included and what should be neglected. The purpose of the study, which was previously defined, is taken into account and is based on practical considerations, based on the desirability of not involving elements that do not in fact have any substantial relevance to the final results.

4. Data Processing: collected the data, these are related to all process units that contribute to the production of the functional unit in the studio where, for each process unit, an appropriate unit of measurement will be determined for the reference flow. Subsequently, the impact data are processed and referred to the functional unit of product, through the definition of a contribution factor that expresses the contribution of each process with respect to the production of a functional unit, expressed through the chosen unit of measurement.

Transport is a vital element for most industrial production processes and the amount of energy associated with them (and the resulting emissions) often accounts for a significant part of the overall energy spent in this process. Trucks, lorries, machinery, tractors, equipment consuming diesel fuel such as picks, etc. may be considered as means of transport.

However, studies on the subject have shown that if road transport is contained within 100 km, the resulting environmental impact is not very significant and does not particularly affect the impacts of the system as a whole.

It is possible to divide the contribution of various contributions, and for energy contributions: energy content of fuels consumed directly by the medium in question, plus the indirect share necessary to produce the fuel, is usually proportional to the distance travelled and depends on the transport system, the range of the vehicle, the type of journey, etc.; energy necessary for the construction and maintenance of the vehicle; necessary to build the infrastructure to allow travel and its maintenance.

For the environmental impact of transport systems, atmospheric emissions related to the direct phase of energy consumption are the most important to know and evaluate.

Information on energy consumption and emissions from means of transport is available in the form of national statistical data for a certain category of vehicle, or in the form of data provided by the vehicle manufacturer.

The units of measurement to be used to express the quantities of energy linked to transport, considering the carrying capacity of the means of transport, it is possible to adopt the unit of energy per ton * kilometer (t*km); or in the case of means of transport which do not carry out full-load transport, it is the energy per vehicle x kilometer. For emissions, the mass unit of the substance emitted (e.g. mg of CO_2) refers to the units used for energy.

The road transport system is the most widely used system for the transport of things and people; it can be estimated that about 60% of the energy associated with this transport is due to fuel consumption, about 30% to construction and maintenance and about 10% to the construction of infrastructure.

The fuel consumption of trucks depends on several factors: the state of the vehicle, driving conditions, type of process, fuel quality, climatic conditions, etc…

Particular attention should be paid to the use of adopted units of measurement. Normally the ton x kilometer (t*km) is used, which reports inputs (fuel) and outputs (emissions) to the transport of 1 ton per 1 kilometer; here it is always advisable to specify the mass transported and the distance traveled, assuming that it travels at full load. A useful precaution used in an LCA analysis concerns the kilometers traveled by fully loaded or unloaded vehicle (as often to collect material you also have to perform a certain empty route before loading the goods); for this problem, the LCA considers an average of the total kilometers traveled, between empty trips and full-load journeys, to realize the transport route. This average of kilometers travelled is multiplied by an experimental coefficient of 1.7, which implicitly takes into account both full-load and empty journeys.

It can be seen from studies carried out that the increase in vehicle size is matched by a rapid increase in consumption and that petrol means of transport are less efficient than diesel vehicles.

The use of such a unit of measurement may be misleading; it is therefore necessary to express energy performance more clearly, explaining the energy required to transport a unit of mass per kilometer, i.e. dividing the values by the load carried.

2.2. LCA CALCULATION: OPEN LCA SOFTWARE

openLCA software, developed by GreenDelta since 2006 (www.greendelta.com), is used in over 80 countries and allows to collect, monitor, analyze the performance of environmental impacts of products and services, examining even complex life cycles, according to the recommendations of the ISO 14040 series standards.

The use of the software involves several phases necessary for the implementation of the product lifecycle study. First of all, it is possible to enter the purpose, scope, motivations and client of the study, and then move on to the choice and setting of data quality requirements, in temporal, geographical and technological terms.

We then proceed with the insertion of the inventory data leading to the modeling of this system.

The approach followed is of a "bottom-up" type, in fact, we begin with the definition of the processes that fix the data relating to the incoming and outgoing materials, and then move on to the determination of the assemblies that contain the processes.

About the input of data relating to inbound and outbound flows, the software has a database, in which the information is classified according to the following categories:

1. materials, which include several subcategories, including chemicals, paper, plastics and wood;
2. energy, which is defined according to the source and energy mix of the country of reference;
3. transport, including road, rail, sea and air transport, with their means of transport which can be used;
4. processes, in which the typical processes are present;
5. use;
6. end-of-life scenario in which the waste flows that characterize the system;
7. end-of-life treatment, in which the different possibilities of waste treatment, including landfill, incineration and recycling.

On the other hand, regarding the impact assessment phase, openLCA calculation code contains several methods, such as: ReCiPe, Eco-indicator, IPCC, IMPACT, Ecological Footprint, etc…

For each component of the product concerned, it is necessary to create a 'Process' (in which the different stages created are assembled), the data that is entered belongs to the method database, which can be implemented or modified depending on the user's need.

In Figure 6 it is scheduled the algorithm process linked to the software.

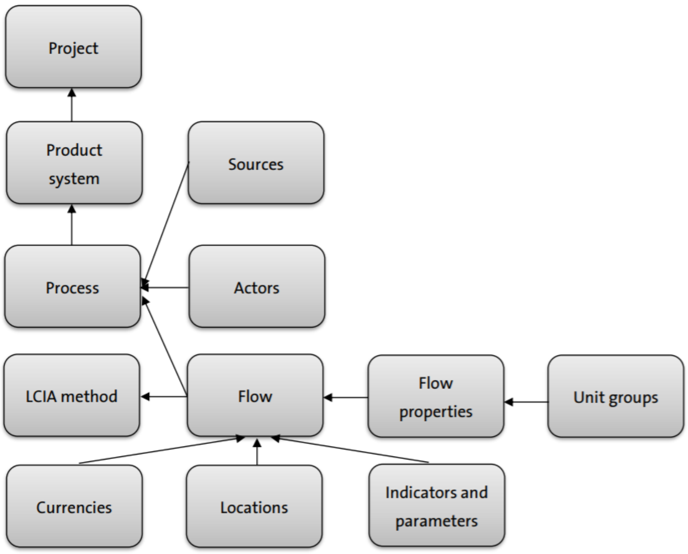

Figure 6 - Database element structure and flow of information

The databases in openLCA contain the following information:

- Actors: people who have provided data or modified models
- Currencies: cost can be assigned to flows and Life Cycle Costing can be performed
- Locations: important for regionalized LCA
- Sources: literature referenced
- Unit groups: groups of units (e.g. units of area include m2, ft2, etc.)
- Flow properties: properties of flows (e.g. length, mass, etc.)
- Flows: products and materials
- Processes: production or modification of products and materials
- Impact methods: impact assessment methods imported into openLCA
- Product systems: process networks (necessary to calculate inventory results and impact assessment)
- Projects: can be created to compare product system variants
- Indicators and parameters: social indicators, global parameters, data quality systems.

To better understand the logical schema that will generate our outputs, we can refer to Figure 7.

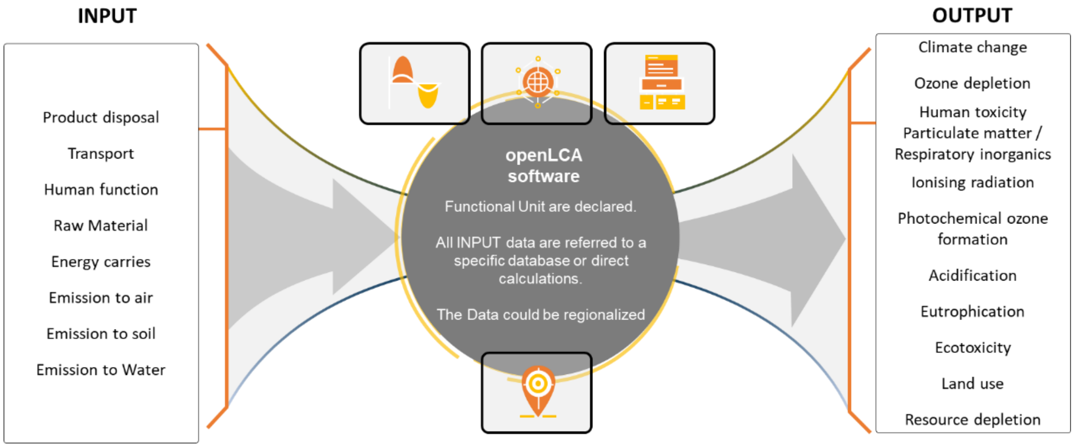

Figure 7 – Schematic outline of the LCA method assumed.

3. IMPACT ASSESSMENT METHODOLOGIES: **IPCC** AND **ILCD**

For this work, the ILCD 2011+ Midpoint and IPCC 2013 GWP 20a impact assessment methods were used. There were two types of methodologies used in impact assessment: the first one converted the extraction of natural resources and emissions of hazardous substances into category indicators at midpoint level (such as "Acidification", "Climate change", "Ecotoxicity") and the second one is adopted to maintain coherence with the emission factor catalogue used for PAES report in D 4.1.

3.1. IPCC 2013 GWP 20A1

IPCC 2013 is the successor of the IPCC 2007 method, which was developed by the Intergovernmental Panel on Climate Change. The Global Warming Potential is calculated over specific time intervals years, for our case the interval is equal to 20 years. GWP is expressed relative to carbon dioxide (whose GWP is standardized to 1). Methane has a lifetime of 12.4 years and climate-carbon feedbacks with global warming potentials of 86 kg CO_2 eq per kg for 20 years. IPCC characterize factors for the direct (except CH_4) global warming potential of air emissions. The emissions are:

- not including indirect formation of dinitrogen monoxide from nitrogen emissions.
- not accounting for radiative forcing due to emissions of NO_x, water, sulphate, etc. in the lower stratosphere + upper troposphere.
- not considering the range of indirect effects given by IPCC.
- not including indirect effects of CO emissions.
- The factor for biogenic methane was calculated by subtracting 2.75 kg of CO_2 per kg of methane from the methane factors. The correction factor of 2.75 is the molar mass of CO_2 divided by the molar mass of CH_4.
- The factors for fossil methane in the IPCC report were not used. the factors for methane in IPCC also apply to fossil methane.

3.2. ILCD 2011+**2**

The ILCD 2011+ Midpoint method was released by the European Commission in 2012. It supports the correct use of the characterization factors for impact assessment as recommended in the ILCD guidance document ""Recommendations for Life Cycle Impact Assessment in the European context - based on existing environmental impact assessment models and factors (EC-JRC, 2011)"".

This LCIA method includes 16 midpoint impact categories:

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[1] SOURCE: http://www.climatechange2013.org. Intergovernmental Panel on Climate Change (IPCC). http://www.ipcc.ch/.

[2] SOURCE: http://eplca.jrc.ec.europa.eu/?page_id=140.

1. Climate change [kg CO_2eq]: The climate change impact category considers the effects caused by the emission of greenhouse gases into the atmosphere, as well as human activities, which affect their atmospheric concentration.
   Such gases have the ability to absorb the infrared radiation reflected from the earth (radiative forcing), which is modeled by determining the variation in the concentration of the test substance and the consequent absorption of infrared radiation. In addition, the residence time of the substance is considered.
   For this category of impact, the IPCC model has been developed and recognized worldwide, specifically, GWP is used to express the contribution to the greenhouse effect, by a given gas emission into the atmosphere, calculating it for a specific time interval. All molecules refer to CO_2, whose GWP value has been assumed to be 1. For the ILCD methodology, the Global Warming Potential is calculated over a 100-year time horizon.
   The Figure 8 shows the environmental mechanism considered for this category impact. It should be noted that the thickness of the arrows indicates the importance of the path, compared to the whole mechanism.

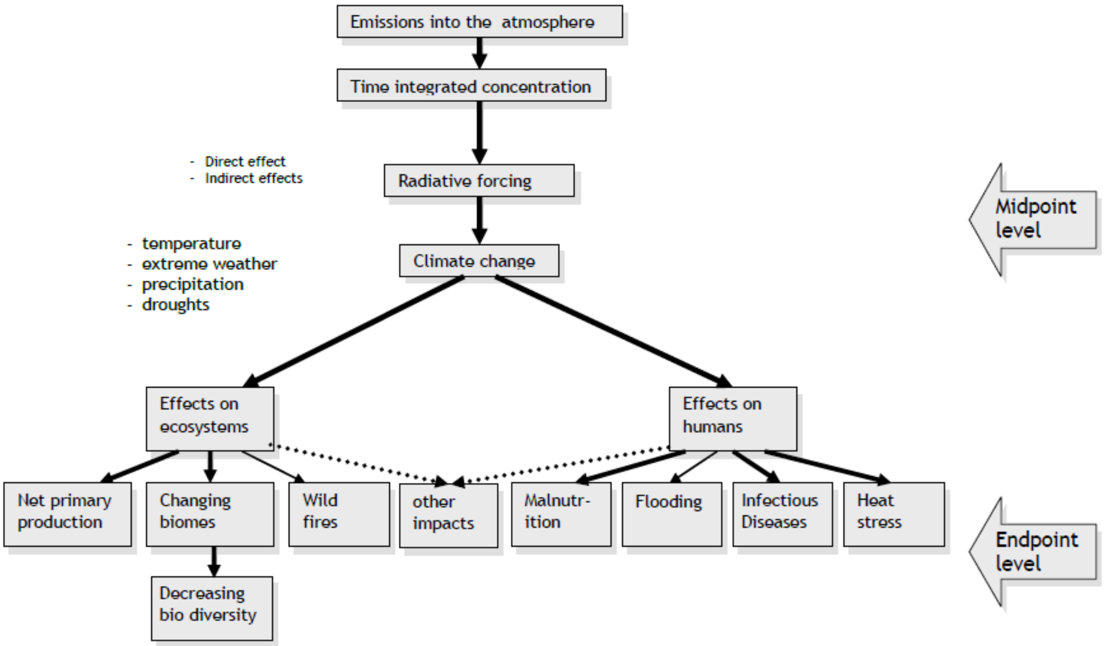


Figure 8 - Environmental mechanism for the climate change impact category, with midpoint levels and endpoints recommended by the ILCD Handbook (source: JRC, 2010b)

2. Ozone depletion [kg CFC-11 eq]: Ozone Depletion Potential (ODP) calculating the destructive effects on the stratospheric ozone layer over a time horizon of 100 years.
3. Human toxicity, cancer effects [CTUh]: Comparative Toxic Unit for humans (CTUh) expressing the estimated increase in morbidity in the total human population per unit mass of a chemical emitted (cases per kilogram). Specific groups of chemicals require further works.

4. Human toxicity, non-cancer effects [CTUh]: Comparative Toxic Unit for humans (CTUh) expressing the estimated increase in morbidity in the total human population per unit mass of a chemical emitted (cases per kilogram). Specific groups of chemicals require further works.
5. Particulate matter [kg PM2.5 eq]: Quantification of the impact of premature death or disability that particulates/respiratory inorganics have on the population, in comparison to PM2.5. It includes the assessment of primary (PM10 and PM2.5) and secondary PM (incl. creation of secondary PM due to SO_x, NO_x and NH3 emissions) and CO.
6. Ionizing radiation HH (human health) [kBq U235 eq]: Quantification of the impact of ionizing radiation on the population, in comparison to Uranium 235.
7. Ionizing radiation E (ecosystems) [CTUe] [note: this method is classified as interim; see reference for explanation]: Comparative Toxic Unit for ecosystems (CTUe) expressing an estimate of the potentially affected fraction of species (PAF) integrated over time and volume per unit mass of a radionuclide emitted (PAF m^3 year/kg). Fate of radionuclide based on USEtox consensus model (multimedia model). Relevant for freshwater ecosystems.
8. Photochemical ozone formation [kg NMVOC eq]: Expression of the potential contribution to photochemical ozone formation. Only for Europe. It includes spatial differentiation.
9. Acidification [molc H+ eq]: Accumulated Exceedance (AE) characterizing the change in critical load exceedance of the sensitive area in terrestrial and main freshwater ecosystems, to which acidifying substances deposit. European-country dependent.
10. Terrestrial eutrophication [molc N eq]: Accumulated Exceedance (AE) characterizing the change in critical load exceedance of the sensitive area, to which eutrophying substances deposit. European-country dependent.
11. Freshwater eutrophication [kg P eq]: Expression of the degree to which the emitted nutrients reach the freshwater end compartment (phosphorus considered as limiting factor in freshwater). European validity. Averaged characterization factors from country dependent characterization factors.
12. Marine eutrophication [kg N eq]: Expression of the degree to which the emitted nutrients reach the marine end compartment (nitrogen considered as limiting factor in marine water). European validity. Averaged characterization factors from country dependent characterization factors.
13. Freshwater ecotoxicity [CTUe]: Comparative Toxic Unit for ecosystems (CTUe) expressing an estimate of the potentially affected fraction of species (PAF) integrated over time and volume per unit mass of a chemical emitted (PAF m3 year/kg). Specific groups of chemicals require further works.
14. Land use [kg C deficit]: Soil Organic Matter (SOM) based on changes in SOM, measured in (kg C/m2/a). Biodiversity impacts not covered by the data set.
15. Water resource depletion [m3 water eq]: Freshwater scarcity: Scarcity-adjusted amount of water used.
16. Mineral, fossil & renewable resource depletion [kg Sb eq]: Scarcity of mineral resource with the scarcity calculated as 'Reserve base'. It refers to identified resources that meets specified

minimum physical and chemical criteria related to current mining practice. The reserve base may encompass those parts of the resources that have a reasonable potential for becoming economically available within planning horizons beyond those that assume proven technology and current economics.

Characterization factors for renewable energy flows were missing, but they have not been supplied by the JRC, so they are all assumed zero and added with a factor zero.

4. LCA ANALYSIS – IPCC AND ILCD

The aim of this paper is to determine the environmental impact of real cases:

- a wood chips plant cogeneration (plants for the combined production of electricity and heat);
- wood chip heat production plants.

The results provided show the decidedly positive impact of the plants with renewable sources, analyzing all the processes involved in the retrieval of raw materials to their combustion, from combustion to energy production, from energy production to waste disposal.
In this study, the reference supply chains analyzed were **wood-energy supply chain**.
The methods and procedures by which the same finished product is arrived at are not unique, since the elementary phases may not appear all, or at least do not appear in the same timeline.
The operational sequence introduced in this study was based on real data and phases, the information of which was sought through on-the-spot interviews and to those directly concerned. It should not be forgotten, for example, that the main chemical-physical and energy characteristics of wood vary, not only from species to species, but also within the same species, depending on the environment in which it has grown.

4.1. FUNCTIONAL UNIT

As visible in Figure 9, it was analyzed three different functional units for the environmental impacts. Each unit it referred to a specific process, in particular:

1. CHIP SUPPLY: 1 kg of wood chip production;
2. OFF-GRID SCENARIO 1 kWh of electric energy from biomass cogeneration + thermal energy deriving from the process;
3. ON-GRID SCENARIO: 1 kWh of HVAC energy from small biomass combustion systems.

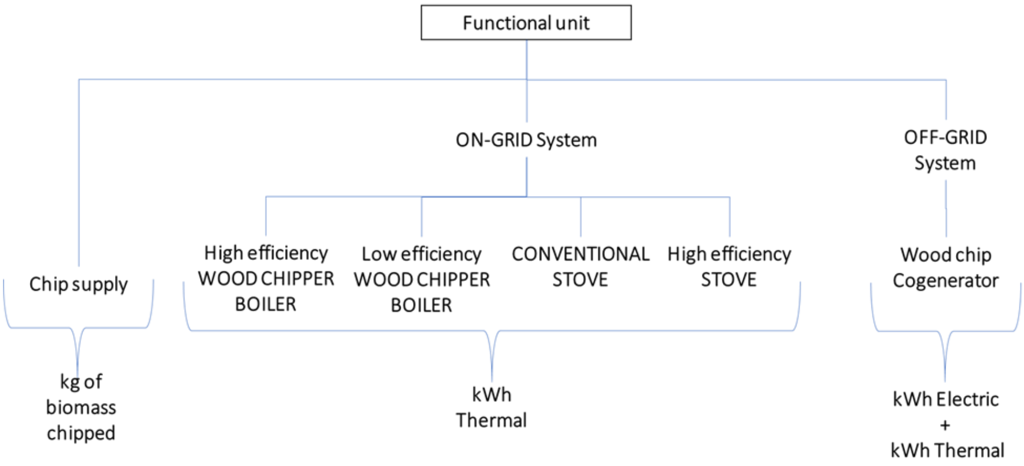


Figure 9 – Summary Scheme of type of functional unit used for each process.

Starting from wood chip, we have an important consideration to evaluate. The supply chains envisaged for the production of chip was divided into two typologies:

1. LOCAL: The first one is a local forestry supply within 100 km from the final end-user;
2. NON-LOCAL: The second one is a foreign forestry supply beyond 100 km from local users.

The functional unit for both processes is "1 kg of chip" obtained from tree sawing until logistic distribution.

In the OFF-GRID case, the functional unit chosen is the amount of energy produced by the cogeneration plant measured in "kWh equivalent", this unit of measurement is understood both the production of kWh electrical and thermal, as the plant works with the same annual quantity of wood chipped conferred. The equivalent kWh is considered to be divided into its electrical and thermal part with the respective percentages of efficiency of the plant.

Meanwhile for the ON-GRID system the "kWh" is referred only to the thermal energy production due to commercial systems of combustion do not produce any form of electricity but need themselves an electric connection to work.

This study has been prepared in order to assess and subsequently compare the environmental impact of the production of electricity and thermal energy produced by the gasification or combustion of wood chips, in order to assess which, supply solution is the least impactful from an environmental point of view.

Although it may be considered likely a priori that a greater distance of supply will have a greater impact related to transport, this is not always the case. In fact, the most distant supply chain provided that great distance transports generate a few CO_2 emissions per journey. This small difference id due to the fact lorries used have a major carrying capacity and therefore provide the same annual quantity of wood chip with less supply journey, thus emitting in total even less carbon dioxide than the nearest supplier.

The factors which most affect non-local supplies will not be transport, but the type of industrial machinery used. Most of industrial machines in the biomass chain are fed by fossil fuel and quantities need for these processes emits the major total amount of CO_2. The following results are going to demonstrate and highlight all the consideration above.

4.2. PHASES OF THE ANALYSIS

The aim of the study is to determine the environmental impact for two scenarios:

- OFF-GRID scenario (for energy community destination): the generation of electric and thermal energy from the cogeneration plant: ECO20x, with nominal electric power of 20 kWp;
- ON-GRID scenario: the production of thermal energy with different type of biomass boilers and stove present on the market while the electric energy is supplied from the national electric grid.

Both scenarios use the same wood chip supply for their functionality, so the process of chipping is equal for each system, but the quantities needed are different. This specification is better visualized in the scheme of Figure 10.

Firstly, there are three major macro phases subcategorized into other phases. These subcategories are different for OFF-GRID or ON-GRID appliance. Moreover, each categories want to compare the same efficiency procedure with local and non-local supply chip.

The total combination of cases would exceed the amount of 20 (precisely 28), it was decided to propose only the relevant ones and narrow cases into 11.

For every case, the first step was to define the "Assembly" of the various components (data on materials, energy used and transport information).

The "Disposal Scenario" must refer to a given "Assembly"; we choose the type of disposal that is considered mostly realistic like "Waste Scenario". The disposal part considers a transportation only for the ashes produced by cogeneration plant due to the great amount generated daily.

As far as database data is concerned, the following are organized as follows:

- Material is divided into categories (Building material, Chemical, metal, Fuels, Nonmetals, etc.) and for each of these is indicated the "Waste Fraction", which will serve to give each component the appropriate treatment ("Waste Treatment"), and the appropriate scenario ("Waste Scenario"). In case it is not indicated, it is necessary to know that the code does not plan to consider such material as waste at the time of disposal.
- Processing is also divided into categories which collect processes relating to a certain type of material.
- Transport is broken down by type (road, rail, water, air) and possible means of transport are reported for each of them.
- Energy allows to evaluate the type of energy used in the production phases and possibly in those of use of the product.

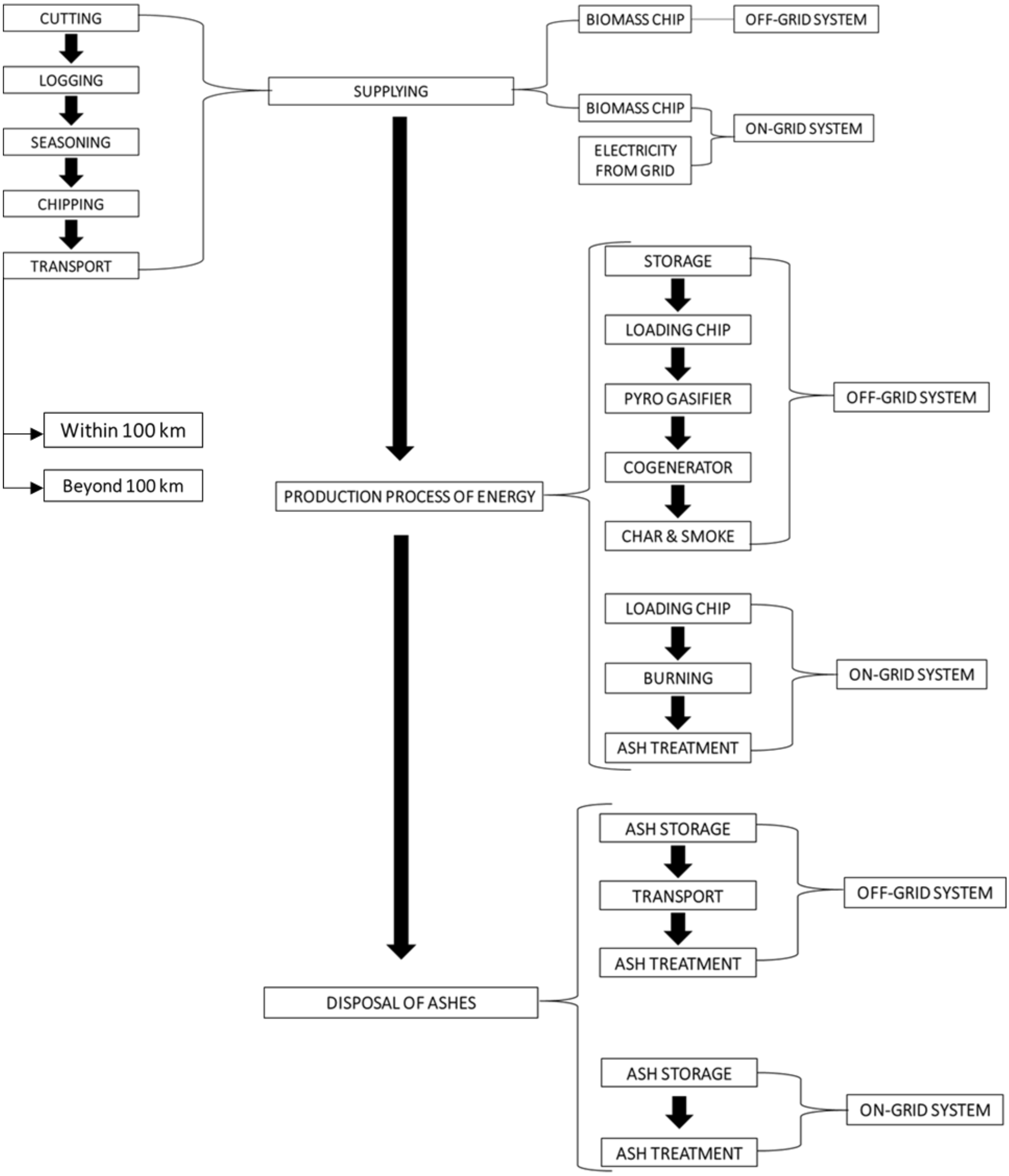


Figure 10 – Total process developed for the analysis.

Focusing only to the common macro phases, as shown in Figure 11, we are going to indicate the total assembly.

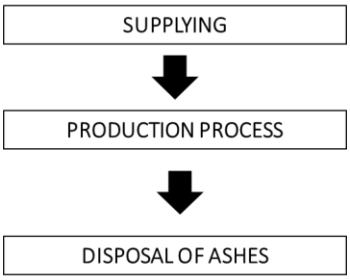


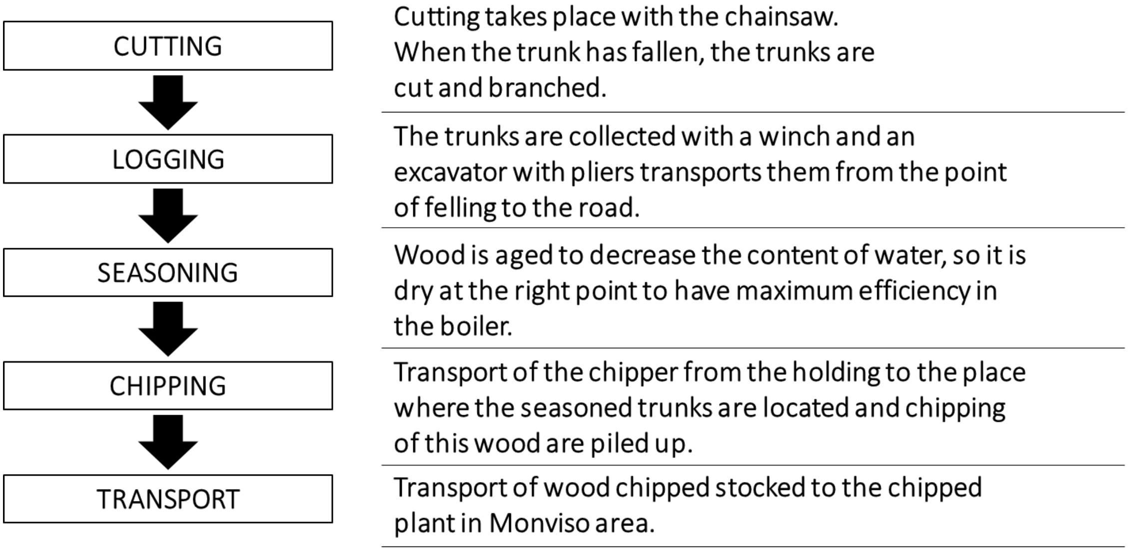
Figure 11 - Schematic representation of the macro phases that make up the wood chips supply chain.

The values included in the LCA analysis was taken by individual data sheets of the different phases. To each phase it is necessary to indicate the unit input that you want to insert, against a certain unitary output referred: for instance in the cutting phase, you want to obtain 1 kg of wood chipped, having as input the hours of chainsaw used referring to obtaining precisely that kg of wood chipped; so also for the ashes, the transport will have a unit value referring to obtaining 1 kg of ash transported as output.

In the calculation of the values, the number to be included in the phase sheets is therefore unitary, in the sense that it refers to a unit quantity.

4.2.1. MACRO PHASE OF SUPPLYING [2]

The stages implied into the supply chain are treated step-by-step. This phase has seen the intersection of a local investigation work with what is stated in Deliverable of WP 2. The procedure for obtaining wood chip was considered standard for both the local (within 100 km of radius) and non-local supply (over 100 km of radius). In Figure 12, it is possible view the standard process adopted.



Cutting takes place with the chainsaw. When the trunk has fallen, the trunks are cut and branched.

The trunks are collected with a winch and an excavator with pliers transports them from the point of felling to the road.

Wood is aged to decrease the content of water, so it is dry at the right point to have maximum efficiency in the boiler.

Transport of the chipper from the holding to the place where the seasoned trunks are located and chipping of this wood are piled up.

Transport of wood chipped stocked to the chipped plant in Monviso area.

Figure 12 – Diagram of the first Macro phase

For this phase, it was considered that 100% of wood collected is come from chestnut tree. Like we are going to see, the cogeneration system and small combustion systems have best performances (not only under emission aspect) with chip labelled A1. This characteristic is important to detail the amount of work needed by machineries in the process. Chestnut trees are selected for the process because they are the most common tree spread in the area analyzed. Using ArcGIS software, it is possible visualize in Figure 13 the total distribution that chestnuts cover in Valle Po (the data in brown color). It is important to know and estimate the type of wood cut for the energy content of the material. The energy content is necessary to evaluate the thermal amount released by the chip in case of combustion. Both local and non-local supply take in consideration the use of 100% chestnut wood.

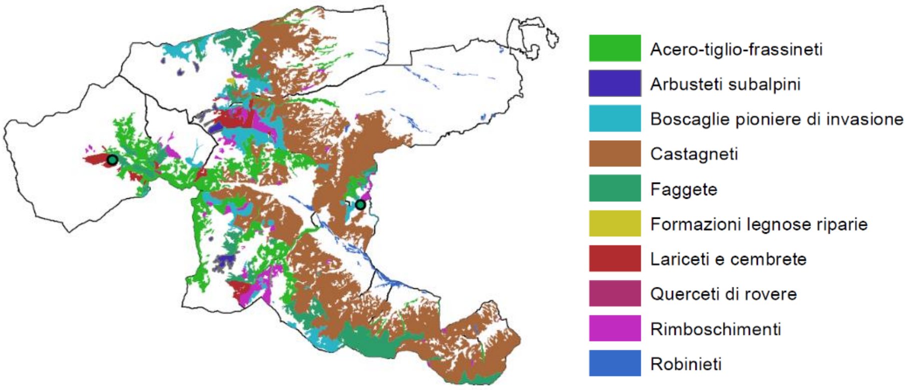


Figure 13 – All types of trees spread in Valle Po.

By analyzing the data collected in the PFT (Territorial Forestry Plan) relating to the wooded area of Monviso Valley and knowing the coefficients related to the chipping aptitude of the woody species disbursed, it is possible to identify areas of interest and make for each of them a first summary estimate of the annual quantity of destined for wood chips.

The index of woodland is given by the ratio of the wooded area to the total area covered; it allows you to immediately view areas of potential interest. Where this index is at least 30%, the area is likely to be exploited for the establishment of a supply chain.

The calculation of the amount of biomass that can be taken is carried out using drawing coefficients relating to wood masses disbursable, classified by forest species and by type of land use intervention. The calculation was already completed in Deliverable 3.2 and it is not reviewed in this document.

After clarifying the conditions of biomass withdrawable, we are focusing on the first step needed in the process: the cutting of the tree. In Monviso area, the cutting is carried out manually with the support of a chainsaw and this condition still considered for the non-local supply chain.

The chainsaw used as cutting equipment works with gasoline oil mixture; the indicative cost of a chainsaw is € 1000. In this phase, the machine identified in the openLCA database was "Power Saw" (in particular within: Wood-power saw). Such machine has a unit of measurement the hours of use to carry out the operations necessary to cut the tree trunks from which to obtain the wood chips. The estimation of the time is directly proportional to the diameter of the mean trunk.

The logging is the phase in which the felled trees are dragged out of the felling area into the woods and piled up in the dock. For local and imported supply is estimated the work of a tractor with a winch and an excavator with pliers connected. The tractor is a SAME Silver 100 hp diesel; the average cost is about € 80.000. The load capacity of the tractor is 5.300 kg.

The path he takes at full load inside the forest to transport the wood felled to the spot for chipping is different according to local forestry and not.

For local forestry, the path is estimate averagely 100 meters meanwhile the path covered by the tractor to arrive at the spot is considered 1000 m from farm to the forest and another 1000 m to return. The total km covered are therefore 2.1 km (1000 m + 1000 m + 500 m).

For non-local forestry, the path is estimated to 5 km while the street segment covered to reach the working spot is considered 20 km. The total km of movement for non-local tractor is 45 km (20 km + 20 km + 5 km).

On an experimental level, it is accepted to use in the multiplicative factor present in openLCA software. The factor already takes into account the total km carried out both fully loaded and empty; this factor is conventionally set at 1.7, to be multiplied by the km covered at full load.

The seasoning was chosen not to be considered in the LCA analysis because of its irrelevance in terms of environmental impact, since the only product resulting from it appears to be a loss of water content that is almost irrelevant and has no negative impact from an environmental point of view.

The chipping phase is carried out at the imposed, bringing the chipper to this area.

The chipper brand used is PEZZOLATO, a small version of series PTH30.70 (hourly production 18 m^3/h) is used for the scenario of local supply chain, the version of series PTH500 (hourly production 30 m^3/h) is used for non-local supply chain scenario.

openLCA identify this typology of machinery as "Diesel in wood chip machine" (within the Energy-Mechanical-Diesel category in wood chip machine).

The unit of measurement for this technology is the hours of usage. This king of unit implies that for industrial chipping machine the amount of time taken to produce 1 kg of chip is much less than small and common chipping appliance. The difference is so relevant that the transportation impact stand in background for the environmental effects.

For the transport phase, the wood chip produced is transported from the imposed up to the distribution plant ready to be used as fuel for any purpose.

In case of residential heat production, the distance considered is equivalent.

The km covered in total during this journey of the transposed wood are different according the local or non-local supply chain, see the Figure 14 for summary of km accounted.

For the reason mentioned above, factor 1.7 is also used at this stage, which takes into account both full-load and unpaid journeys of the means of transport.

	LOCAL SUPPLY CHAIN	NON-LOCAL SUPPLY CHAIN	
Distance from wood chip production to plant/logistic sorting area	around 50 km	beyond Alps ➡	1100 km
	around 100 km	beyond ocean ➡	3100 km

Figure 14 – Km considered for local supply and not-local supply.

The final transport from logistic distribution to final end-users is not considered. For the OFF-GRID solution, it is not considered because the final plant coincides with the cogeneration itself; for the ON-GRID system km could be variable but still less than 4/5 km so it is negligible a priori.
To better understand the total process of the supplying, it is shown in Figure 15 every phase described above. The final plant is the final logistic distribution/cogeneration plant.

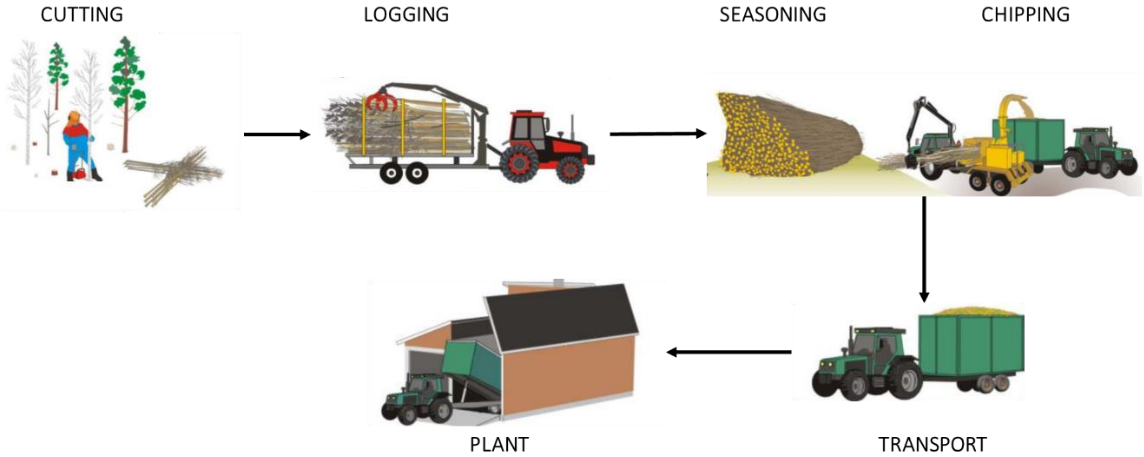
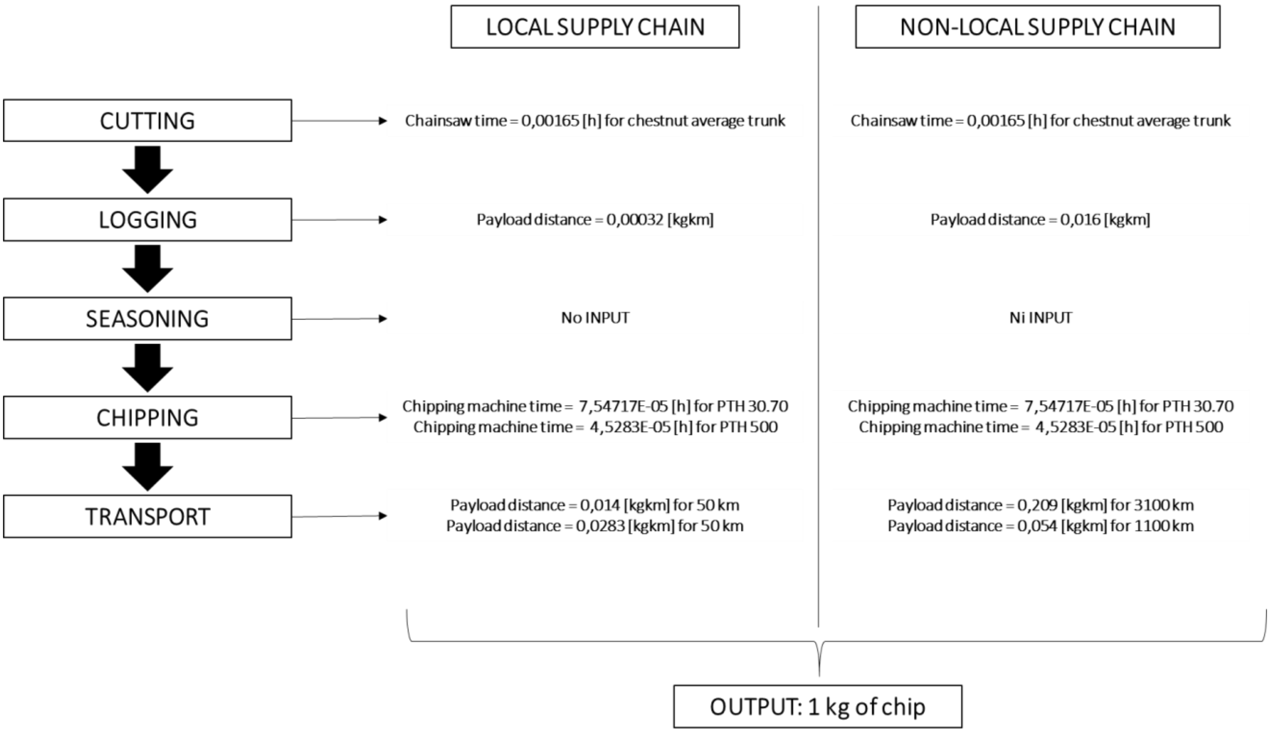


Figure 15 – Conceptual scheme of the Macro phase of supplying and the km-difference between local and non-local chain.

After all the consideration above, it is possible summarized all the values insert in the software as following in Figure 16. The quantities for some phases are different due to the different boundary condition but the final output must be equal for better estimate the environment performances.



	LOCAL SUPPLY CHAIN	NON-LOCAL SUPPLY CHAIN
CUTTING	Chainsaw time = 0,00165 [h] for chestnut average trunk	Chainsaw time = 0,00165 [h] for chestnut average trunk
LOGGING	Payload distance = 0,00032 [kgkm]	Payload distance = 0,016 [kgkm]
SEASONING	No INPUT	Ni INPUT
CHIPPING	Chipping machine time = 7,54717E-05 [h] for PTH 30.70 Chipping machine time = 4,5283E-05 [h] for PTH 500	Chipping machine time = 7,54717E-05 [h] for PTH 30.70 Chipping machine time = 4,5283E-05 [h] for PTH 500
TRANSPORT	Payload distance = 0,014 [kgkm] for 50 km Payload distance = 0,0283 [kgkm] for 50 km	Payload distance = 0,209 [kgkm] for 3100 km Payload distance = 0,054 [kgkm] for 1100 km

OUTPUT: 1 kg of chip

Figure 16 – Summary of input valued inserted for local and local supply cases analyzed.

4.2.2. MACROPHASE OF ELECTRIC AND THERMAL ENERGY PRODUCTION

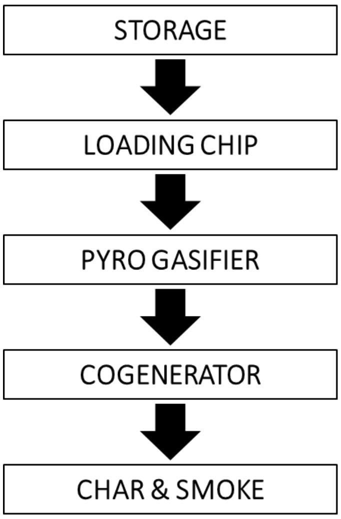
In this phase, it is necessary divided the logical process differently for cogeneration plant and residential combustion system.

4.2.2.1. OFF GRID SCENARIO: COGENERATION SYSTEM

For the electricity production, it was supposed the usage of a small cogeneration system unit. Figure 17 shows the ECO20X plant chosen for the analysis. This unit load the biomass into the beam through a screw operated by the engine inside the reactor.

Figure 17 – Representation of Cogeneration plant selected for the process.
CDM ECO20x.

Thermochemical decomposition of chip take place in the pyro-gasifier and produces syngas. Before using syngas in the internal combustion engine, it needs to be cooled and clean.
The engine generates the effective electricity supply that is released completely to the grid, while the exhaust gases of the engine, before being used in the thermal recovery section, are passed through a drying chamber. In such a way, the biomass inserted into the actual pyro-gasifier by gravity is partially dried before the thermochemical process.
Technical data of CHP: Electric power 20 kWp, Thermal power 40 kWp, Global Efficiency 76%, Startup time 30 minutes, Operability 24h, Wood Chip accepted A1, Consume of chip around 20 kg/h.
The process identified for electricity production is shown in Figure 18.



STORAGE	The wood chips are in the storage of the plant waiting to be loaded from the wepper into the plant. This phase does not have environmental impacts and will not be considered.
LOADING CHIP	The wood chips are loaded by a screw into the gasifier; the screw is activated by an electric motor that involves electrical consumption.
PYRO GASIFIER	The wood chips enter the gasifier and syngas is produced, through the first burner.
COGENERATOR	The internal combustion engine does not absorb energy and works thanks to syngas (only during the initial phase it needs start-up power).
CHAR & SMOKE	On leaving the production process there are waste ash that will have to be disposed of. This phase is considered as output within the previous phase.

Figure 18 – Diagram of the second Macro phase for the cogeneration energy production.

In the loading phase, the wood chips are taken from the warehouse adjacent to the plant, through the use of a screw that loads the appropriate amount of wood into the gasifier from above (up-draft). The screw is operated by an electric motor that will have a certain current absorption, especially in our case it has a power of 1,5 kW. The screw needs 30 minutes to activate and use (only in this period) the electricity from grid. After 30 minutes, it is activated by the same energy produced by the plant. The stating procedure happens after 300 hours of continuous works of the plant, so in the annual amount of consumption the quantity of electricity needed for its operability is negligible.

As we can see in Figure 19 and 20, the actual production process of the plant considers two sub-processes: GASIFICATION + COMBUSTION WITH INTERNAL COMBUSTION ENGINE.

The sub-phase 1 has in input (in addition to biomass and air) the electrical supply necessary to start the gasifier to reach a certain temperature and the power supply to start the burner; in output there will have syngas (thermal energy from engine cooling), ashes and CHAR.

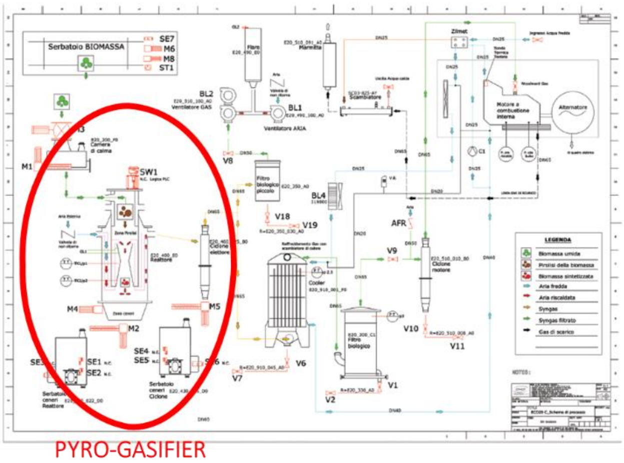


Figure 19 – Sub-process 1

The sub-phase 2 has in input the syngas previously generated and lubricating oil for the engine; in output there will have smokes, emission of various qualities and the energy production.

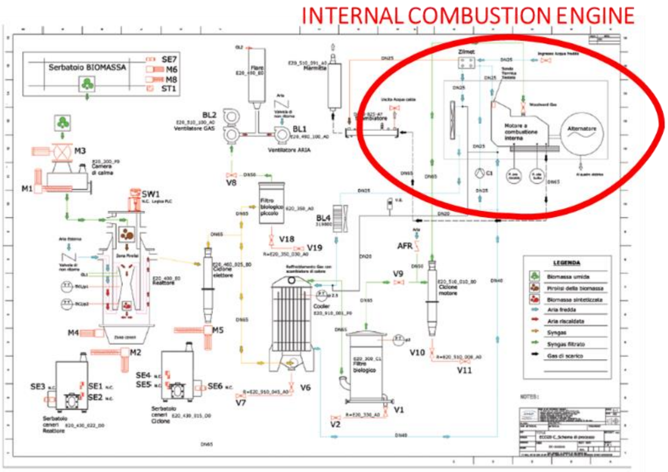


Figure 20 – Sub-process 2

After the consideration above, it is possible read in Figure 21 the values inserted in the software. The sub-categories for the syngas and the equivalent energy permitted an evaluation more reliable. The emission data presented are proportional to what declared into the datasheet of the plant.

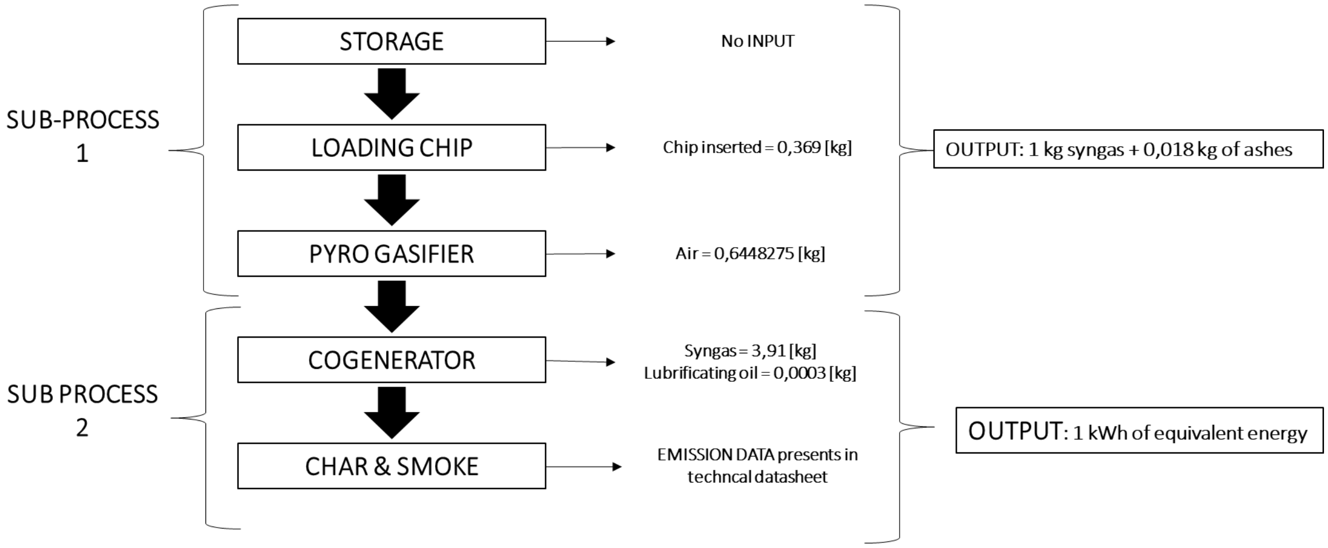


Figure 21 - Summary of input valued inserted for CHP CMD ECO20x analyzed. The type of biomass used (local or non-local) add value of emission impact in the analysis.

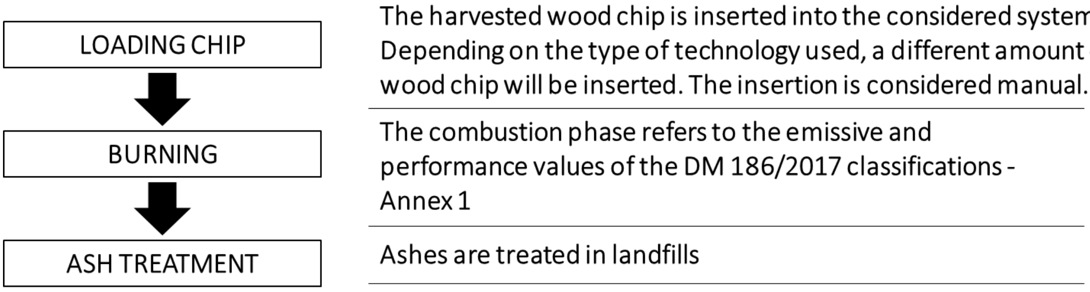
In Figure 20 is presented a value of chip inserted but our concern regarded on which type of process this chip had before incoming to the plant. For this differentiation, the ON-GRID system was simulated in the software 3 times: one with biomass supplied within 50 km, one with biomass supplied within 100 km and the last one supplied at 3100 km.

4.2.2.2. ON GRID SCENARIO: BIOMASS COMBUSTION SYSTEM + NATIONAL ELECTRIC GRID [3]

Small combustion appliances are used to provide thermal energy for heating and cooking. In small combustion installations a wide variety of fuels are used and several combustion technologies are applied. Emissions strongly depend on the fuel, combustion technologies as well as on operational practices and maintenance.

The process for these technologies is simplified rather than the cogeneration system, as we can see in Figure 22.

The performances of output depend on the system used, for our purpose it will be considered the operational condition exposed in the Piedmont D.G.R. 07538 of 2018. An important difference between on-grid and off-grid system is the connection to National grid. While the cogeneration plant generates HVAC energy independently from national condition, most of small combustion systems need a continuous electricity and this element for the calculation part is indicate in the software (from Agribalyse database) as “Energy-Electricity country mix-Low voltage-electricity Italy B250”.



The harvested wood chip is inserted into the considered system. Depending on the type of technology used, a different amount of wood chip will be inserted. The insertion is considered manual.

The combustion phase refers to the emissive and performance values of the DM 186/2017 classifications - Annex 1

Ashes are treated in landfills

Figure 22 - Diagram of the second Macro phase for small combustion for residential energy production.

In our analysis, it was taken into account only the technologies fed by biomass.

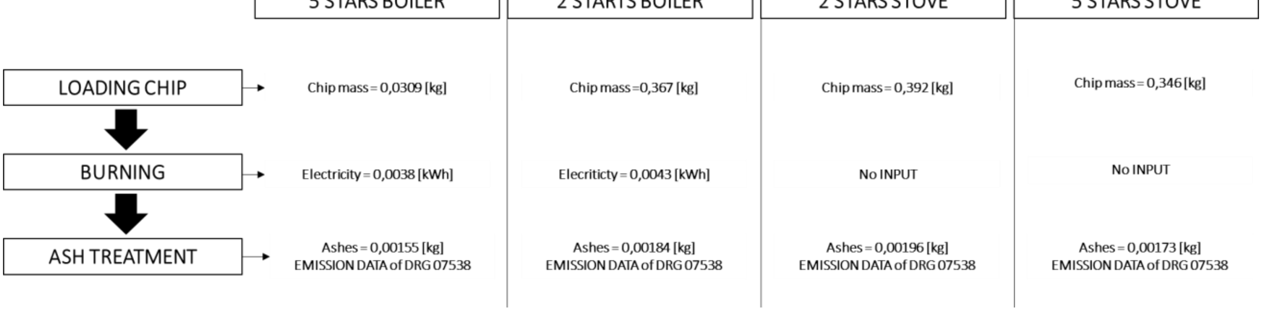
For the thermal production only, it was considered the most common combustion system used in Valle Po residential sector. The system analyzed were 4 types:

- Five stars boiler (η>95%): in general, boilers are devices which heat up water indirectly. They are mainly intended for generation of heat for the central heating system or hot water, or a combination of both. Boilers that meet these descriptions are covered by the EN standards EN12809 for residential independent boilers with capacity up to 50 kWth and EN303-5 for manually and mechanically stoked boilers with capacity up to 500 kWth. However, most small boilers use wood pellet or wood chip. The last one have a fully automatic system for feeding of woodchip fuels and for supply of combustion air, which is distributed into primary (beneath the grate) and secondary (into the gas oxidation zone) air supplies. The boilers are equipped with a small chip storage, which is fuelled manually or by an automatic system from a larger chamber storage. The operation of wood chip boilers is similar to the function of cogeneration system; chips are introduced by screw into the burner. The burners can have different design such as underfeed burners, horizontally fed burners and overfed burners. These boilers are characterized by a high efficiency (usually above 80 %) and their emissions are low.

- <u>Two stars boiler (η>80%)</u> as previously described, it was taken into account wood chip boiler system but in this case it were considered an old boiler with a lower efficiency.
- <u>Two stars stove (η>75%):</u> these appliances typically have poorly organized combustion process resulting in low efficiency (40 % to 50 %) and significant emissions of pollutants mainly originating from incomplete combustion (TSP, CO, NMVOC and PAH). Their autonomy (i.e. the ability to operate without user intervention) is low, lasting from three to eight hours. Those, which are equipped with hot-plate zones, are used also for cooking — kitchen stoves. Some of them could also be used for hot water preparation. Conventional stoves are characterized by high emissions. The further development of their design has resulted in new more advanced technologies which have better efficiencies and lower pollutant emission releases.
- <u>Five stars stove (η>85%):</u> these stoves are characterized by multiple air inlets and pre-heating of secondary combustion air by heat exchange with hot flue gases. This design results in increased efficiency (near 70 % at full load) and reduced CO, NMVOC and TSP emissions in comparison with the conventional stoves.

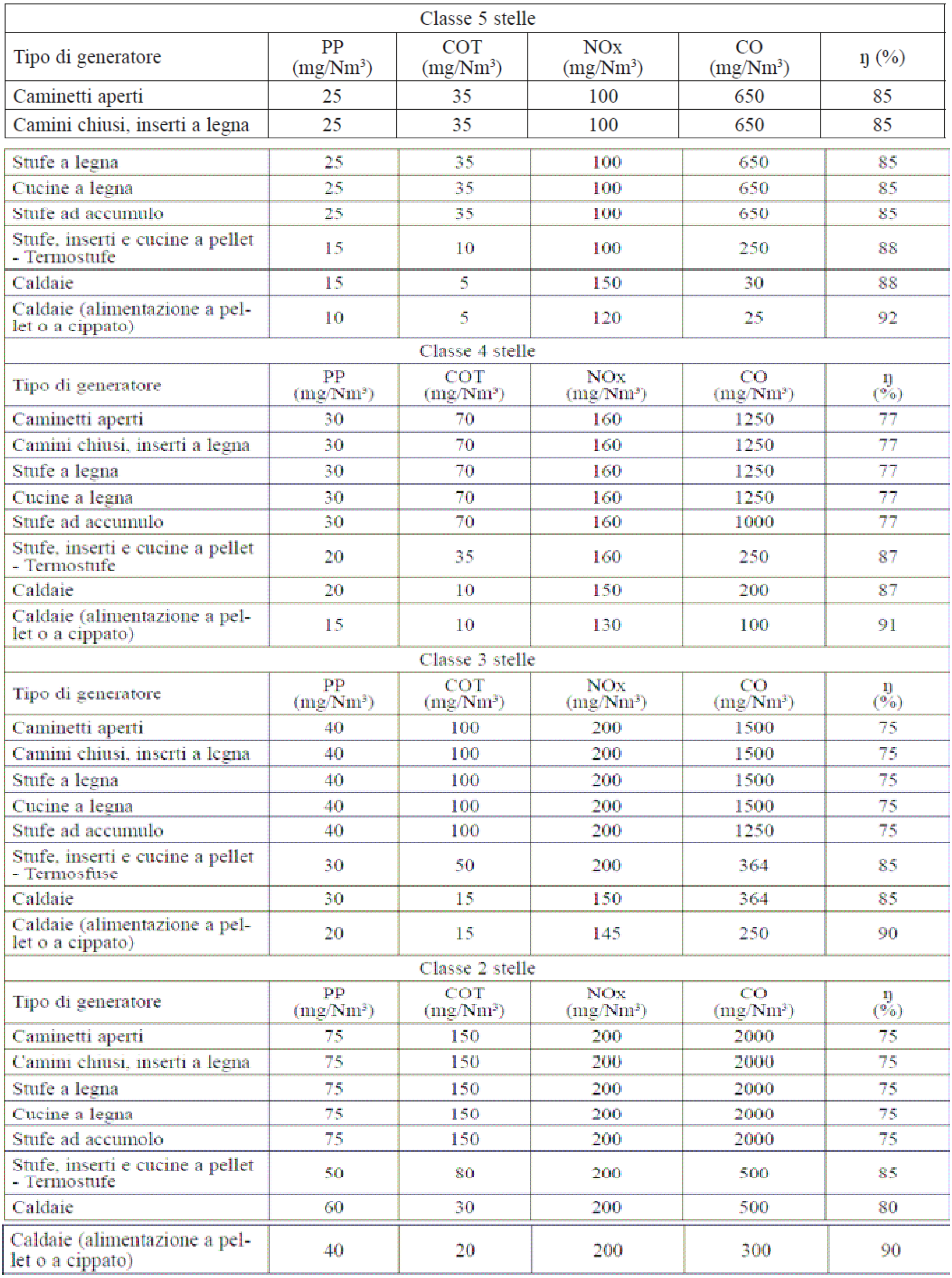
In the LCA evaluation for these types of technologies, the efficiency and emissive values used as a reference were equal to the ones established by the competent authority and expressed in the RPG (Resolution of the Regional Council) of 14 September 2018, n. 29-7538. It should be remembered that the Piedmont Region, under which the legislation of the Monviso Area falls, has been promoting the use of efficient technologies for domestic heating since 2014, especially in relation to the use of biomass. The citizen, in order to verify the belonging of his biomass generator to a specific quality class, has to refer to the documentation made available by the generator manufacturer and compare the overall performance values and CO emissions, shown in the installation booklet of the appliance, with those shown in Figure 24.

After all considerations above, in Figure 23 it is represented the numerical values inserted in the software for each system. Relevant to highlight is the consideration of the electricity supply only for boilers. In Figure 23, the cases presented are 4 but in the final simulation we had evaluated 8 different combinations. For each system it was considered both chips supplied within 50 km of final user and within 3100 km.



	5 STARS BOILER	2 STARTS BOILER	2 STARS STOVE	5 STARS STOVE
LOADING CHIP	Chip mass = 0,0309 [kg]	Chip mass =0,367 [kg]	Chip mass = 0,392 [kg]	Chip mass = 0,346 [kg]
BURNING	Electricity = 0,0038 [kWh]	Elecriticty = 0,0043 [kWh]	No INPUT	No INPUT
ASH TREATMENT	Ashes = 0,00155 [kg] EMISSION DATA of DRG 07538	Ashes = 0,00184 [kg] EMISSION DATA of DRG 07538	Ashes = 0,00196 [kg] EMISSION DATA of DRG 07538	Ashes = 0,00173 [kg] EMISSION DATA of DRG 07538

Figure 23 - Summary of input valued inserted for various residential combustion systems analyzed. The type of biomass used (local or non-local) add value of emission impact in the analysis.



Classe 5 stelle

Tipo di generatore	PP (mg/Nm³)	COT (mg/Nm³)	NOx (mg/Nm³)	CO (mg/Nm³)	η (%)
Caminetti aperti	25	35	100	650	85
Camini chiusi, inserti a legna	25	35	100	650	85
Stufe a legna	25	35	100	650	85
Cucine a legna	25	35	100	650	85
Stufe ad accumulo	25	35	100	650	85
Stufe, inserti e cucine a pellet - Termostufe	15	10	100	250	88
Caldaie	15	5	150	30	88
Caldaie (alimentazione a pellet o a cippato)	10	5	120	25	92

Classe 4 stelle

Tipo di generatore	PP (mg/Nm³)	COT (mg/Nm³)	NOx (mg/Nm³)	CO (mg/Nm³)	η (%)
Caminetti aperti	30	70	160	1250	77
Camini chiusi, inserti a legna	30	70	160	1250	77
Stufe a legna	30	70	160	1250	77
Cucine a legna	30	70	160	1250	77
Stufe ad accumulo	30	70	160	1000	77
Stufe, inserti e cucine a pellet - Termostufe	20	35	160	250	87
Caldaie	20	10	150	200	87
Caldaie (alimentazione a pellet o a cippato)	15	10	130	100	91

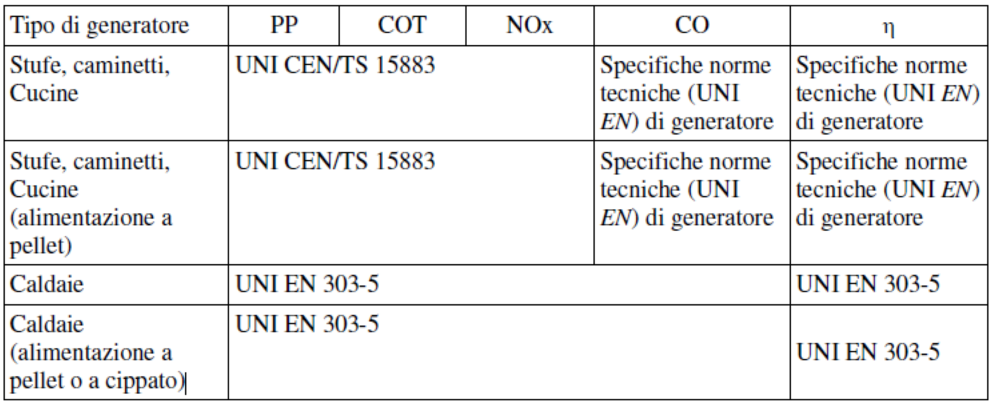
Classe 3 stelle

Tipo di generatore	PP (mg/Nm³)	COT (mg/Nm³)	NOx (mg/Nm³)	CO (mg/Nm³)	η (%)
Caminetti aperti	40	100	200	1500	75
Camini chiusi, inserti a legna	40	100	200	1500	75
Stufe a legna	40	100	200	1500	75
Cucine a legna	40	100	200	1500	75
Stufe ad accumulo	40	100	200	1250	75
Stufe, inserti e cucine a pellet - Termosfuse	30	50	200	364	85
Caldaie	30	15	150	364	85
Caldaie (alimentazione a pellet o a cippato)	20	15	145	250	90

Classe 2 stelle

Tipo di generatore	PP (mg/Nm³)	COT (mg/Nm³)	NOx (mg/Nm³)	CO (mg/Nm³)	η (%)
Caminetti aperti	75	150	200	2000	75
Camini chiusi, inserti a legna	75	150	200	2000	75
Stufe a legna	75	150	200	2000	75
Cucine a legna	75	150	200	2000	75
Stufe ad accumolo	75	150	200	2000	75
Stufe, inserti e cucine a pellet - Termostufe	50	80	200	500	85
Caldaie	60	30	200	500	80
Caldaie (alimentazione a pellet o a cippato)	40	20	200	300	90

Figure 24 - Classification of heat generators present in D.G.R. 07538.



Tipo di generatore	PP	COT	NOx	CO	η
Stufe, caminetti, Cucine	UNI CEN/TS 15883			Specifiche norme tecniche (UNI *EN*) di generatore	Specifiche norme tecniche (UNI *EN*) di generatore
Stufe, caminetti, Cucine (alimentazione a pellet)	UNI CEN/TS 15883			Specifiche norme tecniche (UNI *EN*) di generatore	Specifiche norme tecniche (UNI *EN*) di generatore
Caldaie	UNI EN 303-5				UNI EN 303-5
Caldaie (alimentazione a pellet o a cippato)	UNI EN 303-5				UNI EN 303-5

Figure 25 - Reference test methods for the estimation of quantities presented in DGR 07538.

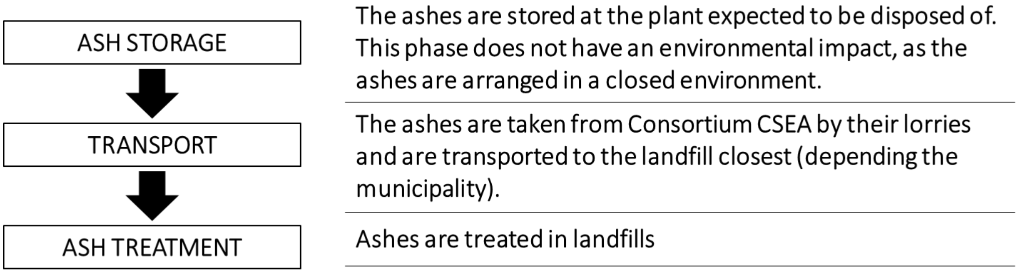
The emission data concern quantities for unspecified firewood, but, due to the mentioned uncertainties and the non-negligible fact that the emission values are valid for all burning habits, they were deemed satisfactory for burning of chestnut wood in this analysis.
The end of life of the appliances is not included in the evaluation.

4.2.3. MACROPHASE OF ASH DISPOSAL

It was preferred to manage the disposal of ash with a further phase, thus having more clearly the impact of the production process separate from the impact of the disposal of ash produced.
This procedure is still divided into OFF-GRID or ON-GRIS systems.

OFF-GRID

In Figure 26, there is a representation of the disposal process for the ash-waste produced by the plant. It is to be remind that the plant (at nominal power) generates around 1 kg of ashes per hours. This amount needs a periodic transportation scheduled during year to bring the waste from the plant to the nearest ecological island. The ashes, for Italian legislation, are not considered as "special waste" (which needs specific treatment) so this condition simplify its transportation.



The ashes are stored at the plant expected to be disposed of. This phase does not have an environmental impact, as the ashes are arranged in a closed environment.

The ashes are taken from Consortium CSEA by their lorries and are transported to the landfill closest (depending the municipality).

Ashes are treated in landfills

Figure 26 – Diagram of the disposal Macro phase for off-grid system.

The disposal takes place in specific landfill, in the Monviso area each municipalities has a disposal area within the territory. The company that deals with waste disposal is the consortium CSEA, which also guarantee the transportation of waste, collects ashes and takes them to the landfill. The vehicle used by the company is a discardable truck with 2 boxes of the Iveco Magirus 260 S model, a capacity equal to 35 m^3 per body (total 70 m^3). Consumption is 1 liter of diesel every 2,5 km. The medium distance covered by disposal transportation is equal to 8 km, neglecting the empty travels required. In the Figure 27 it is possible to visualize the input amount indicated for this process.

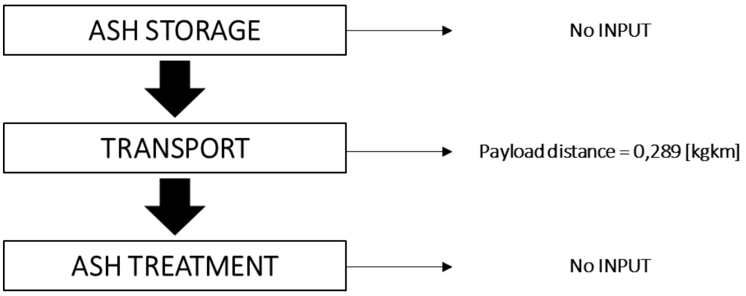


Figure 27 – summary of the values indicated for the waste process.

Treated ashes are considered inserts of peat ash.
In openLCA, for every energy production process, was used the waste output: “Waste in inert landfill” (indicating the quantity of inert materials disposed) and added the payload distance for the required transportation.

ON-GRID

The disposal of ashes in small systems is simpler to treat and handle. As visible in Figure 28, the process does not consider the transportation phase because subjects holding the system treat ashes as unsorted waste.

Figure 28 - Diagram of the disposal Macro phase for on-grid system.

Treated ashes are considered inert of peat ash.
As waste treatment was used: “Waste (inert) to landfill”, into category “Waste Treatment” – Landfill – Inert Material

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5. INVENTORY RESULTS

Completed the inventory of consumption attributable to the OFF-GRID and ON_GRID system of Valle Po, it is possible to evaluate of the emissions with which each individual phase contributes and relate that amount to the various categories of damage considered.

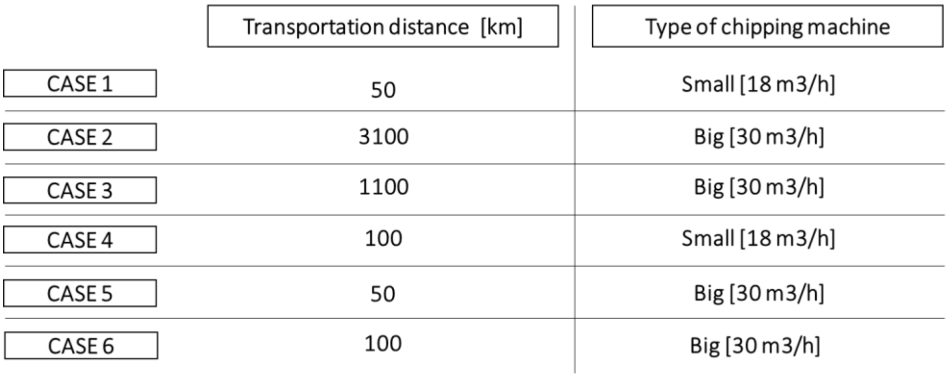
As listed in Chapter 3, environmental impacts of a process are several and each category refer to a specific measurement unit. Categories represent the potential impact on the natural environment, human health or the depletion of natural resources, caused by the interventions between the technology sphere and the ecological sphere. The categories selected for our purpose are:

- Climate change [kg CO2eq];
- Land Use [kg C deficit];
- Particulate matter [kg PM 2.5 eq];
- Ozone depletion [kg CFC-11 eq];
- Photochemical ozone formation [kg NMVOC eq].

We are going to verify the CO_2 emission in Climate Change impact category throughout a comparison between ILCD 2011 Midpoint method and IPCC method. For other impact category only the ILCD method is taken as a refence. At this stage, it is considered that all the data used in the study have an uncertainty. Uncertainties are inevitable and should be considered when comparing different product systems to determine whether the differences obtained in environmental impacts are real or caused by such errors. In particular, a total uncertainty margin of ±5% was applied for experimentally measured data (datasheet of technologies) and a margin of ±10% for estimated data (the estimation deriving from data collected with specialists in the life territory).

5.1.1. RESULTS FOR THE SUPPLY CHAIN OF BIOMASS

For the supply chain it was considered six scenarios, different for km covered by transportation and chipping machine. A summary scheme is reported in Figure 29.

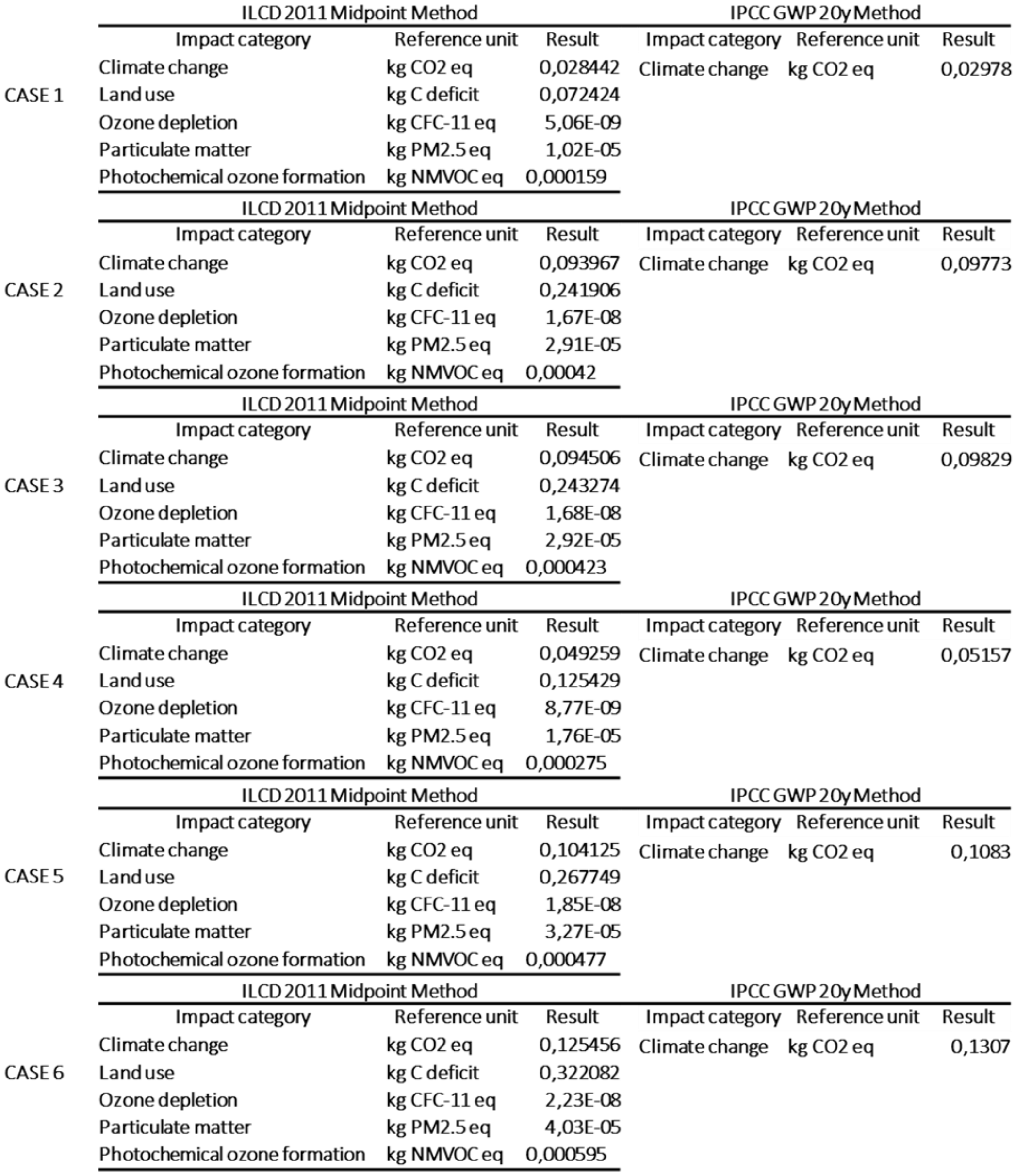


	Transportation distance [km]	Type of chipping machine
CASE 1	50	Small [18 m3/h]
CASE 2	3100	Big [30 m3/h]
CASE 3	1100	Big [30 m3/h]
CASE 4	100	Small [18 m3/h]
CASE 5	50	Big [30 m3/h]
CASE 6	100	Big [30 m3/h]

Figure 29 – Nomenclature of cases for the supply of 1 kg of wood chip. The distance indicates the km traveled from the moment of cutting with chainsaw to the wood sorting plant in the Monviso area.

The six scenarios maintain the same assembly line as seen in Chapter 4.2.1. Cases 1, 4, 5 and 6 aim to assess a local forest supply (**local management**) by changing the type of chippers used. Cases 2 and 3, on the other hand, assess a **non-local forest** supply using only industrial chippers. The difference between a local management and not is also evident in the length of the disbursement route. In the Monviso area the towing of the trunks remains in a range of 1- 2 km while in the case of imported biomass the disbursement is considered to be more than 30 km.

Thanks to these cases it was possible to evaluate globally what was the type of supply chain with the least environmental impact to recover a kg of chestnut wood chip. From the table in Figure 30 below, you can view the values extrapolated from the software used according to both IPCC GWP 2013 20a and ILCD 2011+ Midpoint methodologies.



	ILCD 2011 Midpoint Method			IPCC GWP 20y Method		
	Impact category	Reference unit	Result	Impact category	Reference unit	Result
	Climate change	kg CO2 eq	0,028442	Climate change	kg CO2 eq	0,02978
CASE 1	Land use	kg C deficit	0,072424			
	Ozone depletion	kg CFC-11 eq	5,06E-09			
	Particulate matter	kg PM2.5 eq	1,02E-05			
	Photochemical ozone formation	kg NMVOC eq	0,000159			
	ILCD 2011 Midpoint Method			**IPCC GWP 20y Method**		
	Impact category	Reference unit	Result	Impact category	Reference unit	Result
	Climate change	kg CO2 eq	0,093967	Climate change	kg CO2 eq	0,09773
CASE 2	Land use	kg C deficit	0,241906			
	Ozone depletion	kg CFC-11 eq	1,67E-08			
	Particulate matter	kg PM2.5 eq	2,91E-05			
	Photochemical ozone formation	kg NMVOC eq	0,00042			
	ILCD 2011 Midpoint Method			**IPCC GWP 20y Method**		
	Impact category	Reference unit	Result	Impact category	Reference unit	Result
	Climate change	kg CO2 eq	0,094506	Climate change	kg CO2 eq	0,09829
CASE 3	Land use	kg C deficit	0,243274			
	Ozone depletion	kg CFC-11 eq	1,68E-08			
	Particulate matter	kg PM2.5 eq	2,92E-05			
	Photochemical ozone formation	kg NMVOC eq	0,000423			
	ILCD 2011 Midpoint Method			**IPCC GWP 20y Method**		
	Impact category	Reference unit	Result	Impact category	Reference unit	Result
	Climate change	kg CO2 eq	0,049259	Climate change	kg CO2 eq	0,05157
CASE 4	Land use	kg C deficit	0,125429			
	Ozone depletion	kg CFC-11 eq	8,77E-09			
	Particulate matter	kg PM2.5 eq	1,76E-05			
	Photochemical ozone formation	kg NMVOC eq	0,000275			
	ILCD 2011 Midpoint Method			**IPCC GWP 20y Method**		
	Impact category	Reference unit	Result	Impact category	Reference unit	Result
	Climate change	kg CO2 eq	0,104125	Climate change	kg CO2 eq	0,1083
CASE 5	Land use	kg C deficit	0,267749			
	Ozone depletion	kg CFC-11 eq	1,85E-08			
	Particulate matter	kg PM2.5 eq	3,27E-05			
	Photochemical ozone formation	kg NMVOC eq	0,000477			
	ILCD 2011 Midpoint Method			**IPCC GWP 20y Method**		
	Impact category	Reference unit	Result	Impact category	Reference unit	Result
	Climate change	kg CO2 eq	0,125456	Climate change	kg CO2 eq	0,1307
CASE 6	Land use	kg C deficit	0,322082			
	Ozone depletion	kg CFC-11 eq	2,23E-08			
	Particulate matter	kg PM2.5 eq	4,03E-05			
	Photochemical ozone formation	kg NMVOC eq	0,000595			

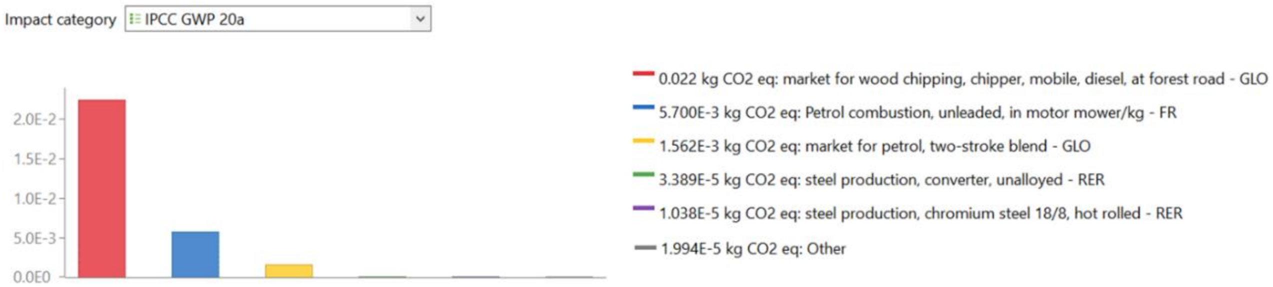
Figure 30 – Table with environmental impact results, distinguished for each case according to the methodology used.

It has been noted that for the categories analyzed, the phase that contributes most to the relevant score is chipping. The Graph below expresses as reference units the contribution that various phases lead to the definition of the overall score, relating to the different impact categories. In practice, it visualizes graphically and therefore immediately what has just been said by looking at the previous table. In fact, the most impacting phase is the Chipping (red) and the petrol combustion (blue). The chipping phase is the most impacting in the category of Climate Change. Wood chipping consumes a large amount of energy from fossil fuel (diesel chipping) that emits substances into the environment that are harmful to human health certainly and to the planet's ecosystem and does not directly concern the use of natural resources and fossil fuels.

The graphics presented below compare only the impact category of Climate Change [kgCO$_2$eq] both for IPCC and ILCD method.

CASE 1: transport < 50 km; chipping machine capacity =18 m3/h

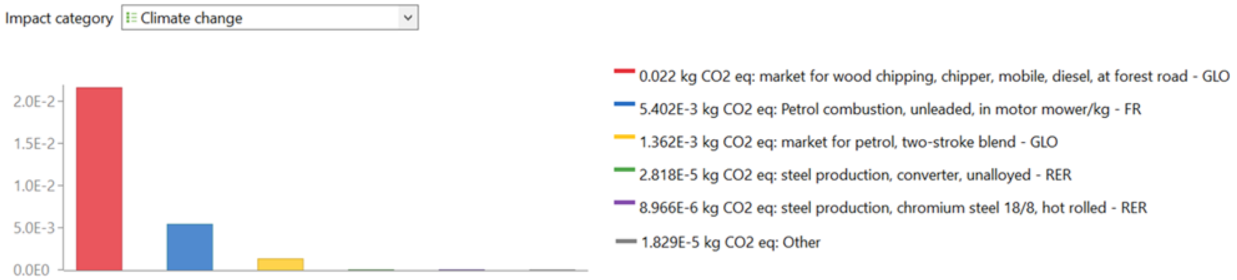
IPCC GWP 20 y



Impact category: IPCC GWP 20a

Figure 31 – Contribution of each phase in local chip supply chain [50 km of transportation] for IPCC

ILCD 2011+ Midpoint

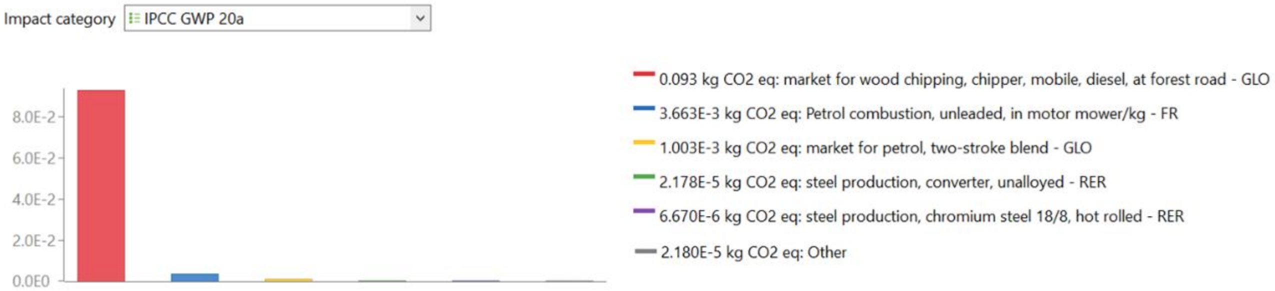


Impact category: Climate change

Figure 32 - Contribution of each phase in local chip supply chain [50 km of transportation] for ILCD

CASE 2: transport > 3100 km; chipping machine capacity =30 m3/h

IPCC GWP 20 y



Impact category: IPCC GWP 20a

Figure 33 – Contribution of each phase in non-local chip supply chain [3100 km of transportation] for IPCC

ILCD 2011+ Midpoint

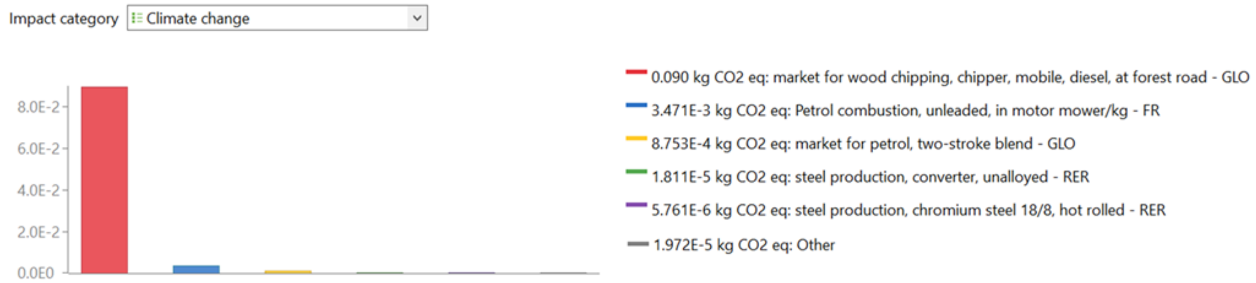

Impact category: Climate change

Figure 34 - Contribution of each phase in non-local chip supply chain [3100 km of transportation] for ILCD

CASE 3: transport > 1100 km; chipping machine capacity =30 m3/h

IPCC GWP 20a

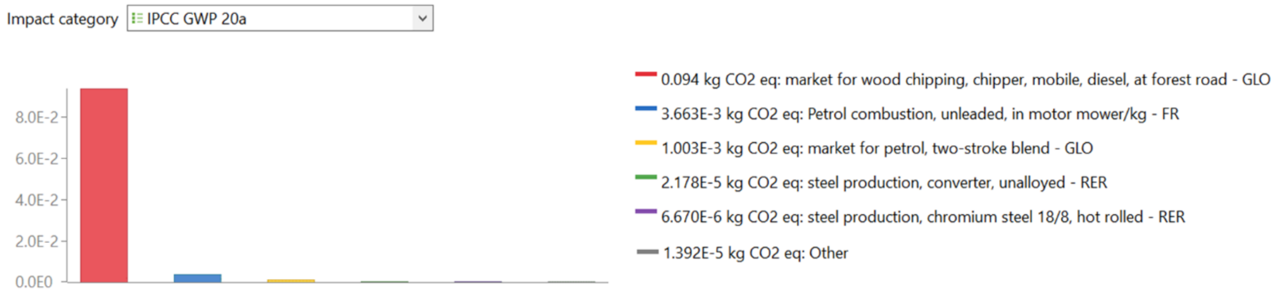

Impact category: IPCC GWP 20a

Figure 35 - Contribution of each phase in non-local chip supply chain [1100 km of transportation] for IPCC

ILCD 2011+ Midpoint

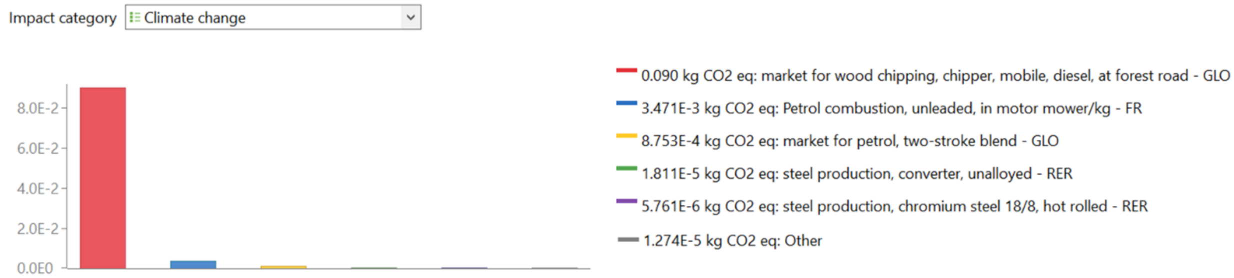

Impact category: Climate change

Figure 36 - Contribution of each phase in non-local chip supply chain [1100 km of transportation] for ILCD

CASE 4: transport < 100 km; chipping machine capacity =18 m3/h

IPCC GWP 20a

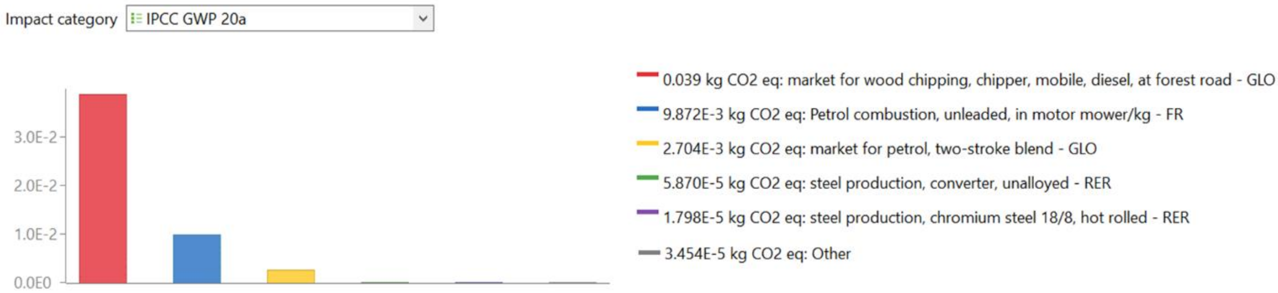
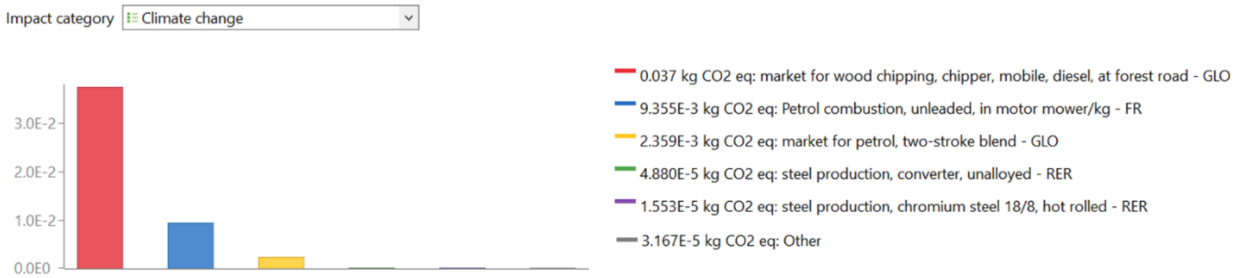

Impact category: IPCC GWP 20a

Figure 37 - Contribution of each phase in local chip supply chain [100 km of transportation] for IPCC

ILCD 2011+ Midpoint

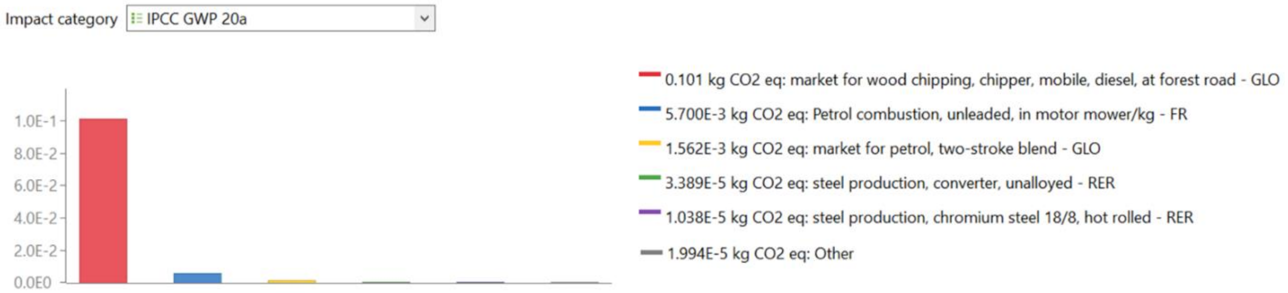

Impact category: Climate change

0.037 kg CO2 eq: market for wood chipping, chipper, mobile, diesel, at forest road - GLO
9.355E-3 kg CO2 eq: Petrol combustion, unleaded, in motor mower/kg - FR
2.359E-3 kg CO2 eq: market for petrol, two-stroke blend - GLO
4.880E-5 kg CO2 eq: steel production, converter, unalloyed - RER
1.553E-5 kg CO2 eq: steel production, chromium steel 18/8, hot rolled - RER
3.167E-5 kg CO2 eq: Other

Figure 38 - Contribution of each phase in local chip supply chain [50 km of transportation] for ILCD

CASE 5: transport < 50 km; chipping machine capacity =30 m3/h

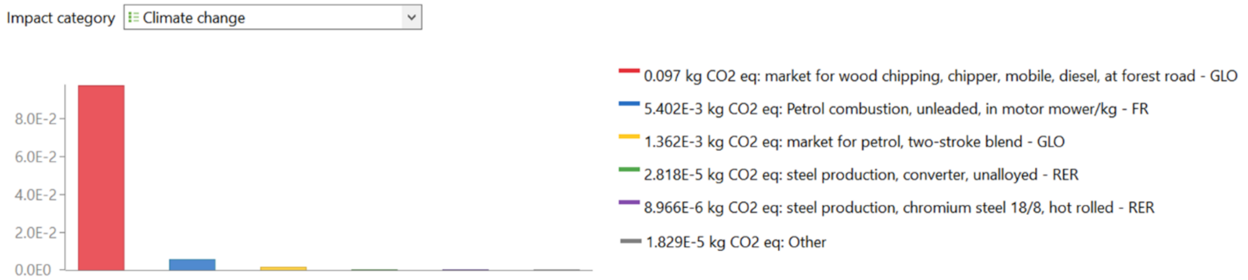
IPCC GWP 20a


Impact category: IPCC GWP 20a

0.101 kg CO2 eq: market for wood chipping, chipper, mobile, diesel, at forest road - GLO
5.700E-3 kg CO2 eq: Petrol combustion, unleaded, in motor mower/kg - FR
1.562E-3 kg CO2 eq: market for petrol, two-stroke blend - GLO
3.389E-5 kg CO2 eq: steel production, converter, unalloyed - RER
1.038E-5 kg CO2 eq: steel production, chromium steel 18/8, hot rolled - RER
1.994E-5 kg CO2 eq: Other

Figure 39 – Contribution of each phase in local chip supply chain [50 km of transportation but with industrial chipping machine] for IPCC

ILCD 2011+ Midpoint

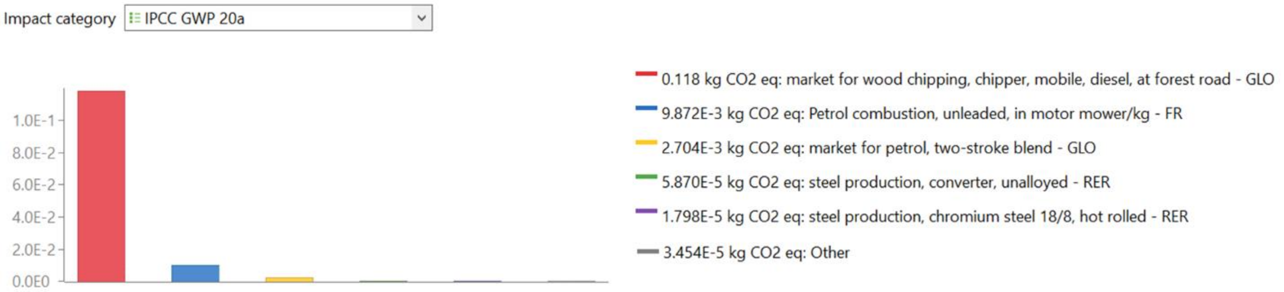

Impact category: Climate change

0.097 kg CO2 eq: market for wood chipping, chipper, mobile, diesel, at forest road - GLO
5.402E-3 kg CO2 eq: Petrol combustion, unleaded, in motor mower/kg - FR
1.362E-3 kg CO2 eq: market for petrol, two-stroke blend - GLO
2.818E-5 kg CO2 eq: steel production, converter, unalloyed - RER
8.966E-6 kg CO2 eq: steel production, chromium steel 18/8, hot rolled - RER
1.829E-5 kg CO2 eq: Other

Figure 40 - Contribution of each phase in local chip supply chain [50 km of transportation but with industrial chipping] for ILCD

CASE 6: transport < 100 km; chipping machine capacity =30 m3/h

IPCC GWP 20a


Impact category: IPCC GWP 20a

0.118 kg CO2 eq: market for wood chipping, chipper, mobile, diesel, at forest road - GLO
9.872E-3 kg CO2 eq: Petrol combustion, unleaded, in motor mower/kg - FR
2.704E-3 kg CO2 eq: market for petrol, two-stroke blend - GLO
5.870E-5 kg CO2 eq: steel production, converter, unalloyed - RER
1.798E-5 kg CO2 eq: steel production, chromium steel 18/8, hot rolled - RER
3.454E-5 kg CO2 eq: Other

Figure 41 – Contribution of each phase in local chip supply chain [100 km of transportation] for IPCC

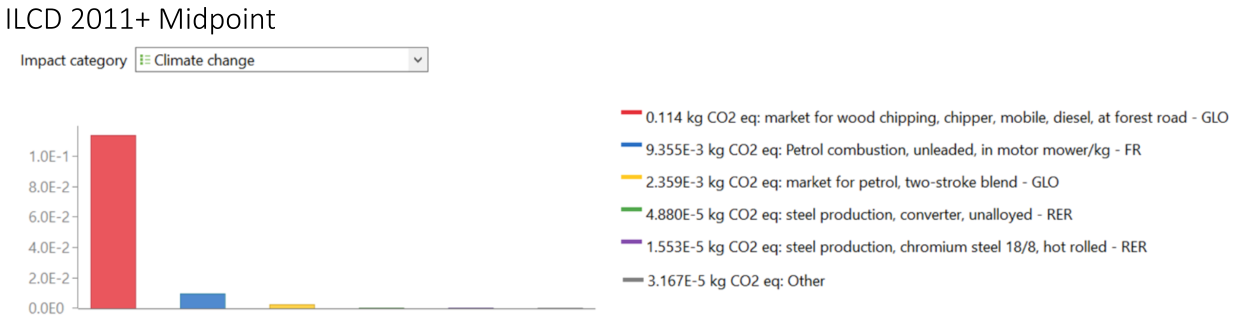


Figure 42 - Contribution of each phase in local chip supply chain [100 km of transportation] for ILCD

In Figure 43, it is reported the histogram related to the impact categories listed, to get an even clearer and more immediate idea of the impact of the different cases at the most macro level.

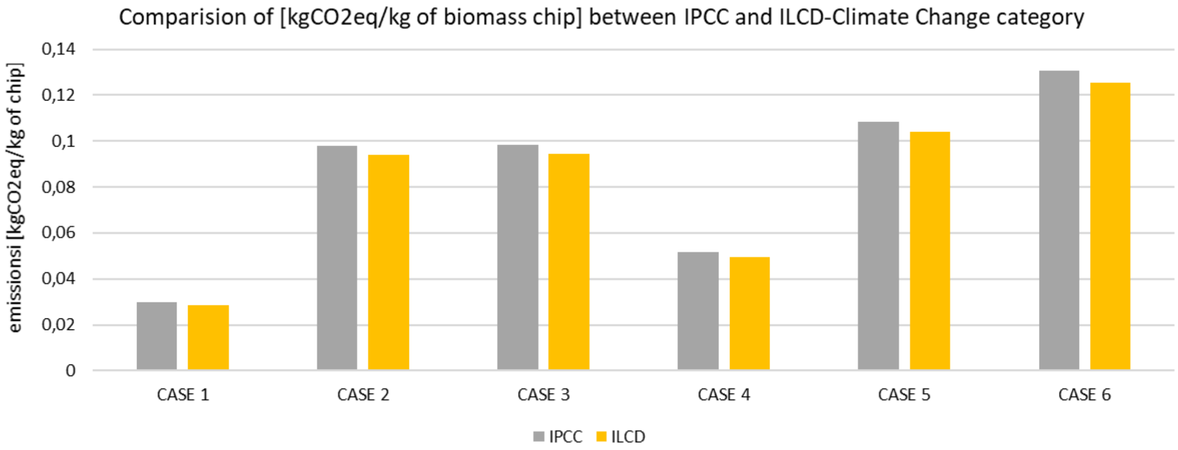


Figure 43 – Comparison of emission in Climate Change impact category in each case.

Analyzing other impact categories present in ILCD method, we reported the histogram in Figure 44, 45, 46 and 47.

Land use is a main driver of global biodiversity loss. During transformation, the land is modified to make it suitable for an intended use, such as deforesting to make space for agriculture. During land occupation, land is used in the intended productive way (e.g. agriculture) and the land cannot develop towards a “natural reference state” (i.e. the regrowth of forest is avoided). The land use impacts result from both land transformation (because the ecosystems characteristics are changed) and land occupation (because ecosystem quality is kept at a different level than its natural state). [4][3]

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[3] *See References for hint immissions*

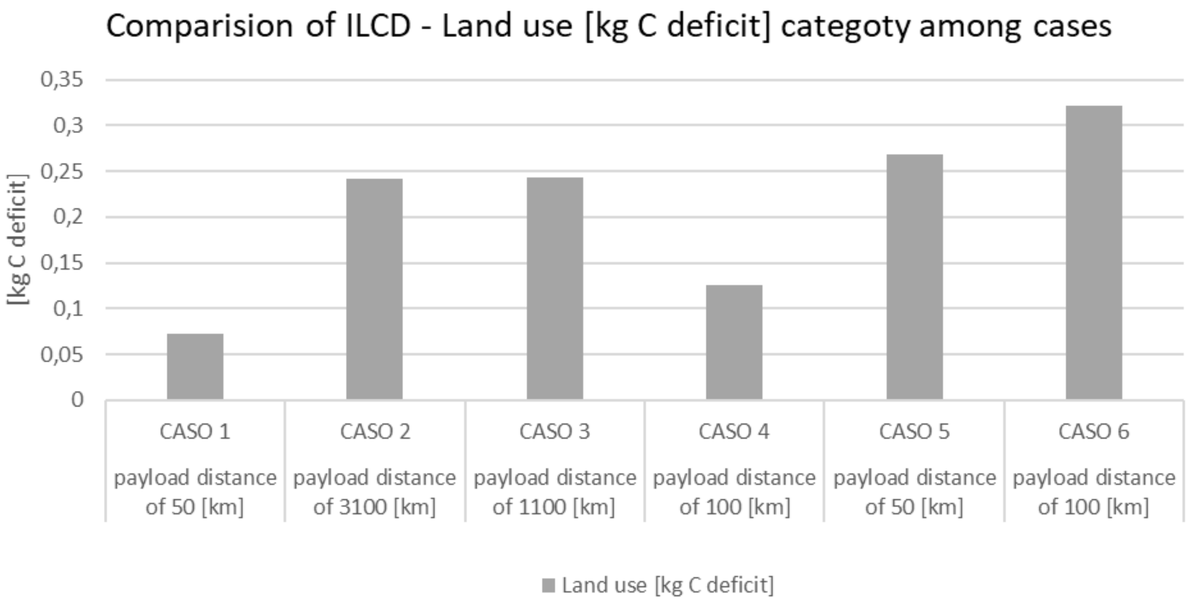

Figure 44 – Comparison of emission in Land Use impact category in each case.

The ozone layer in the stratosphere absorbs a large part of the harmful UV-radiation coming from the sun. In the natural situation ozone is continuously being formed and destroyed. However, a number of man-made chemicals that contain fluorine, bromine and chlorine groups, called Ozone Depleting Substances (ODS), can greatly increase the rate of destruction, leading to a reduction in the thickness of the ozone layer. With the thickness of the layer reduced, more of the UV-B radiation will reach the earth's surface. Increased exposure to UV-B radiation can lead to adverse human health effects such as skin cancer and cataract and effects on ecosystems. The latter are not considered here. The relative amount of degradation to the ozone layer it measures in kg of trichlorofluoromethane (CFC-11). [4]

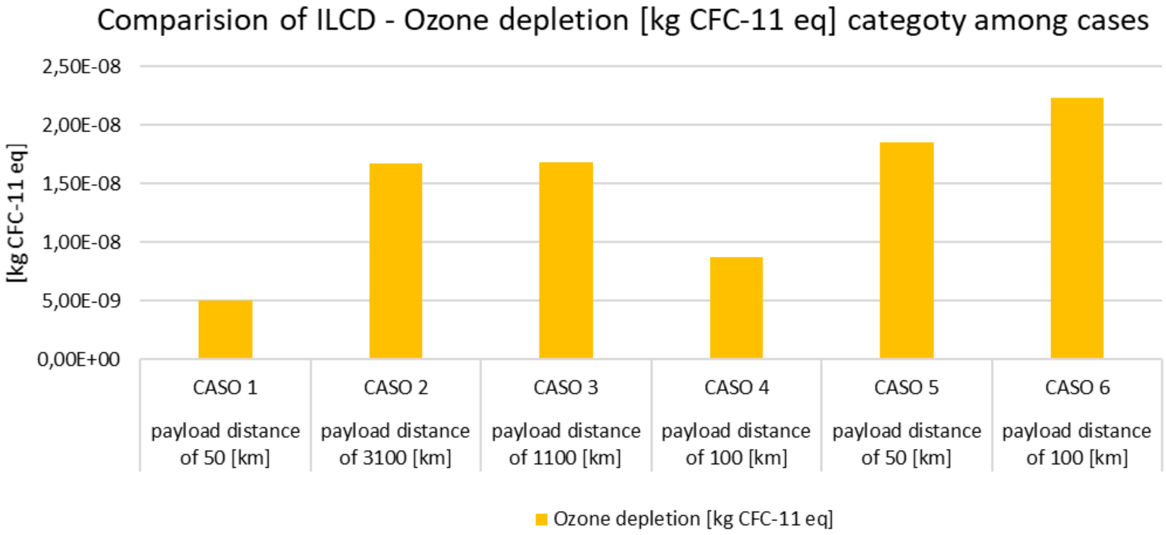

Figure 45 - Comparison of emission in Ozone Depletion impact category in each case.

Air pollution causing primary and secondary aerosols in the atmosphere can have a substantial negative impact on human health, ranging from respiratory symptoms to hospital admissions and death. Inhalation of different particulate sizes can cause various health problems. The effects of chronic PM exposure on mortality (life expectancy) are most likely attributable to PM2.5 rather than to coarser particles. [4]

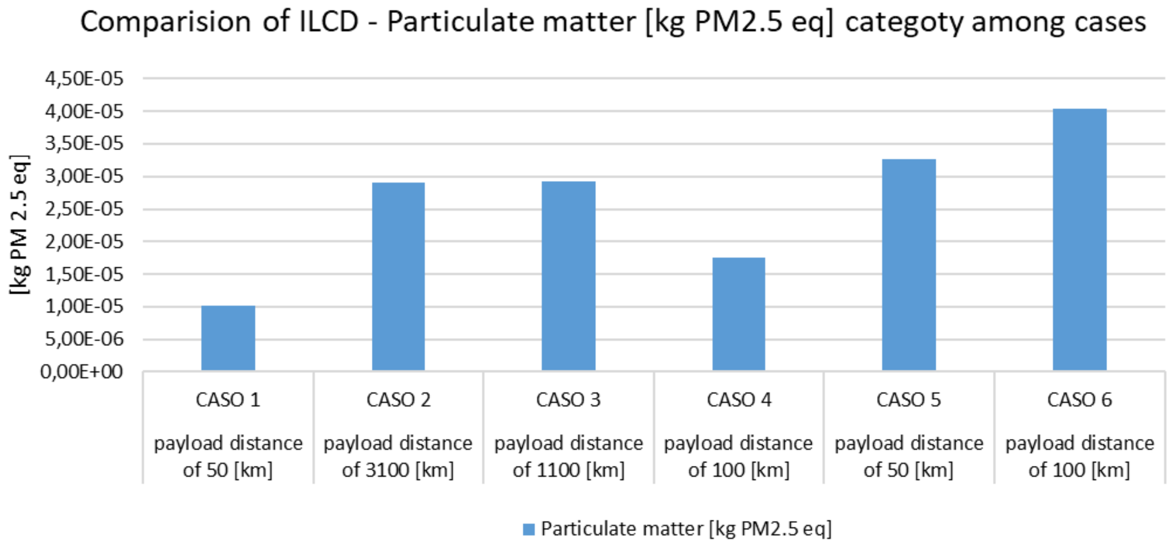

Figure 46 - Comparison of emission in Particulate Matter impact category in each case.

Air pollution causing tropospheric ozone in the atmosphere can have a negative impact on human health, e.g. respiratory problems, and terrestrial ecosystems, e.g. plant biomass decrease.

The impact model is addressing emissions of nitrogen oxides (NOx), and non-methane volatile organic compounds (NMVOC) and consequent effects on the Areas of protection 'Human Health' and 'Terrestrial ecosystems. This overview will focus on the human health effects only. [4]

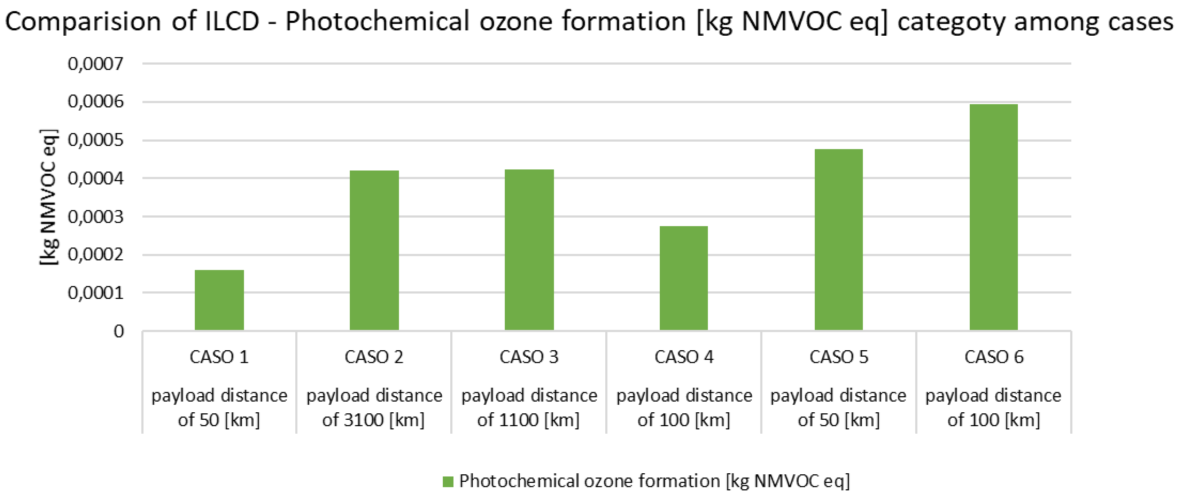

Figure 47 – Comparison of emission in Photochemical Ozone Formation impact category in each case.

As it could be seen, all the impact values are dependent on chipping procedure. The last two cases, Case 5 and 6, are selected just to evaluate the impact of the industrial chipping machine despite the lower distance of supply chain. The value in all categories for these two cases are similar and comparable to the nonlocal supply.

This phenomenon is crucial to understand how develop the local chain for LIFE project. Including a chipping machine oversized rather than local necessity could influence negatively to local environment. In previous histograms, we compared always values among cases selected but now we want to detect the percentage of contribution that every single process has in a category. Because of noticing the relevant role od the chip machinery, it is important to understand the weight that its utilization has in total impact.

The estimation of every contribution is reported only for cases of chip supply used for OFF-GRID and ON-GRID scenarios. The cases examined are 1 (transport <50 km) in Figure 48, 2 (transport >3100) in Figure 49 and 4 (transport <100) in Figure 50.

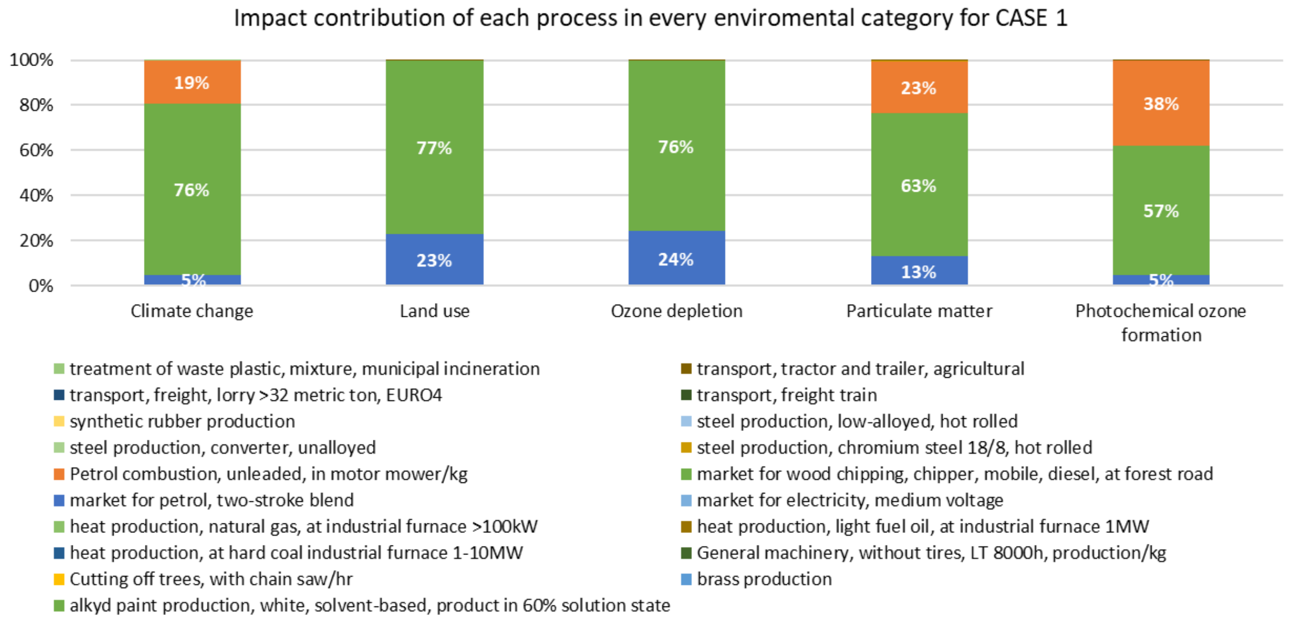

Figure 48 – Percentage comparison of impact contributions of every process involved in CASE 1 (local supply <50 km).

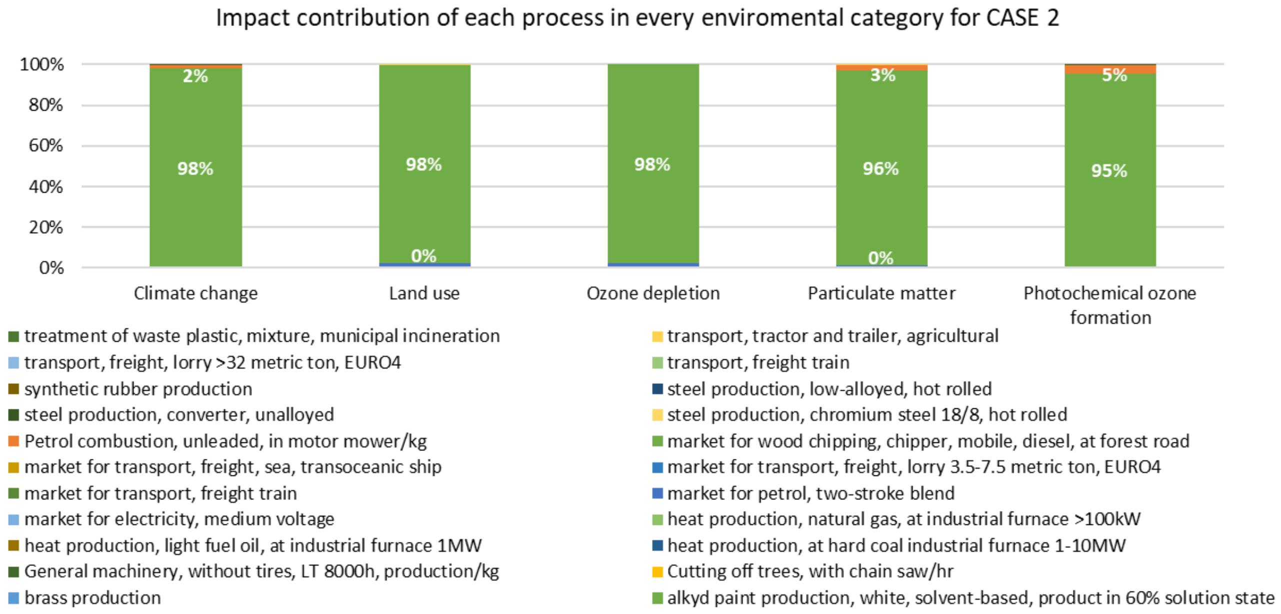

Figure 49 – Percentage comparison of impact contributions of every process involved in CASE 2 (local supply >3100 km).

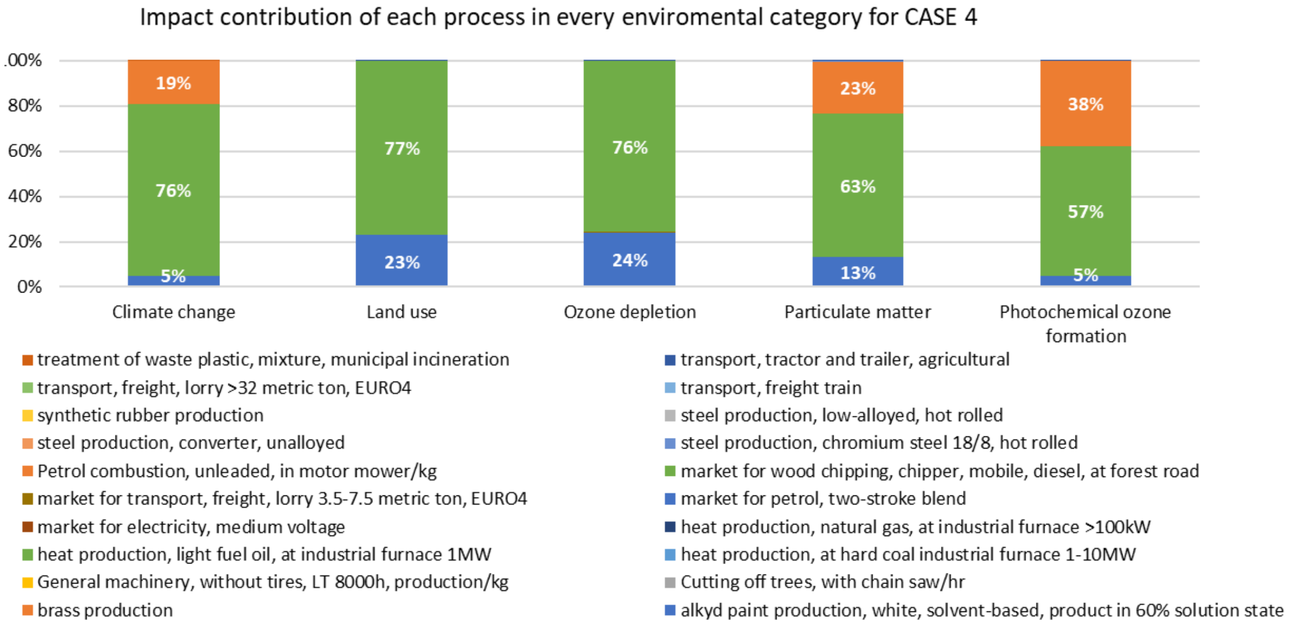

Figure 50 - Percentage comparison of impact contributions of every process involved in CASE 4 (not-local supply <100 km).

It is therefore clear, by taking an overall environmental assessment, that the most impactful phase is chipping. This result is in line with results reported in literature and this is mainly due to the fact that the chipper consumes a lot of energy, for which a high consumption of diesel fuel is consequently required from the tractor power outlet and therefore emits harmful substances into the atmosphere. It is therefore clear that, proportionally, compared with chipping, transport has a smaller overall impact than the latter. This finding is also plausible because studies have been carried out showing that 100 km or less, as is the case at issue, is almost irrelevant to the environmental impact of transport.

We can therefore conclude in this first analysis that the short biomass supply chain (at 50 km maximum transport) is the least impacting process among all the categories analyzed.
We have a value of 0,02844 [kgCO2eq/kg wood chips]. According to the estimates presented by the LENO[4] project in Piedmont Region, the supply of wood fuel from the short chain generates 6 [gCO2eq/kWh] where [kWh] means the calorific value of the fuel. In our case, by attributing to chestnut wood with a water content of 40% a calorific value of 3,26 [kWh/kg] we obtain 7,06 [gCO2eq/kWh], in line with the estimates highlighted by the Piedmont project.

5.1.2. RESULTS FOR OFF GRID SCENARIO

The environmental impacts for this part involve the study of three types of cases:

- CASE E.1: local biomass (50km) chipped with small machine, using for cogeneration.
- CASE E.2: non-local biomass (3100km) chipped with big machine, using for cogeneration.
- CASE E.4: local biomass (100km) chipped with small machine, using for cogeneration

In the Figure 51 and 52 there is presented a summary scheme of the nomenclature of cases according of transportation (51) and chipping machine size (52).

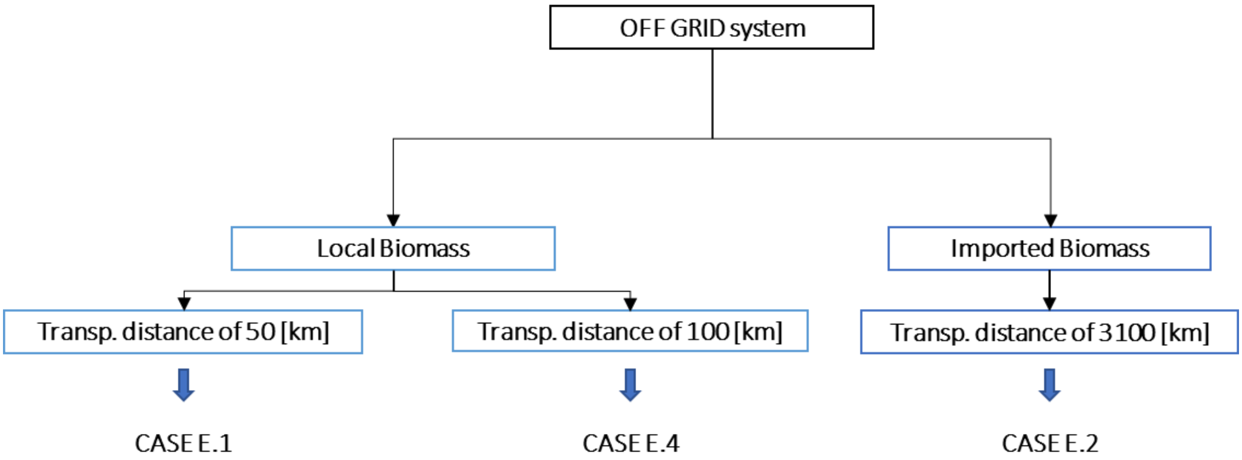

Figure 51 – Summary scheme of nomenclature of electricity cases analyzed.

	Type of chipping machine
CASE E.1	Small [18 m3/h]
CASE E.2	Big [30 m3/h]
CASE E.4	Small [18 m3/h]

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[4] SOURCE: https://www.legnoenergia.org/pubblicazioni/video/webinar-combustione-biomasse/

Figure 52 – Scheme of the type of chipping machines assumed for the cases, due to the relevant influence in the process.

Cogeneration plants usually arise in the vicinity of thermal users because, due to high transmission losses, it is neither technically simple nor cost-effective to transmit heat over long distances.
Having established from previous chapter the greatest environmental impact due to imported biomass rather than locally supplied, in this section we are going to calculate the total amount of emissivity from equivalent energy produced by biomass cogeneration plant.

The electrical cogeneration efficiency ηel indicates how much of the fuel energy is converted into electricity:

$$\eta el = \frac{Eel}{Ec}$$

The thermal cogeneration efficiency ηt indicates how much of the fuel energy is converted into useful thermal energy:

$$\eta t = \frac{Qr}{Ec}$$

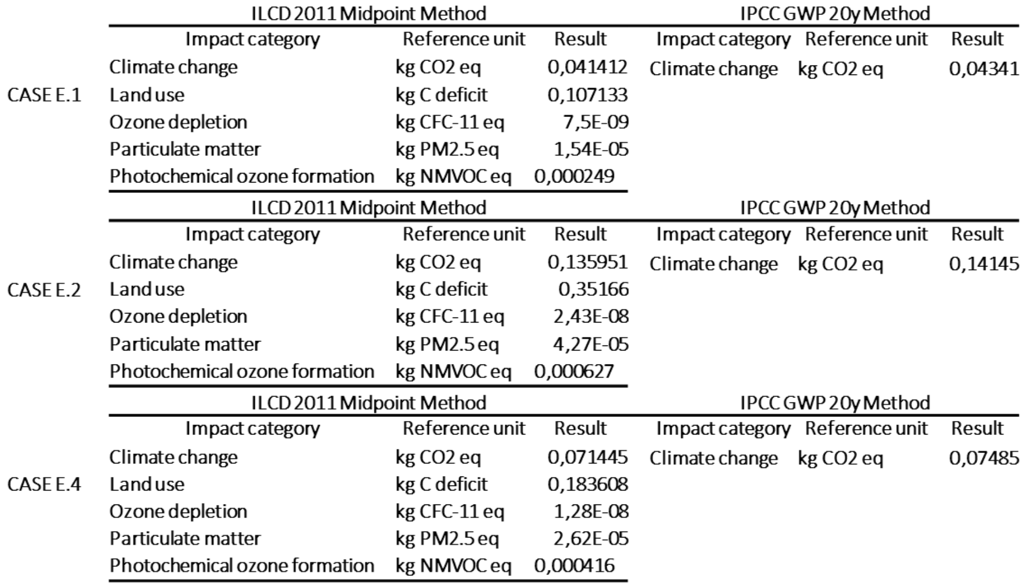
The Energy Utilization Factor (EUF) indicates how much of the fuel energy is used in electrical or thermal form:

$$EUF = Eel + \frac{Qr}{Ec} = \eta el + \eta t$$

Finally, it is possible to define the cogeneration ratio y as the ratio between electricity and useful thermal energy made available by the plant:

$$y = \frac{Eel}{Qr}$$

Before proceeding with the result presentation, it is important to clarify the importance of emission related of this system. The software works out the emission generate in the production of electrical part; in other hand the relative quantity of thermal energy generated is proportional to the electrical part but the emissions still maintain the same value.
In Figure 53 are reported the emission values of method selected only for the three cases.



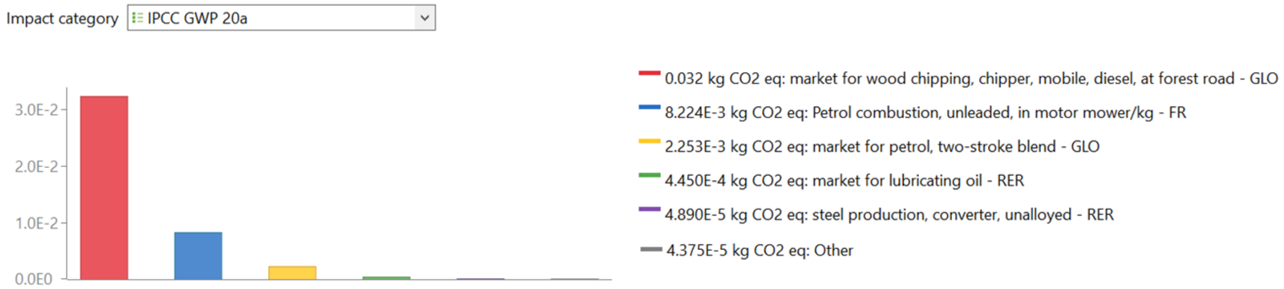
	ILCD 2011 Midpoint Method			IPCC GWP 20y Method		
	Impact category	Reference unit	Result	Impact category	Reference unit	Result
CASE E.1	Climate change	kg CO2 eq	0,041412	Climate change	kg CO2 eq	0,04341
	Land use	kg C deficit	0,107133			
	Ozone depletion	kg CFC-11 eq	7,5E-09			
	Particulate matter	kg PM2.5 eq	1,54E-05			
	Photochemical ozone formation	kg NMVOC eq	0,000249			
	ILCD 2011 Midpoint Method			IPCC GWP 20y Method		
	Impact category	Reference unit	Result	Impact category	Reference unit	Result
CASE E.2	Climate change	kg CO2 eq	0,135951	Climate change	kg CO2 eq	0,14145
	Land use	kg C deficit	0,35166			
	Ozone depletion	kg CFC-11 eq	2,43E-08			
	Particulate matter	kg PM2.5 eq	4,27E-05			
	Photochemical ozone formation	kg NMVOC eq	0,000627			
	ILCD 2011 Midpoint Method			IPCC GWP 20y Method		
	Impact category	Reference unit	Result	Impact category	Reference unit	Result
CASE E.4	Climate change	kg CO2 eq	0,071445	Climate change	kg CO2 eq	0,07485
	Land use	kg C deficit	0,183608			
	Ozone depletion	kg CFC-11 eq	1,28E-08			
	Particulate matter	kg PM2.5 eq	2,62E-05			
	Photochemical ozone formation	kg NMVOC eq	0,000416			

Figure 53 - Table with environmental impact results, distinguished for each case according to the methodology used.

Following histogram want to show the importance of processes. It is interesting to notice that, despite the process of syngas and motor combustion, chipping phase remains in pole position in terms of contribution.

CASE E.1: chip supply within 50 km

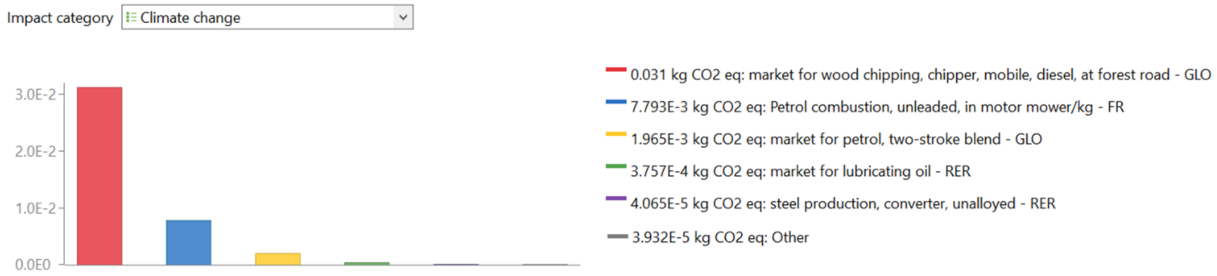
IPCC GWP 20a



Impact category: IPCC GWP 20a

Figure 54 – Contribution of each phase in electricity production with local biomass chip for IPCC

ILCD 2011+ Midpoint



Impact category: Climate change

Figure 55 - Contribution of each phase in electricity production with local biomass chip for ILCD

CASE E.2: chip supply within 3100 km

IPCC GWP 20a

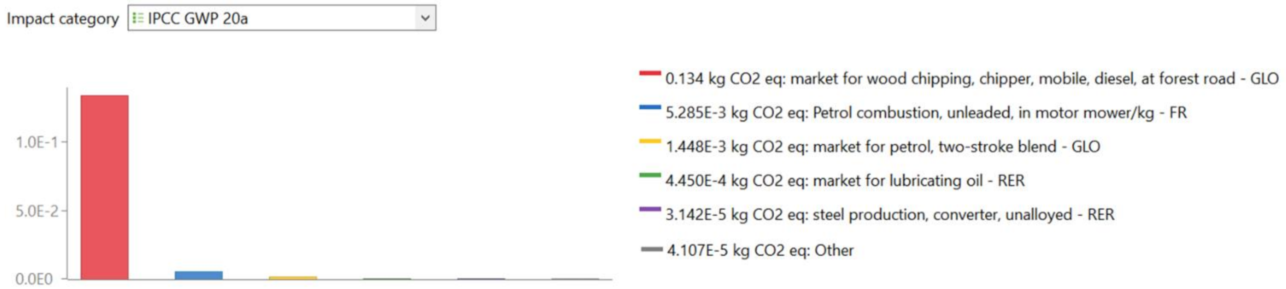

Impact category IPCC GWP 20a

Figure 56 – Contribution of each phase in electricity production with non-local biomass chip for IPCC

ILCD 2011+ Midpoint

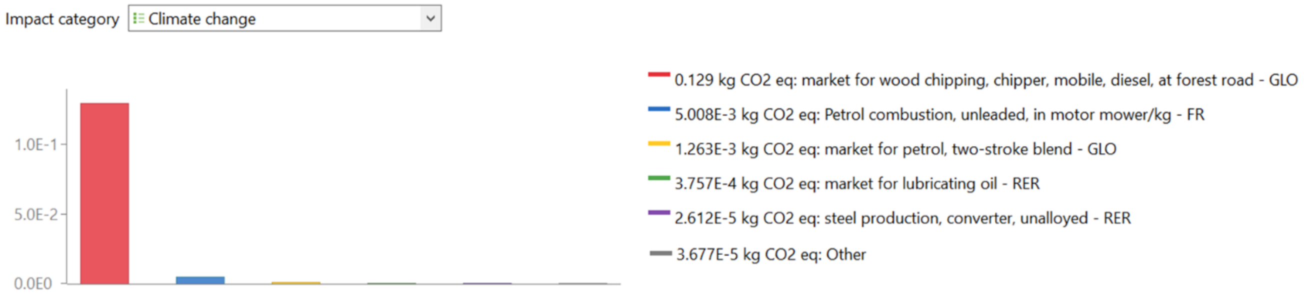

Impact category Climate change

Figure 57 - Contribution of each phase in electricity production with non-local biomass chip for ILCD

CASE E.4: chip supply within 100 km

IPCC GWP 20a

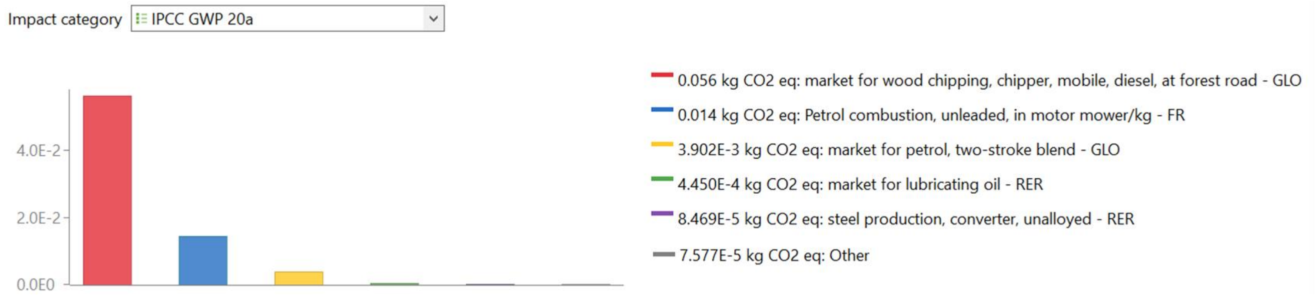

Impact category IPCC GWP 20a

Figure 58 – Contribution of each phase in electricity production with local biomass chip for IPCC

ILCD 2011+ Midpoint

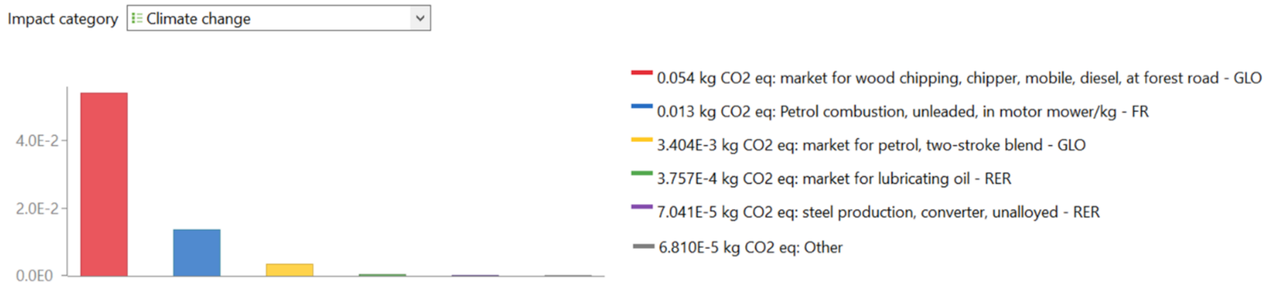

Impact category Climate change

Figure 59 - Contribution of each phase in electricity production with local biomass chip for ILCD

The final comparison of Climate Change emissions confirms the relevant role of biomass withdrawn and Figure 60 explicates it.

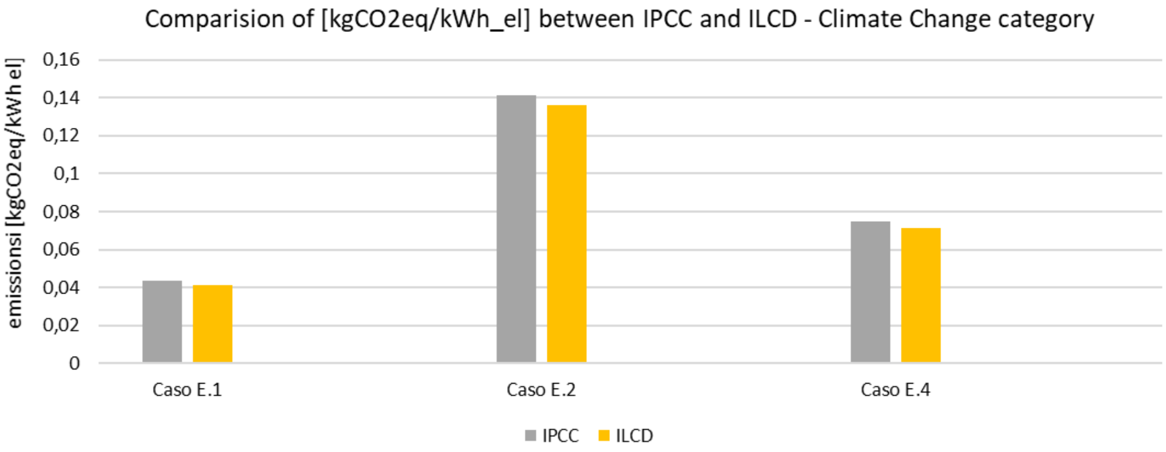


Figure 60 - Comparison of emission in Climate Change impact category in each case

Impact categories, already seen in Chapter 5.1.1., has a same value profile expected for the imported biomass. The emission of energy production is added to the chip supply so the combination of two factors raises the final emission. Respectively the Figures 61, 62, 63 and 64 shown the emission in Land Use, Ozone Depletion, Particulate Matter, Photochemical Ozone Depletion.

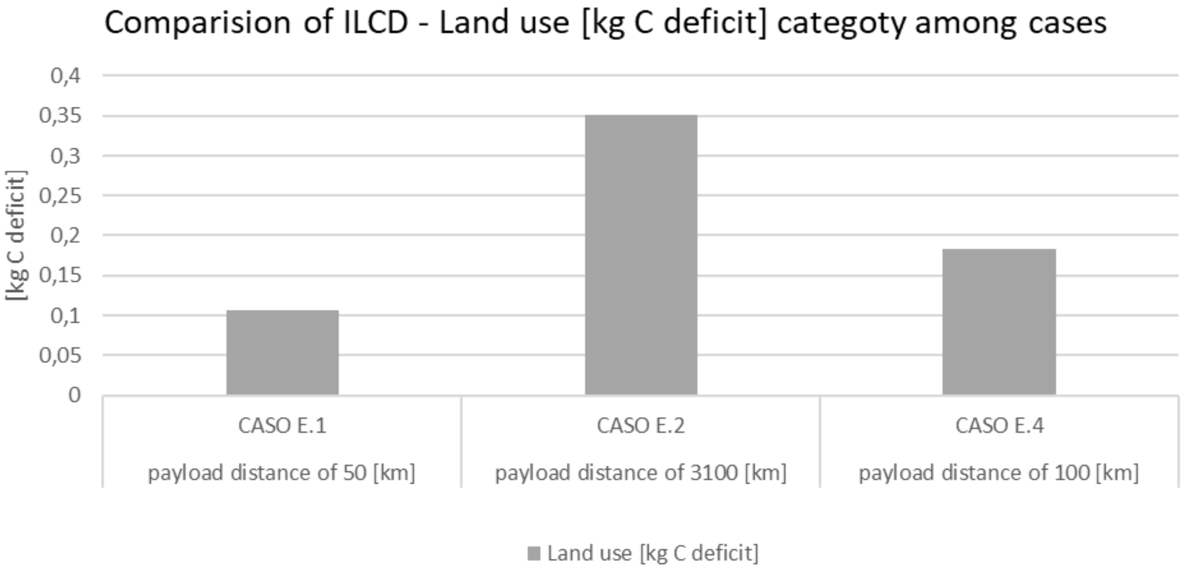


Figure 61- Comparison of emission in Land Use impact category in each case

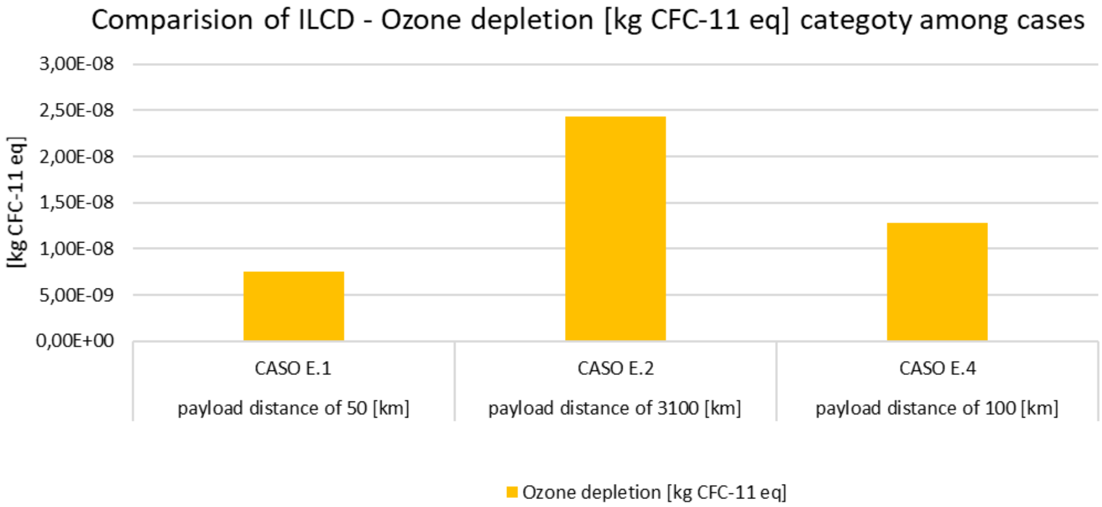


Figure 62 - Comparison of emission in Ozone Depletion impact category in each case

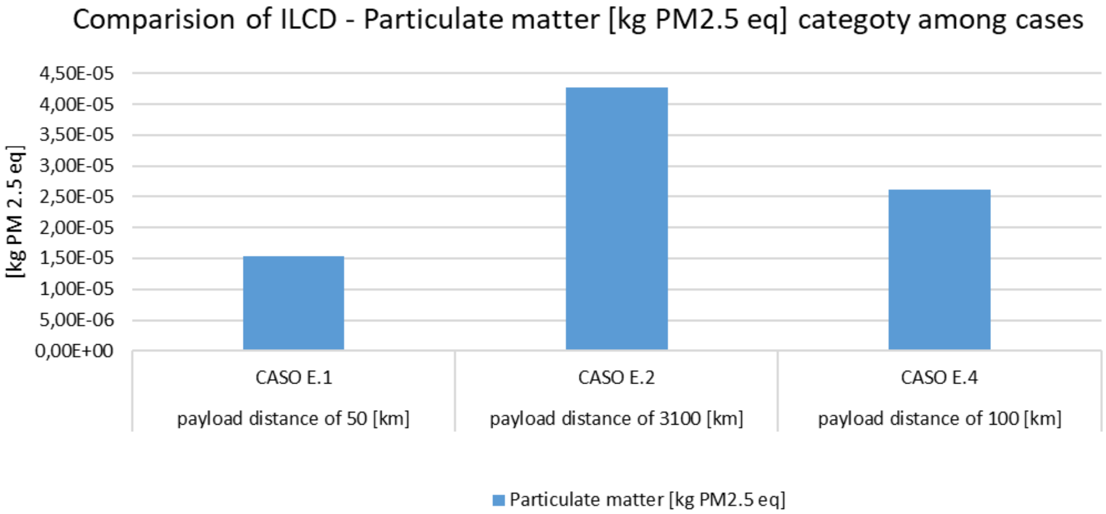


Figure 63 - Comparison of emission in Particulate Matter impact category in each case

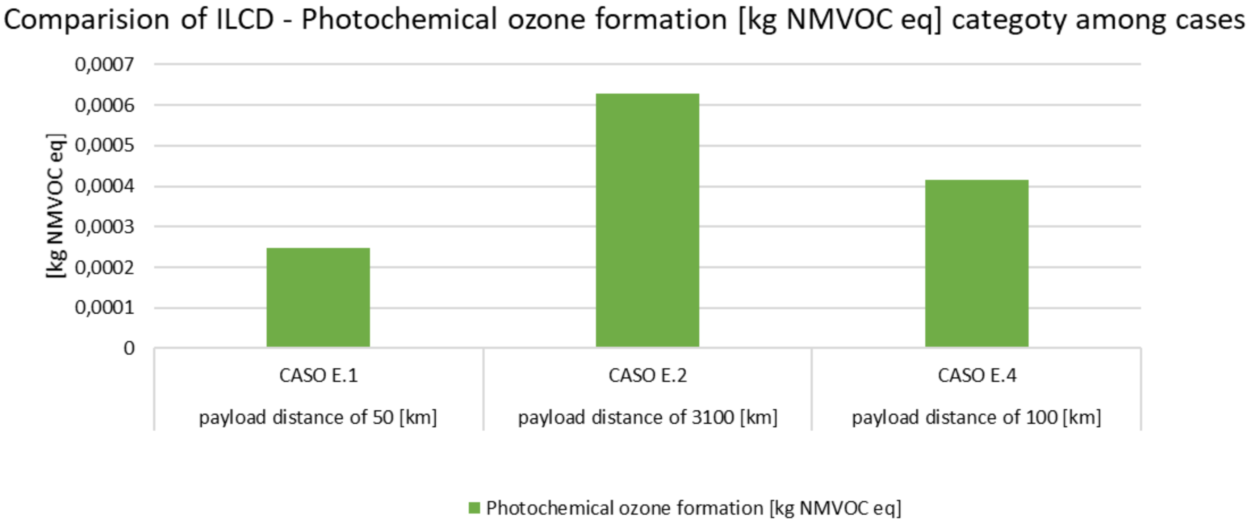


Figure 64 - Comparison of emission in Photochemical Ozone Formation impact category in each case

The final analysis, the least impactful process for the OFF-GRID system is assuming the local chip in Case 1. The emission of Climate Change in this case is 0,04141 [kg CO_2eq/kW eq]. This emission is coherent about literature values because, considering the mean value of specific emission factor for biomass Cogeneration systems in Sweden, they have 17 [gCO2/kWh of biomass fuel], the [kWh/kg of chestnut biomass] is 3,26. So the order of magnitude is the same. In Figure 65 are reported the literature values.

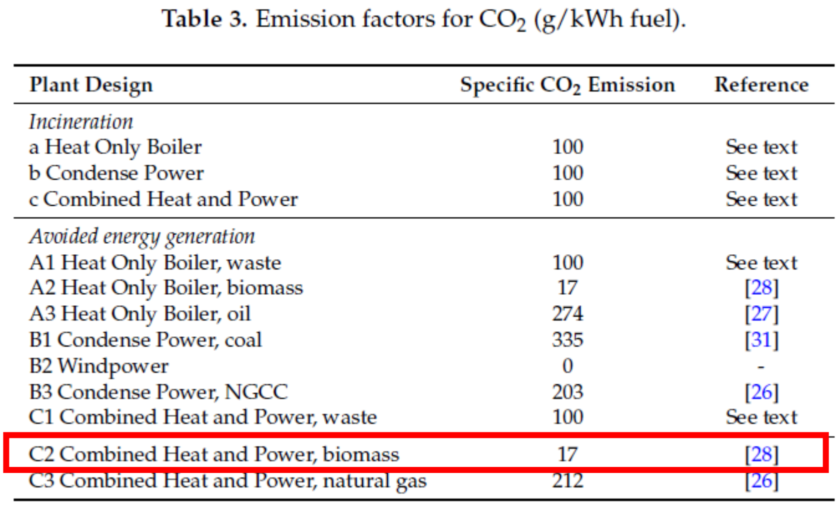
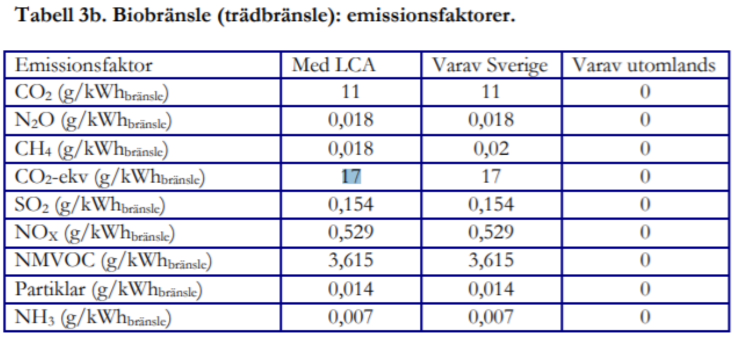


Table 3. Emission factors for CO_2 (g/kWh fuel).

Plant Design	Specific CO_2 Emission	Reference
Incineration		
a Heat Only Boiler	100	See text
b Condense Power	100	See text
c Combined Heat and Power	100	See text
Avoided energy generation		
A1 Heat Only Boiler, waste	100	See text
A2 Heat Only Boiler, biomass	17	[28]
A3 Heat Only Boiler, oil	274	[27]
B1 Condense Power, coal	335	[31]
B2 Windpower	0	-
B3 Condense Power, NGCC	203	[26]
C1 Combined Heat and Power, waste	100	See text
C2 Combined Heat and Power, biomass	17	[28]
C3 Combined Heat and Power, natural gas	212	[26]



Tabell 3b. Biobränsle (trädbränsle): emissionsfaktorer.

Emissionsfaktor	Med LCA	Varav Sverige	Varav utomlands
CO_2 (g/kWh$_{bränsle}$)	11	11	0
N_2O (g/kWh$_{bränsle}$)	0,018	0,018	0
CH_4 (g/kWh$_{bränsle}$)	0,018	0,02	0
CO_2-ekv (g/kWh$_{bränsle}$)	17	17	0
SO_2 (g/kWh$_{bränsle}$)	0,154	0,154	0
NO_X (g/kWh$_{bränsle}$)	0,529	0,529	0
NMVOC (g/kWh$_{bränsle}$)	3,615	3,615	0
Partiklar (g/kWh$_{bränsle}$)	0,014	0,014	0
NH_3 (g/kWh$_{bränsle}$)	0,007	0,007	0

Figure 65 – Values for different energy systems in Sweden. Article: Energy Recovery from Waste Incineration—The Importance of Technology Data and System Boundaries on CO2 Emissions

5.1.3. RESULTS FOR OFF GRID SCENARIO [4]

Eight types of scenarios were analyzed for the emissions for OFF-GRID systems, starting from the two more rapresentative cases of wood-chip supply chain:

- CASE E.1: local biomass (50km) chipped with small machine;
- CASE E.2: non-local biomass (3100km) chipped with big machine.

Considering the emissions established by the Piedmont D.G.R. of 2018, the categories of environmental impact differ for the wood chip used. If it was derived from import, it generate a certain amount of impact higher then the one bought from the local supply chain.
In Figure 66 there is an explainantion of cases hypothesed.

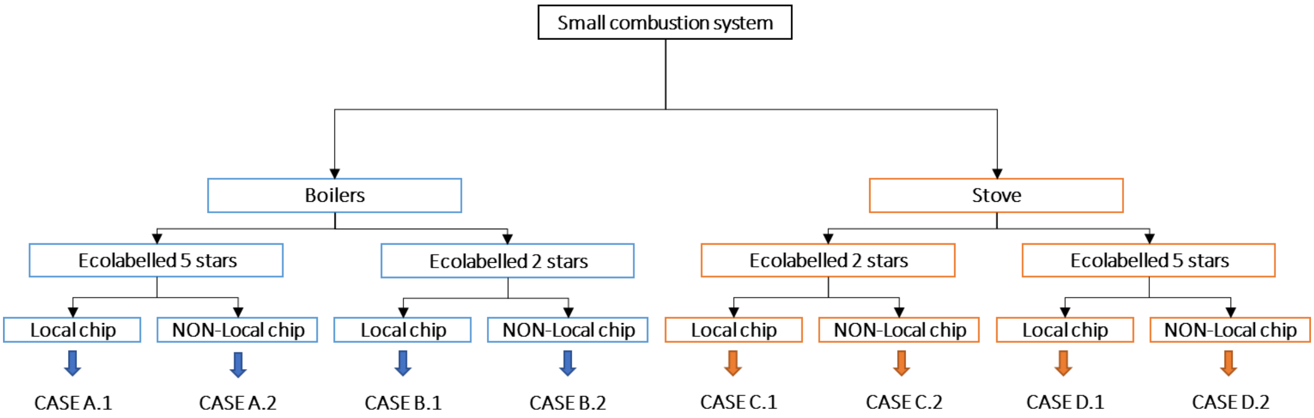


Figure 66 – Summary scheme of nomenclature of cases for small combustion.

The life cycle inventory results of the cases presented had notice that the reduction in emissions varies from about 15% between 5 stars and 2 stars class, an effect purely caused by higher efficiency and reduced demand of chip as result of significantly improved combustion conditions.
The 2-stars-appliances are important for all selected impact categories but particularly for particulates impacts. Even so, a global warming potential of about 30 [gCO_2eq/kWh] for an old boiler and about 11 [gCO_2eq/kWh] for a new one indicates a reduction, but nothing compared to 1-kWh heat delivered by cogeneration. Thanks to the presence of a CHP system, it is possible reach an emission of 43 gCO2eq/kWh per 1-kWh electric but at the same time we could gain a value around 2,43-kWh for HVAC necessities. The result came out from analysis are presented in tables of Figure 67 and 68. All values are compared between IPCC and ILCD methodologies.

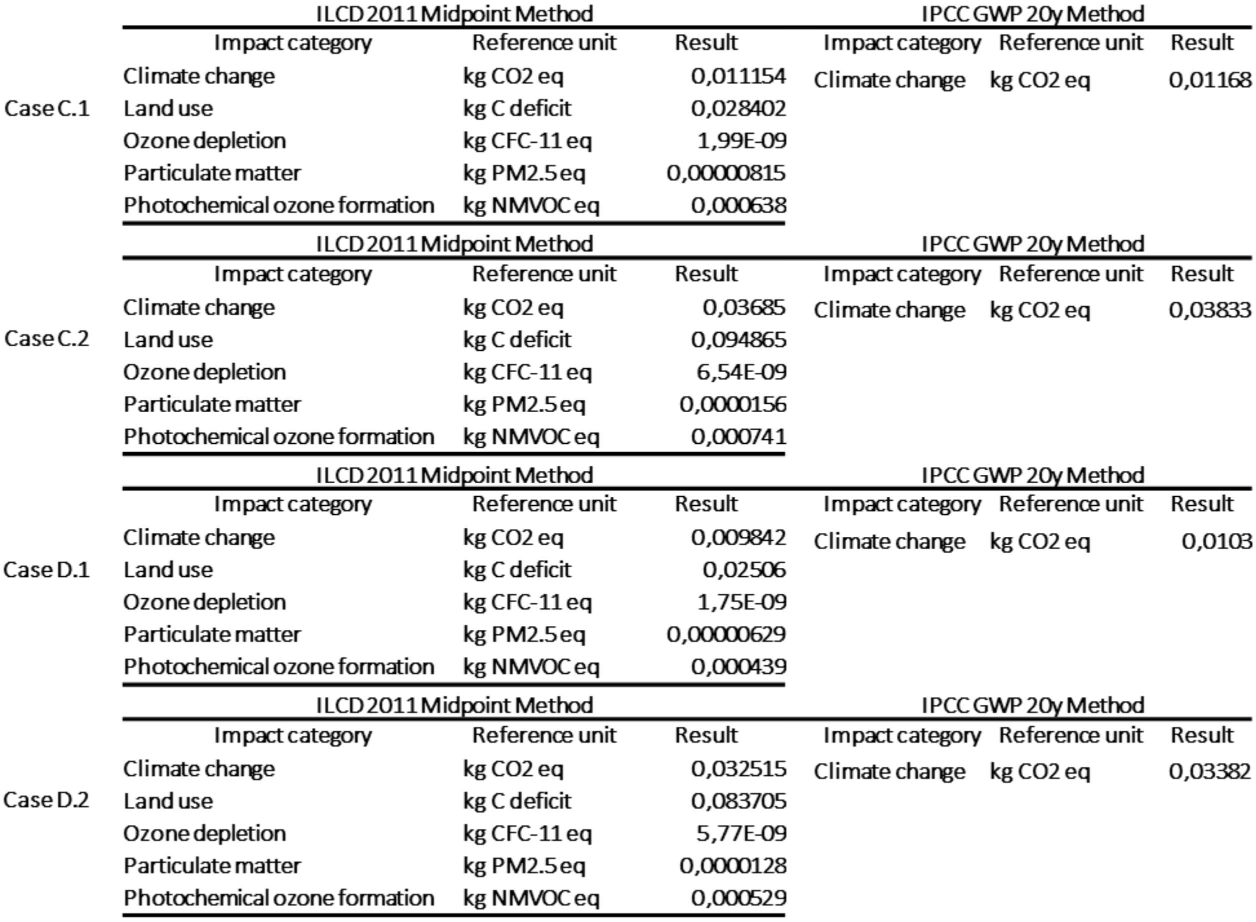
	ILCD 2011 Midpoint Method			IPCC GWP 20y Method		
	Impact category	Reference unit	Result	Impact category	Reference unit	Result
Case A.1	Climate change	kg CO2 eq	0,010457	Climate change	kg CO2 eq	0,01101
	Land use	kg C deficit	0,026215			
	Ozone depletion	kg CFC-11 eq	1,75E-09			
	Particulate matter	kg PM2.5 eq	0,00000611			
	Photochemical ozone formation	kg NMVOC eq	0,000353			

	ILCD 2011 Midpoint Method			IPCC GWP 20y Method		
	Impact category	Reference unit	Result	Impact category	Reference unit	Result
Case A.2	Climate change	kg CO2 eq	0,030743	Climate change	kg CO2 eq	0,03205
	Land use	kg C deficit	0,078687			
	Ozone depletion	kg CFC-11 eq	5,34E-09			
	Particulate matter	kg PM2.5 eq	0,000012			
	Photochemical ozone formation	kg NMVOC eq	0,000434			

	ILCD 2011 Midpoint Method			IPCC GWP 20y Method		
	Impact category	Reference unit	Result	Impact category	Reference unit	Result
Case B.1	Climate change	kg CO2 eq	0,012108	Climate change	kg CO2 eq	0,01274
	Land use	kg C deficit	0,03042			
	Ozone depletion	kg CFC-11 eq	2,04E-09			
	Particulate matter	kg PM2.5 eq	0,00000791			
	Photochemical ozone formation	kg NMVOC eq	0,000529			

	ILCD 2011 Midpoint Method			IPCC GWP 20y Method		
	Impact category	Reference unit	Result	Impact category	Reference unit	Result
Case B.2	Climate change	kg CO2 eq	0,036198	Climate change	kg CO2 eq	0,03772
	Land use	kg C deficit	0,092729			
	Ozone depletion	kg CFC-11 eq	6,31E-09			
	Particulate matter	kg PM2.5 eq	0,0000149			
	Photochemical ozone formation	kg NMVOC eq	0,000625			

Figure 67 - Table with environmental impact results, distinguished for boiler cases according to the methodology used (part 1).



	ILCD 2011 Midpoint Method			IPCC GWP 20y Method		
	Impact category	Reference unit	Result	Impact category	Reference unit	Result
Case C.1	Climate change	kg CO2 eq	0,011154	Climate change	kg CO2 eq	0,01168
	Land use	kg C deficit	0,028402			
	Ozone depletion	kg CFC-11 eq	1,99E-09			
	Particulate matter	kg PM2.5 eq	0,00000815			
	Photochemical ozone formation	kg NMVOC eq	0,000638			

	ILCD 2011 Midpoint Method			IPCC GWP 20y Method		
	Impact category	Reference unit	Result	Impact category	Reference unit	Result
Case C.2	Climate change	kg CO2 eq	0,03685	Climate change	kg CO2 eq	0,03833
	Land use	kg C deficit	0,094865			
	Ozone depletion	kg CFC-11 eq	6,54E-09			
	Particulate matter	kg PM2.5 eq	0,0000156			
	Photochemical ozone formation	kg NMVOC eq	0,000741			

	ILCD 2011 Midpoint Method			IPCC GWP 20y Method		
	Impact category	Reference unit	Result	Impact category	Reference unit	Result
Case D.1	Climate change	kg CO2 eq	0,009842	Climate change	kg CO2 eq	0,0103
	Land use	kg C deficit	0,02506			
	Ozone depletion	kg CFC-11 eq	1,75E-09			
	Particulate matter	kg PM2.5 eq	0,00000629			
	Photochemical ozone formation	kg NMVOC eq	0,000439			

	ILCD 2011 Midpoint Method			IPCC GWP 20y Method		
	Impact category	Reference unit	Result	Impact category	Reference unit	Result
Case D.2	Climate change	kg CO2 eq	0,032515	Climate change	kg CO2 eq	0,03382
	Land use	kg C deficit	0,083705			
	Ozone depletion	kg CFC-11 eq	5,77E-09			
	Particulate matter	kg PM2.5 eq	0,0000128			
	Photochemical ozone formation	kg NMVOC eq	0,000529			

Figure 67 – Table with environmental impact results, distinguished for stove cases according to the methodology used (part 2).

The contribution of different processes and pollutants to the category indicator results is presented in following Figures. Products of incomplete combustion, such as methane, dioxin, NMVOCs and particulates (as PM2.5) are the dominant contributors to most impact categories.
Our results are therefore sensitive to the emissions' measurements for the wood stoves and the extrapolation of these into real-life usage.

CASE A.1: 5-stars boiler with local chip

IPCC GWP 20a

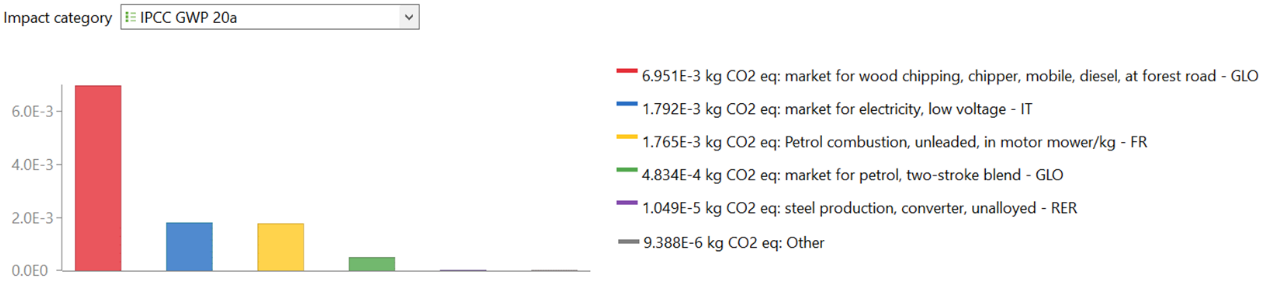
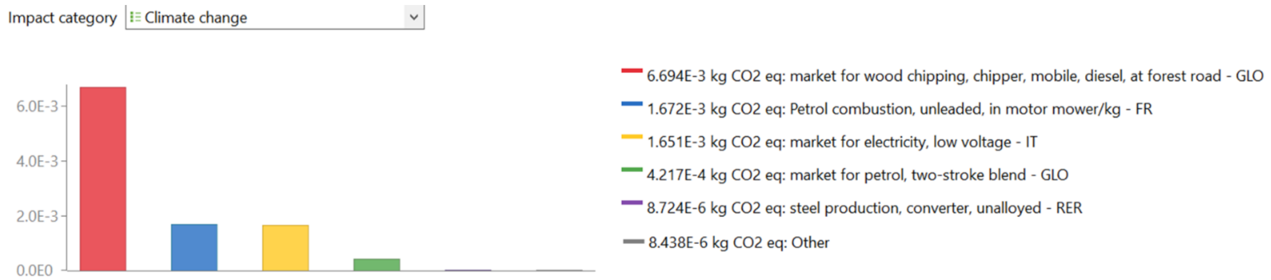

Impact category: IPCC GWP 20a

Figure 68 – Contribution of each phase in HVAC production with local biomass and new boiler for IPCC

ILCD 2011+ Midpoint

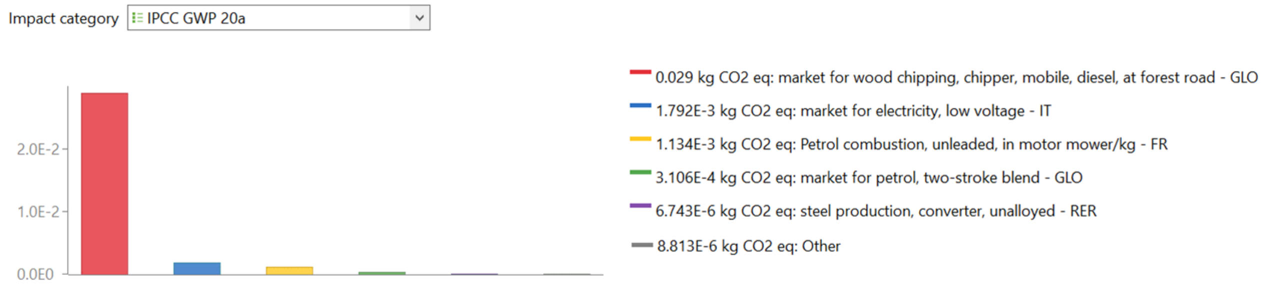

Impact category: Climate change

6.694E-3 kg CO2 eq: market for wood chipping, chipper, mobile, diesel, at forest road - GLO
1.672E-3 kg CO2 eq: Petrol combustion, unleaded, in motor mower/kg - FR
1.651E-3 kg CO2 eq: market for electricity, low voltage - IT
4.217E-4 kg CO2 eq: market for petrol, two-stroke blend - GLO
8.724E-6 kg CO2 eq: steel production, converter, unalloyed - RER
8.438E-6 kg CO2 eq: Other

Figure 69 - Contribution of each phase in HVAC production with local biomass and new boiler for ILCD

CASE A.2: 5-stars boiler with imported chip

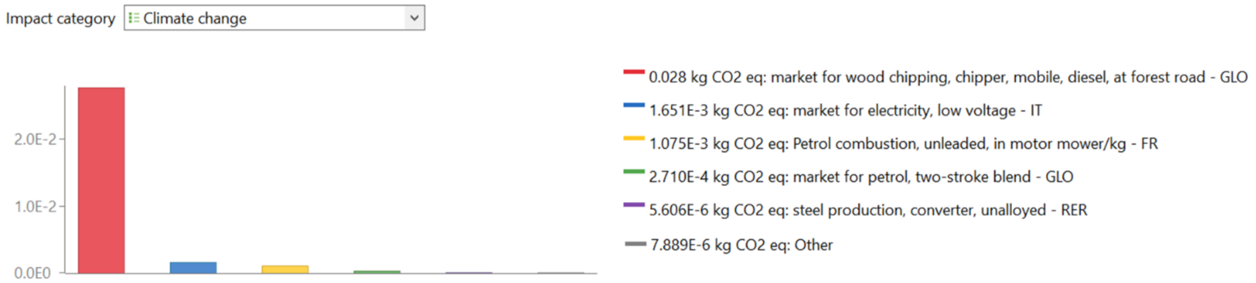
IPCC GWP 20a


Impact category: IPCC GWP 20a

0.029 kg CO2 eq: market for wood chipping, chipper, mobile, diesel, at forest road - GLO
1.792E-3 kg CO2 eq: market for electricity, low voltage - IT
1.134E-3 kg CO2 eq: Petrol combustion, unleaded, in motor mower/kg - FR
3.106E-4 kg CO2 eq: market for petrol, two-stroke blend - GLO
6.743E-6 kg CO2 eq: steel production, converter, unalloyed - RER
8.813E-6 kg CO2 eq: Other

Figure 70 – Contribution of each phase in HVAC production with non-local biomass and new boiler for IPCC

ILCD 2011+ Midpoint

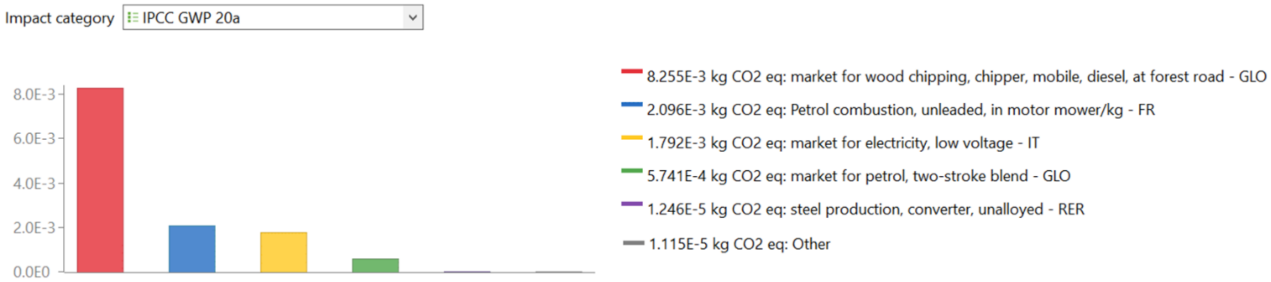

Impact category: Climate change

0.028 kg CO2 eq: market for wood chipping, chipper, mobile, diesel, at forest road - GLO
1.651E-3 kg CO2 eq: market for electricity, low voltage - IT
1.075E-3 kg CO2 eq: Petrol combustion, unleaded, in motor mower/kg - FR
2.710E-4 kg CO2 eq: market for petrol, two-stroke blend - GLO
5.606E-6 kg CO2 eq: steel production, converter, unalloyed - RER
7.889E-6 kg CO2 eq: Other

Figure 71 - Contribution of each phase in HVAC production with non-local biomass and new boiler for ILCD

CASE B.1: 2-stars boier with local chip

IPCC GWP 20a


Impact category: IPCC GWP 20a

8.255E-3 kg CO2 eq: market for wood chipping, chipper, mobile, diesel, at forest road - GLO
2.096E-3 kg CO2 eq: Petrol combustion, unleaded, in motor mower/kg - FR
1.792E-3 kg CO2 eq: market for electricity, low voltage - IT
5.741E-4 kg CO2 eq: market for petrol, two-stroke blend - GLO
1.246E-5 kg CO2 eq: steel production, converter, unalloyed - RER
1.115E-5 kg CO2 eq: Other

Figure 72 – Contribution of each phase in HVAC production with local biomass and old boiler for IPCC

ILCD 2011+ Midpoint

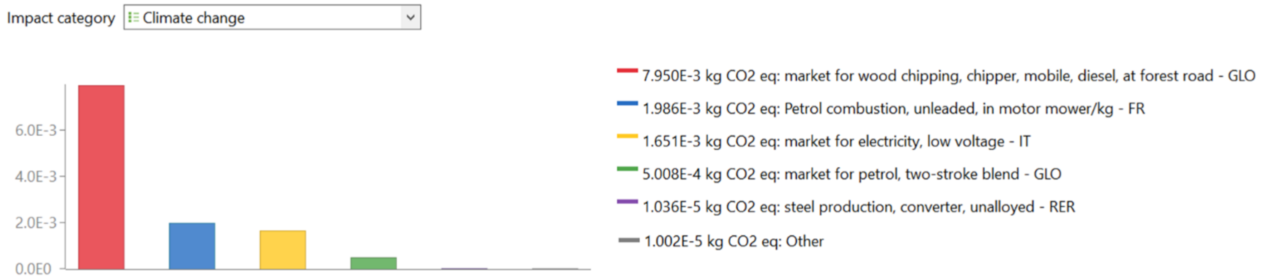

Impact category: Climate change

Figure 73 - Contribution of each phase in HVAC production with local biomass and old boiler for ILCD

CASE B.2: 2-stars boiler with imported chip

IPCC GWP 20a

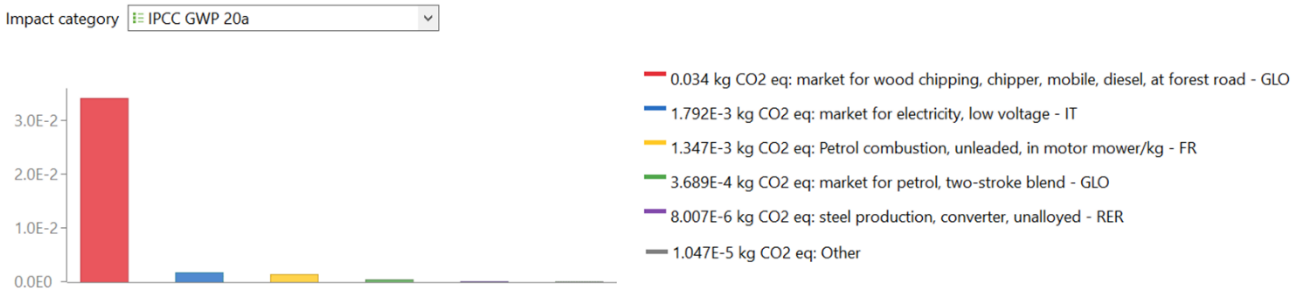

Impact category: IPCC GWP 20a

Figure 74 – Contribution of each phase in HVAC production with non-local biomass and old boiler for IPCC

ILCD 2011+ Midpoint

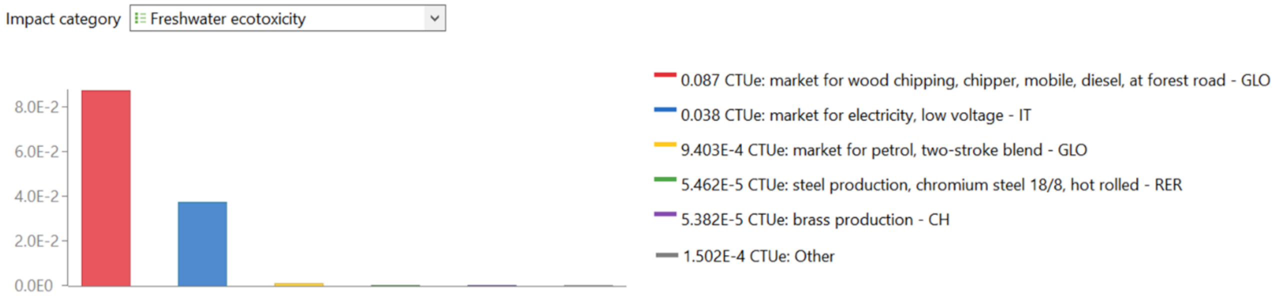

Impact category: Freshwater ecotoxicity

Figure 75 - Contribution of each phase in HVAC production with non-local biomass and old boiler for ILCD

CASE C.1: 2-stars stove with local chip

IPCC GWP 20a

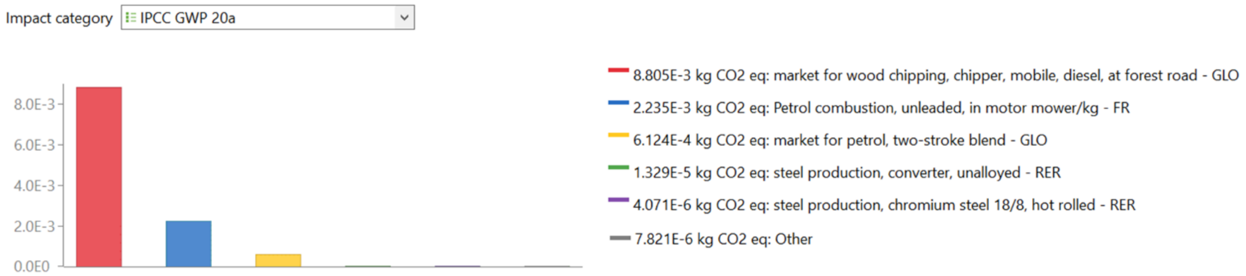
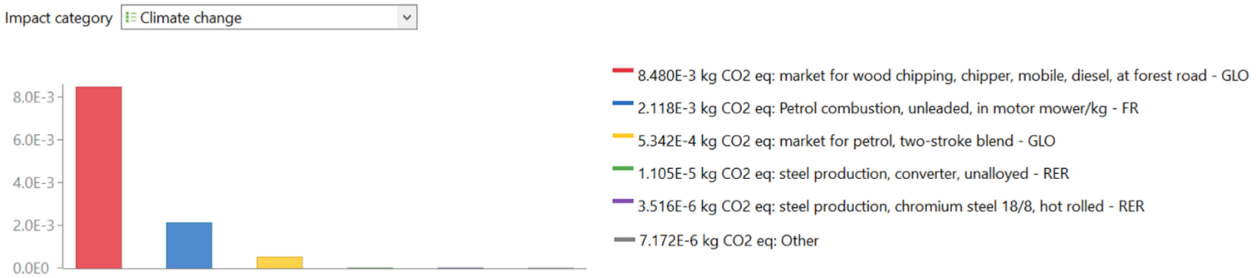

Impact category: IPCC GWP 20a

Figure 76 – Contribution of each phase in HVAC production with local biomass and old stove for IPCC

ILCD 2011+ Midpoint

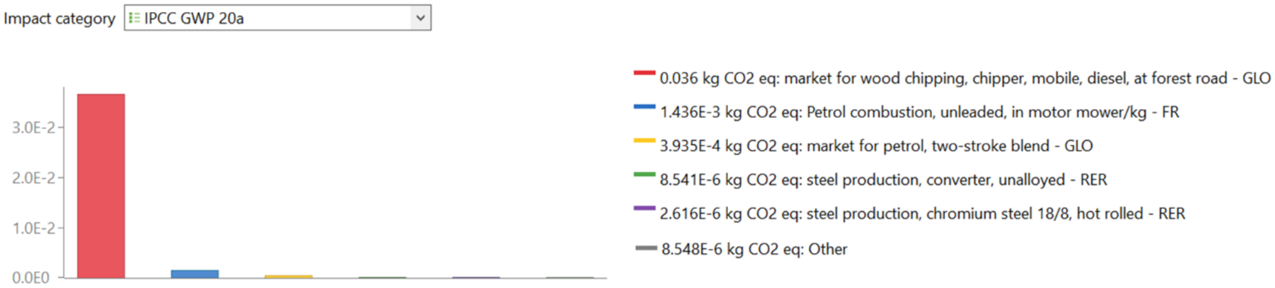

Impact category: Climate change

- 8.480E-3 kg CO2 eq: market for wood chipping, chipper, mobile, diesel, at forest road - GLO
- 2.118E-3 kg CO2 eq: Petrol combustion, unleaded, in motor mower/kg - FR
- 5.342E-4 kg CO2 eq: market for petrol, two-stroke blend - GLO
- 1.105E-5 kg CO2 eq: steel production, converter, unalloyed - RER
- 3.516E-6 kg CO2 eq: steel production, chromium steel 18/8, hot rolled - RER
- 7.172E-6 kg CO2 eq: Other

Figure 77 - Contribution of each phase in HVAC production with local biomass and old stove for ILCD

CASE C.2: 2-stars stove with imported chip

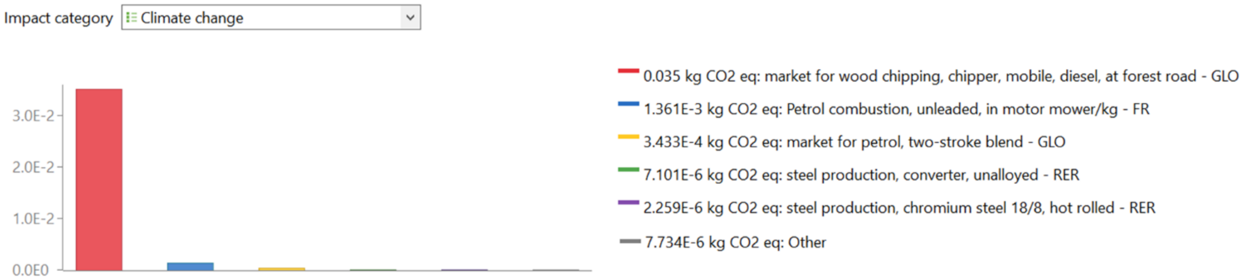
IPCC GWP 20a


Impact category: IPCC GWP 20a

- 0.036 kg CO2 eq: market for wood chipping, chipper, mobile, diesel, at forest road - GLO
- 1.436E-3 kg CO2 eq: Petrol combustion, unleaded, in motor mower/kg - FR
- 3.935E-4 kg CO2 eq: market for petrol, two-stroke blend - GLO
- 8.541E-6 kg CO2 eq: steel production, converter, unalloyed - RER
- 2.616E-6 kg CO2 eq: steel production, chromium steel 18/8, hot rolled - RER
- 8.548E-6 kg CO2 eq: Other

Figure 78 - Contribution of each phase in HVAC production with non-local biomass and old stove for IPCC

ILCD 2011+ Midpoint

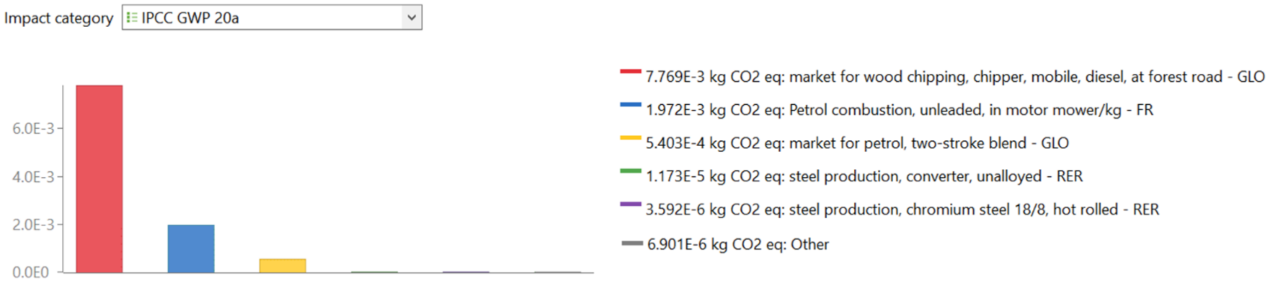

Impact category: Climate change

- 0.035 kg CO2 eq: market for wood chipping, chipper, mobile, diesel, at forest road - GLO
- 1.361E-3 kg CO2 eq: Petrol combustion, unleaded, in motor mower/kg - FR
- 3.433E-4 kg CO2 eq: market for petrol, two-stroke blend - GLO
- 7.101E-6 kg CO2 eq: steel production, converter, unalloyed - RER
- 2.259E-6 kg CO2 eq: steel production, chromium steel 18/8, hot rolled - RER
- 7.734E-6 kg CO2 eq: Other

Figure 79 - Contribution of each phase in HVAC production with non-local biomass and old stove for ILCD

CASE D.1: 5-stars stove with local chip

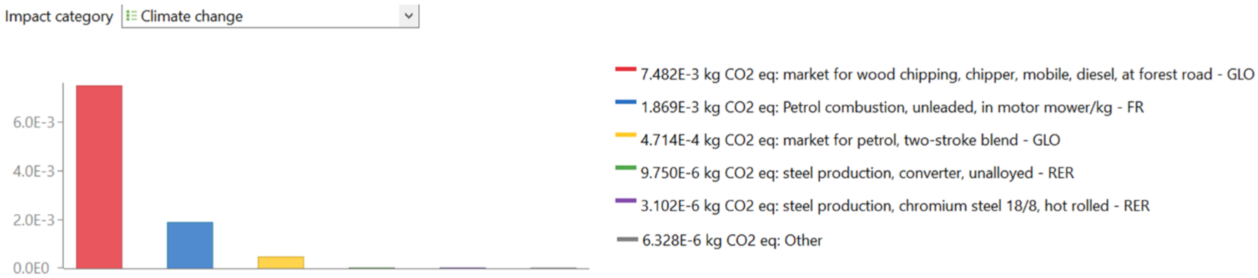
IPCC GWP 20a


Impact category: IPCC GWP 20a

- 7.769E-3 kg CO2 eq: market for wood chipping, chipper, mobile, diesel, at forest road - GLO
- 1.972E-3 kg CO2 eq: Petrol combustion, unleaded, in motor mower/kg - FR
- 5.403E-4 kg CO2 eq: market for petrol, two-stroke blend - GLO
- 1.173E-5 kg CO2 eq: steel production, converter, unalloyed - RER
- 3.592E-6 kg CO2 eq: steel production, chromium steel 18/8, hot rolled - RER
- 6.901E-6 kg CO2 eq: Other

Figure 80 – Contribution of each phase in HVAC production with local biomass and new stove for IPCC

ILCD 2011+ Midpoint

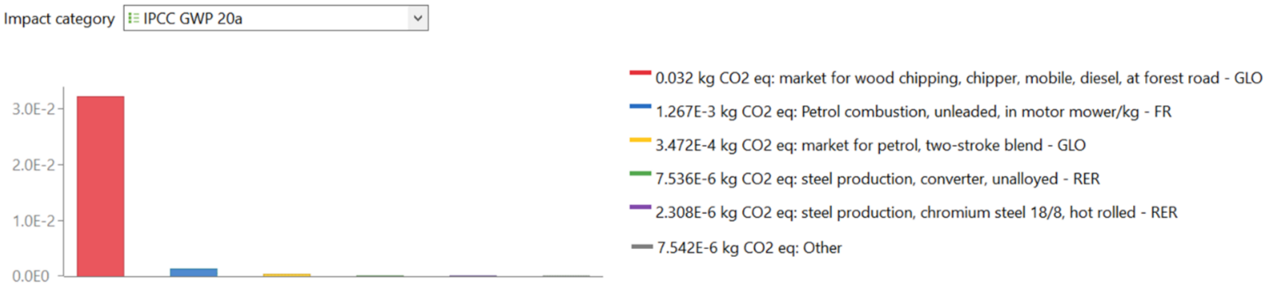


Impact category Climate change

Figure 81 - Contribution of each phase in HVAC production with local biomass and new stove for ILCD

CASE D.2: 5-stars stove with imported chip

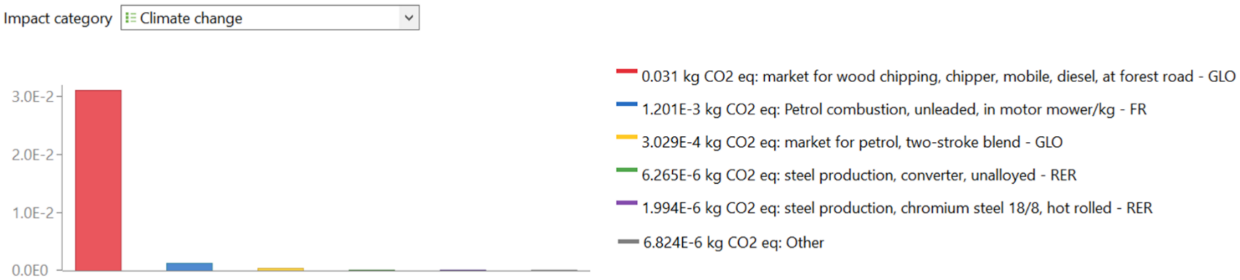
IPCC GWP 20a



Impact category IPCC GWP 20a

Figure 82 – Contribution of each phase in HVAC production with non-local biomass and new stove for IPCC

ILCD 2011+ Midpoint



Impact category Climate change

Figure 83 - Contribution of each phase in HVAC production with non-local biomass and new stove for ILCD

It is redundant to repeat that the local supply chain added to the local system of combustion is less impactful of imported one. Also, as we can clearly see, the chipping machine usage stands constantly as an important factor. For any kind of system used, the type of firewood contributes significantly, about 63% in the final Climate Change results.

Emissions from transportation is shaded in comparison of chipping machine. Even though the transportation distance is increased like in importing firewood conditions, chipping transformation remains the most important source of emissions affecting global warming. That underline how performance of wood as an energy source depends on the performance of the firewood system, from producer to consumer. If there is a local resource base of wood, short transportation distances should be preferred.

For the final comparison of all impact categories chosen, we are comparing only the cases with local chip supply in order to mainly focus on the best system choice. Figure 84, 85 86, 87 and 88 report the histogram for Climate Change, Land Use, Ozone Depletion, Particulate matter and Photochemical ozone formation.

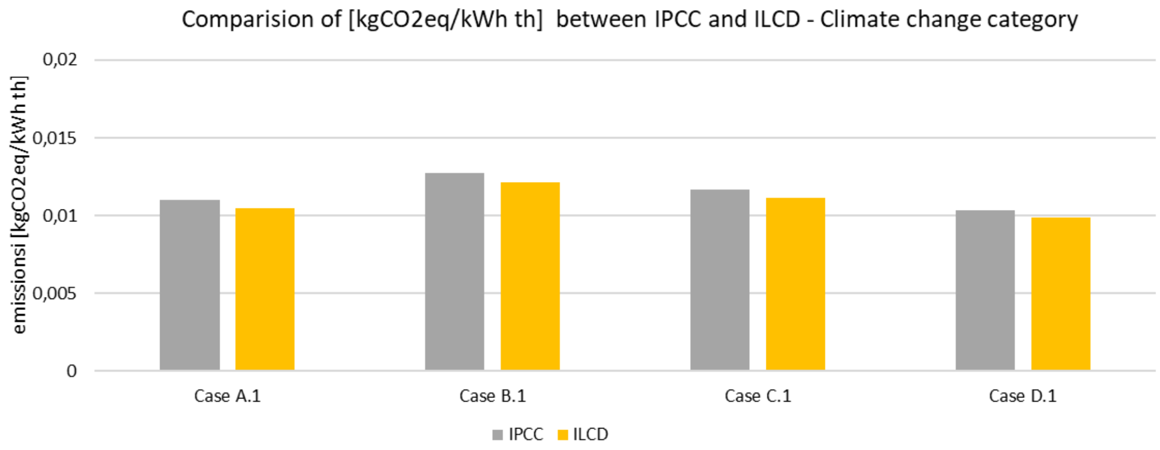


Figure 84 – Comparison of emission in Climate change impact category in each case

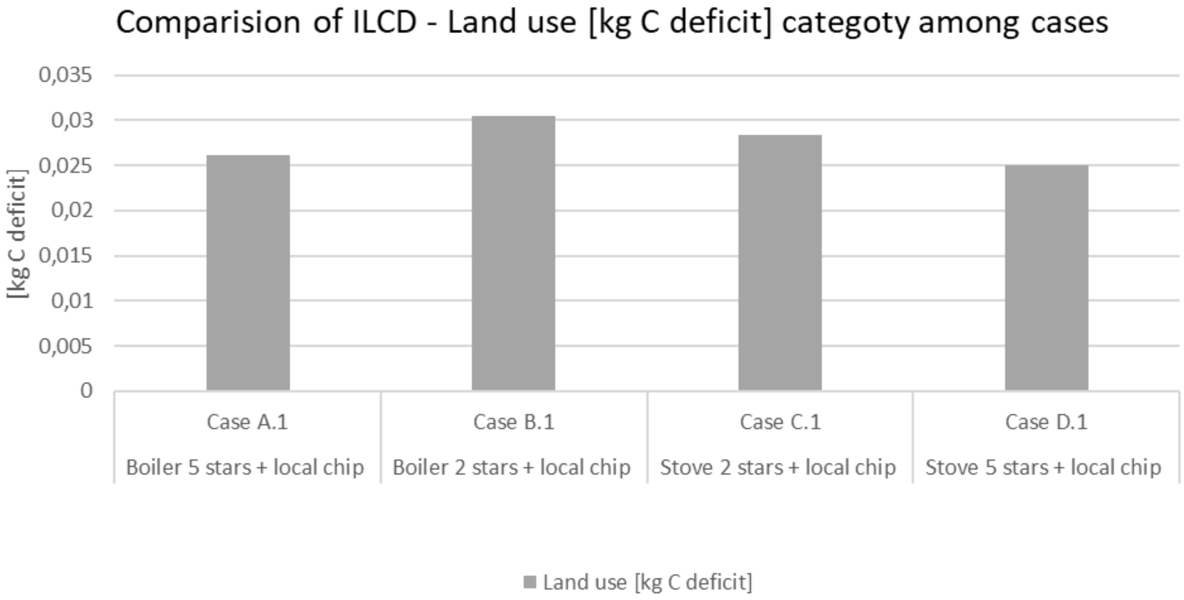


Figure 85 - Comparison of emission in Ladd Use impact category in each case

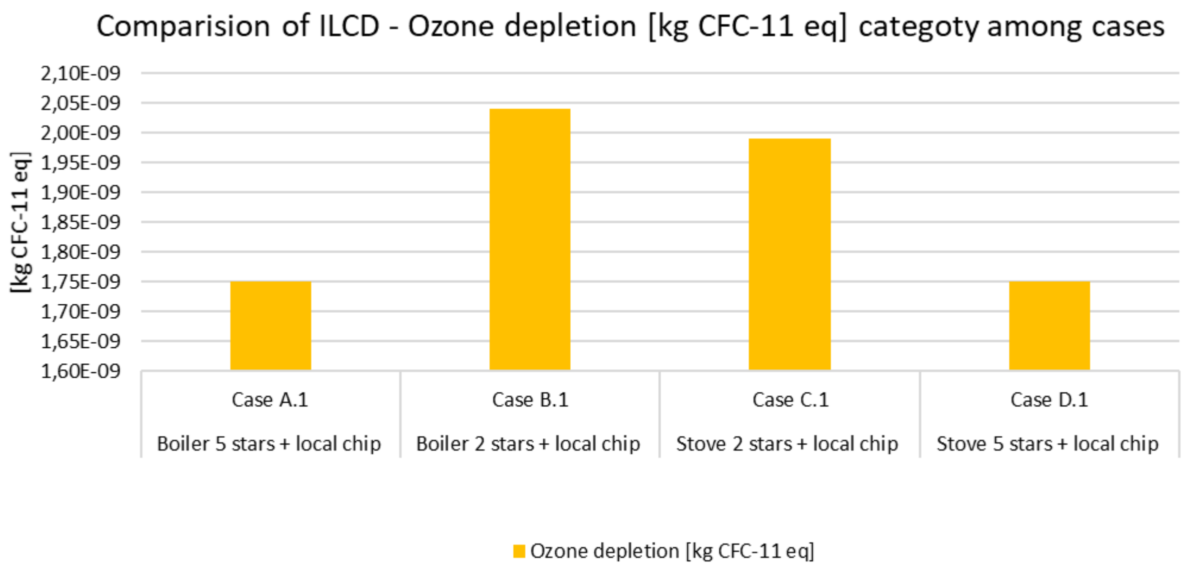


Figure 86 – Comparison of emission in Ozone Depletion impact category in each case

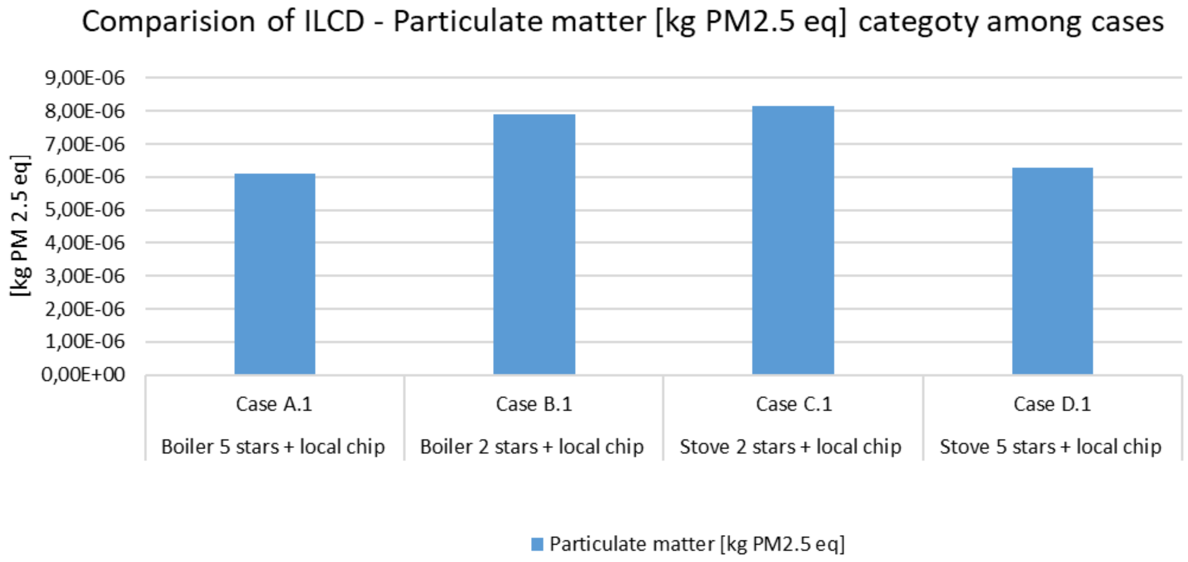


Figure 87 - Comparison of emission in Particulate Matter impact category in each case

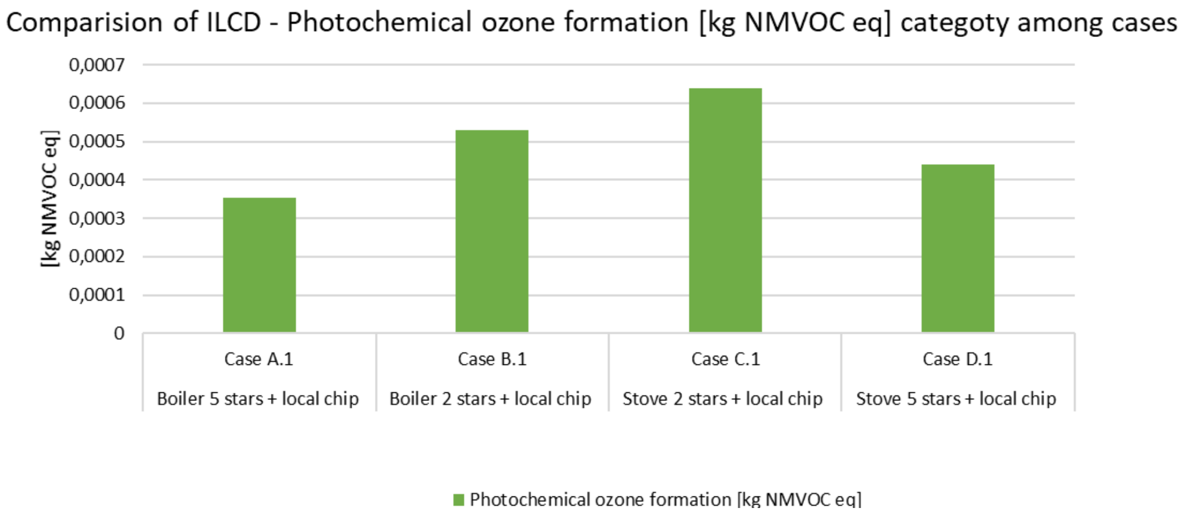


Figure 88 - Comparison of emission in Photochemical Ozone Formation impact category in each case.

The reduction of direct emissions is due to decrease fuel requirements and associated transport for the cases selected. The emissions from stove/boilers construction and transportation remain negligible, so it is safe to say that the emission scale is proportional to the efficiency. For the old stove/boiler, a 1%-point change in efficiency would result in 2% change in [kgCO_2eq] emissions.

Now it is crucial to underline the differences between stove and boilers systems. From previous part, it was clear that 5-stars systems have better performances in term of emission. But two high quality systems are mostly close in performances so we are going to analyze the little differences that could help to indicate the most suitable appliance in term of environmental impact.

The comparison of the two models is shown in Figure 89. The histogram below wants to declare how much a 5-stars stove decrease emission rather than 5-stars boilers. If the percentage is positive means that the stove has better performances, otherwise boiler wins.

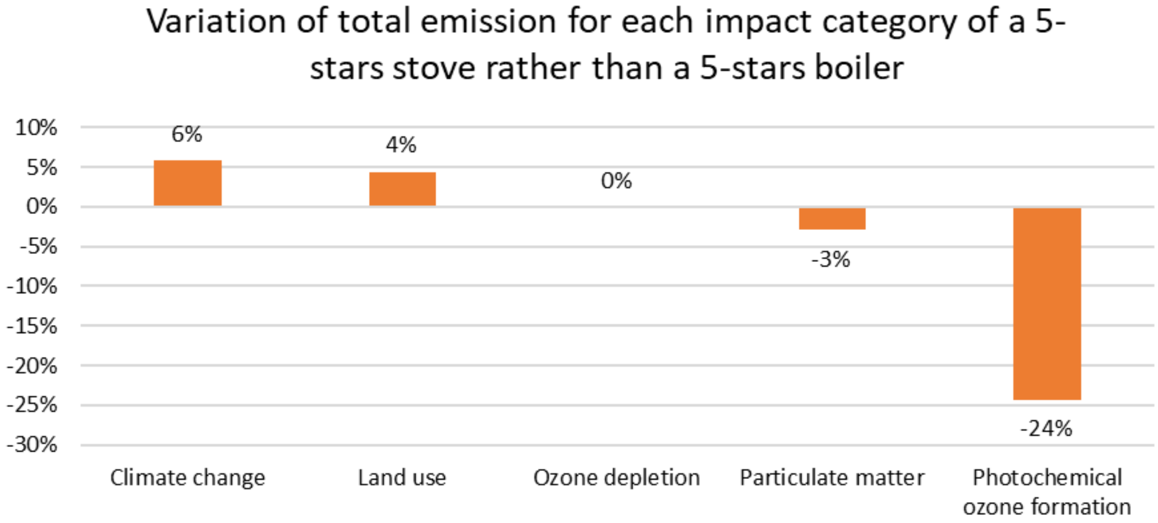
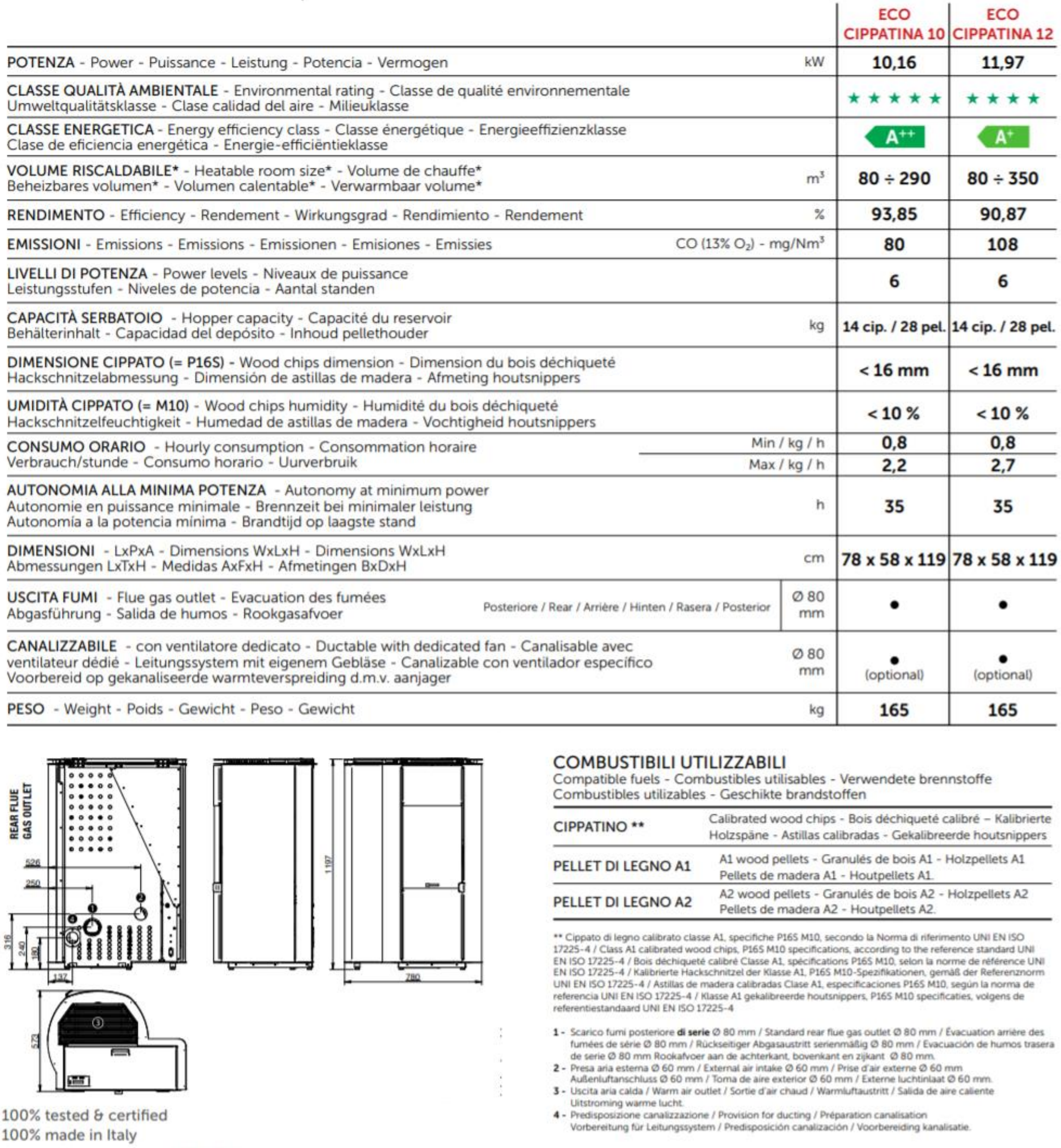


Figure 89 – Reduction of emission for each impact categories. The graph expresses in percentage the reduction of emissions in a 5-stars stove rather than a 5-stars boiler. It means that for Climate change and Land Use a stove system is better than boiler because we have a significand reduction, in Particulate Matter and Ozone Formation the stove has very bad performances.

The decreased performances in PM2.5 emissions for the stove is due to the un-combustion process formed. A chip-boiler system has a controlled combustion that guarantee stoichiometric combustion flames. About Climate Change emission the variation is negligible, both systems have efficiencies comparable but the little discrepancy is due to the consideration of electricity supply for boilers functionality. We have to remember that chip-boilers present a mechanical screw which deliver the biofuel into the combustion chamber. The screw is generally automated by electricity from the grid (not self-produced). This supply is not considered in the stove system because the delivered chip is assumed as a manual process, instead auxiliaries need a bit of energy supply but just for the sensor functionalities so the amount is negligible too. For the life cycle, adding the energy factor increase the kg of CO_2 released into the environment. openLCA assumes that the electricity produced in Italy is generated from fossil sources. In overall, boilers maintain high performances under other aspects.

Firstly, the combustion uncontrolled of the stove emits into environments carcinogen materials like Benzo(A)pyrene or NOx [5]. The stove is in contact with people space and the emission of toxic dust is immediate into human health. Chip-boilers, usually, need specific and limited spaces outside the inhabitant places and this precaution prevent any possible of dust transmission or ashes contact.
For final disposition and conclusion, we are going to select the 5-stars boiler as the best environmental combustion solution. The emission coefficient in IPCC methodology is 0,01101 [$kgCO_2$/kWh_th]. In Figures 90 and 91 we want to report the technical datasheet of a common stove and boiler, whose data were used to balance the openLCA software input. As demonstrate, the stove doesn't present any electricity supply.



		ECO CIPPATINA 10	ECO CIPPATINA 12
POTENZA - Power - Puissance - Leistung - Potencia - Vermogen	kW	10,16	11,97
CLASSE QUALITÀ AMBIENTALE - Environmental rating - Classe de qualité environnementale Umweltqualitätsklasse - Clase calidad del aire - Milieuklasse		★★★★★	★★★★
CLASSE ENERGETICA - Energy efficiency class - Classe énergétique - Energieeffizienzklasse Clase de eficiencia energética - Energie-efficiëntieklasse		A++	A+
VOLUME RISCALDABILE* - Heatable room size* - Volume de chauffe* Beheizbares volumen* - Volumen calentable* - Verwarmbaar volume*	m^3	80 ÷ 290	80 ÷ 350
RENDIMENTO - Efficiency - Rendement - Wirkungsgrad - Rendimiento - Rendement	%	93,85	90,87
EMISSIONI - Emissions - Emissions - Emissionen - Emisiones - Emissies	CO (13% O_2) - mg/Nm^3	80	108
LIVELLI DI POTENZA - Power levels - Niveaux de puissance Leistungsstufen - Niveles de potencia - Aantal standen		6	6
CAPACITÀ SERBATOIO - Hopper capacity - Capacité du reservoir Behälterinhalt - Capacidad del depósito - Inhoud pellethouder	kg	14 cip. / 28 pel.	14 cip. / 28 pel.
DIMENSIONE CIPPATO (= P16S) - Wood chips dimension - Dimension du bois déchiqueté Hackschnitzelabmessung - Dimensión de astillas de madera - Afmeting houtsnippers		< 16 mm	< 16 mm
UMIDITÀ CIPPATO (= M10) - Wood chips humidity - Humidité du bois déchiqueté Hackschnitzelfeuchtigkeit - Humedad de astillas de madera - Vochtigheid houtsnippers		< 10 %	< 10 %
CONSUMO ORARIO - Hourly consumption - Consommation horaire Verbrauch/stunde - Consumo horario - Uurverbruik	Min / kg / h	0,8	0,8
	Max / kg / h	2,2	2,7
AUTONOMIA ALLA MINIMA POTENZA - Autonomy at minimum power Autonomie en puissance minimale - Brennzeit bei minimaler leistung Autonomía a la potencia mínima - Brandtijd op laagste stand	h	35	35
DIMENSIONI - LxPxA - Dimensions WxLxH - Dimensions WxLxH Abmessungen LxTxH - Medidas AxFxH - Afmetingen BxDxH	cm	78 x 58 x 119	78 x 58 x 119
USCITA FUMI - Flue gas outlet - Evacuation des fumées Abgasführung - Salida de humos - Rookgasafvoer — Posteriore / Rear / Arrière / Hinten / Rasera / Posterior	Ø 80 mm	●	●
CANALIZZABILE - con ventilatore dedicato - Ductable with dedicated fan - Canalisable avec ventilateur dédié - Leitungssystem mit eigenem Gebläse - Canalizable con ventilador específico Voorbereid op gekanaliseerde warmteverspreiding d.m.v. aanjager	Ø 80 mm	● (optional)	● (optional)
PESO - Weight - Poids - Gewicht - Peso - Gewicht	kg	165	165

100% tested & certified
100% made in Italy

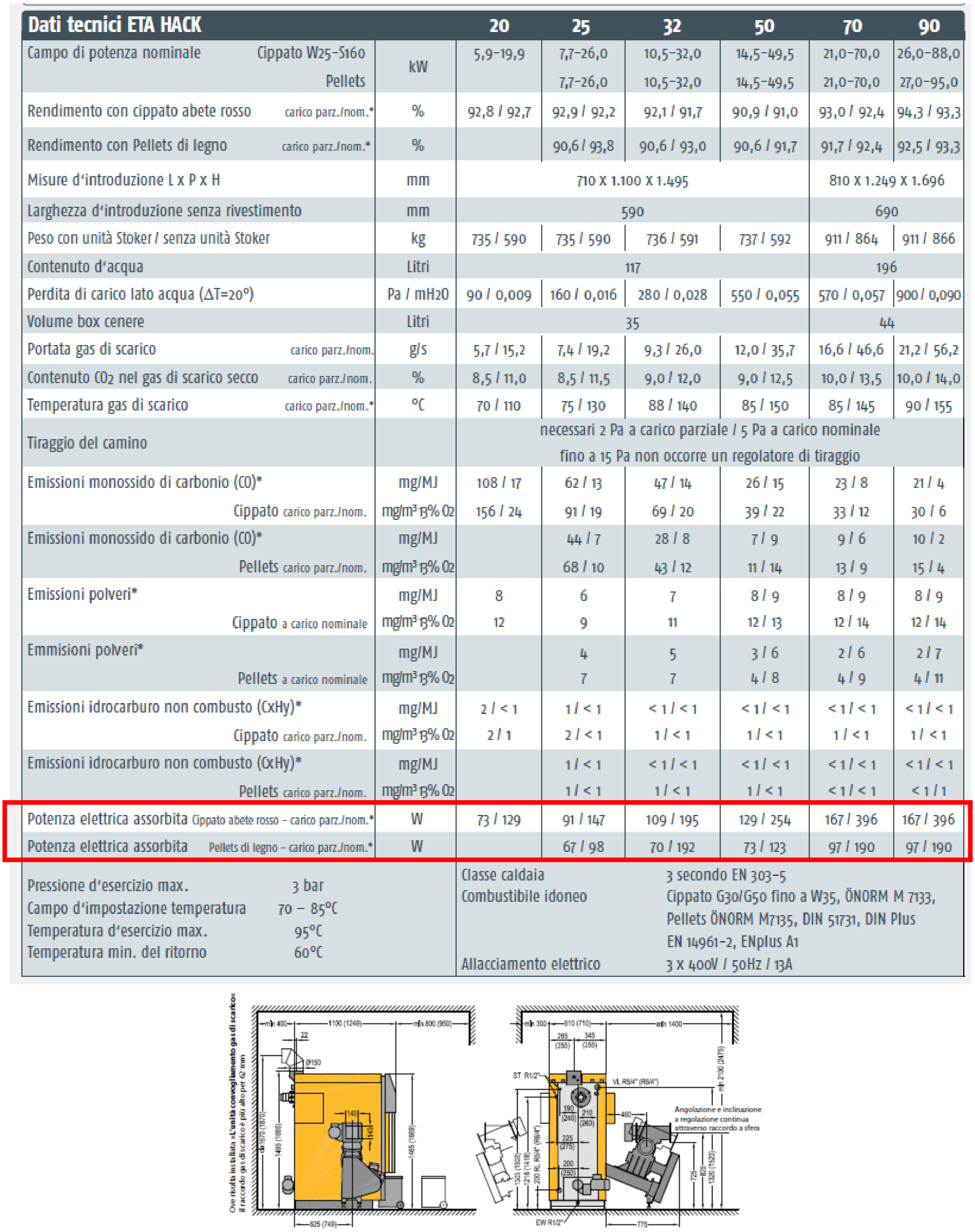
COMBUSTIBILI UTILIZZABILI
Compatible fuels - Combustibles utilisables - Verwendete brennstoffe
Combustibles utilizables - Geschikte brandstoffen

CIPPATINO **	Calibrated wood chips - Bois déchiqueté calibré – Kalibrierte Holzspäne - Astillas calibradas - Gekalibreerde houtsnippers
PELLET DI LEGNO A1	A1 wood pellets - Granulés de bois A1 - Holzpellets A1 Pellets de madera A1 - Houtpellets A1.
PELLET DI LEGNO A2	A2 wood pellets - Granulés de bois A2 - Holzpellets A2 Pellets de madera A2 - Houtpellets A2.

** Cippato di legno calibrato classe A1, specifiche P16S M10, secondo la Norma di riferimento UNI EN ISO 17225-4 / Class A1 calibrated wood chips, P16S M10 specifications, according to the reference standard UNI EN ISO 17225-4 / Bois déchiqueté calibré Classe A1, spécifications P16S M10, selon la norme de référence UNI EN ISO 17225-4 / Kalibrierte Hackschnitzel der Klasse A1, P16S M10-Spezifikationen, gemäß der Referenznorm UNI EN ISO 17225-4 / Astillas de madera calibradas Clase A1, especificaciones P16S M10, según la norma de referencia UNI EN ISO 17225-4 / Klasse A1 gekalibreerde houtsnippers, P16S M10 specificaties, volgens de referentiestandaard UNI EN ISO 17225-4

1 - Scarico fumi posteriore **di serie** Ø 80 mm / Standard rear flue gas outlet Ø 80 mm / Évacuation arrière des fumées de série Ø 80 mm / Rückseitiger Abgasaustritt serienmäßig Ø 80 mm / Evacuación de humos trasera de serie Ø 80 mm Rookafvoer aan de achterkant, bovenkant en zijkant Ø 80 mm.
2 - Presa aria esterna Ø 60 mm / External air intake Ø 60 mm / Prise d'air externe Ø 60 mm Außenluftanschluss Ø 60 mm / Toma de aire exterior Ø 60 mm / Externe luchtinlaat Ø 60 mm.
3 - Uscita aria calda / Warm air outlet / Sortie d'air chaud / Warmluftaustritt / Salida de aire caliente Uitstroming warme lucht.
4 - Predisposizione canalizzazione / Provision for ducting / Préparation canalisation Vorbereitung für Leitungssystem / Predisposición canalización / Voorbereiding kanalisatie.

Figure 90 – Datasheet of an example stove used as example for the analysis.



Dati tecnici ETA HACK		20	25	32	50	70	90
Campo di potenza nominale Cippato W25-S160	kW	5,9-19,9	7,7-26,0	10,5-32,0	14,5-49,5	21,0-70,0	26,0-88,0
Pellets			7,7-26,0	10,5-32,0	14,5-49,5	21,0-70,0	27,0-95,0
Rendimento con cippato abete rosso carico parz./nom.*	%	92,8 / 92,7	92,9 / 92,2	92,1 / 91,7	90,9 / 91,0	93,0 / 92,4	94,3 / 93,3
Rendimento con Pellets di legno carico parz./nom.*	%		90,6 / 93,8	90,6 / 93,0	90,6 / 91,7	91,7 / 92,4	92,5 / 93,3
Misure d'introduzione L x P x H	mm	710 X 1.100 X 1.495				810 X 1.249 X 1.696	
Larghezza d'introduzione senza rivestimento	mm	590				690	
Peso con unità Stoker / senza unità Stoker	kg	735 / 590	735 / 590	736 / 591	737 / 592	911 / 864	911 / 866
Contenuto d'acqua	Litri	117				196	
Perdita di carico lato acqua (ΔT=20°)	Pa / mH20	90 / 0,009	160 / 0,016	280 / 0,028	550 / 0,055	570 / 0,057	900 / 0,090
Volume box cenere	Litri	35				44	
Portata gas di scarico carico parz./nom.	g/s	5,7 / 15,2	7,4 / 19,2	9,3 / 26,0	12,0 / 35,7	16,6 / 46,6	21,2 / 56,2
Contenuto CO_2 nel gas di scarico secco carico parz./nom.	%	8,5 / 11,0	8,5 / 11,5	9,0 / 12,0	9,0 / 12,5	10,0 / 13,5	10,0 / 14,0
Temperatura gas di scarico carico parz./nom.*	°C	70 / 110	75 / 130	88 / 140	85 / 150	85 / 145	90 / 155
Tiraggio del camino		necessari 2 Pa a carico parziale / 5 Pa a carico nominale fino a 15 Pa non occorre un regolatore di tiraggio					
Emissioni monossido di carbonio (CO)*	mg/MJ	108 / 17	62 / 13	47 / 14	26 / 15	23 / 8	21 / 4
Cippato carico parz./nom.	mg/m³ 13% O_2	156 / 24	91 / 19	69 / 20	39 / 22	33 / 12	30 / 6
Emissioni monossido di carbonio (CO)*	mg/MJ		44 / 7	28 / 8	7 / 9	9 / 6	10 / 2
Pellets carico parz./nom.	mg/m³ 13% O_2		68 / 10	43 / 12	11 / 14	13 / 9	15 / 4
Emissioni polveri*	mg/MJ	8	6	7	8 / 9	8 / 9	8 / 9
Cippato a carico nominale	mg/m³ 13% O_2	12	9	11	12 / 13	12 / 14	12 / 14
Emmisioni polveri*	mg/MJ		4	5	3 / 6	2 / 6	2 / 7
Pellets a carico nominale	mg/m³ 13% O_2		7	7	4 / 8	4 / 9	4 / 11
Emissioni idrocarburo non combusto (CxHy)*	mg/MJ	2 / < 1	1 / < 1	< 1 / < 1	< 1 / < 1	< 1 / < 1	< 1 / < 1
Cippato carico parz./nom.	mg/m³ 13% O_2	2 / 1	2 / < 1	1 / < 1	1 / < 1	1 / < 1	1 / < 1
Emissioni idrocarburo non combusto (CxHy)*	mg/MJ		1 / < 1	< 1 / < 1	< 1 / < 1	< 1 / < 1	< 1 / < 1
Pellets carico parz./nom.	mg/m³ 13% O_2		1 / < 1	1 / < 1	1 / < 1	< 1 / < 1	< 1 / 1
Potenza elettrica assorbita Cippato abete rosso – carico parz./nom.*	W	73 / 129	91 / 147	109 / 195	129 / 254	167 / 396	167 / 396
Potenza elettrica assorbita Pellets di legno – carico parz./nom.*	W		67 / 98	70 / 192	73 / 123	97 / 190	97 / 190

Pressione d'esercizio max.	3 bar	Classe caldaia	3 secondo EN 303-5
Campo d'impostazione temperatura	70 – 85°C	Combustibile idoneo	Cippato G30/G50 fino a W35, ÖNORM M 7133, Pellets ÖNORM M7135, DIN 51731, DIN Plus EN 14961-2, ENplus A1
Temperatura d'esercizio max.	95°C		
Temperatura min. del ritorno	60°C	Allacciamento elettrico	3 x 400V / 50Hz / 13A

Figure 91 – Datasheet of an example chip-boiler used as example for the analysis. As it can be visible, the electricity supply for its operational function is present and underline in red.

5.2. FINAL RESULTS

From the simulations carried out in open LCA and from all the scenarios highlighted, we can summarize the selected cases 'emission in Figure 92 according to the IPCC values.
For Local biomass we assert the only supply process to obtain 1 kg of chip collected within 50 km of a hypothetical logistic delivery plant.
The chip selected in the area are then considered combustion part of two local system: OFF-GRID (a cogeneration plant providing electricity and thermal energy to habitants) and ON-GRID (small combustion systems providing only thermal energy but still connected to the grid for auxiliary's functionality).

Local chip production (CASE 1)
kgCO2eq/kg
0,02978

OFF-GRID system (CASE E.1)	kgCO2eq/kWh_el	0,03493
	kgCO2eq/kWh_th	0
ON-GRID Scenario (CASE A.1)	kgCO2eq/kWh_el	0,312
	kgCO2eq/kWh_th	0,011

Figure 92 – Coefficient estimated by openLCA according to IPCC methodology and used for next simulation. Local biomass selected (within 50km) is the combustion source for the two system of energy supply.

As noticing, values are low due to the starting process of collecting biomass. The local biomass supply chain guarantees high standard in environmental impact and avoid excesses in term of emission.

5.3. COMPARISON WITH EMISSION FACTOR DL 3.2

From Deliverable 3.2 there was an annual emission strongly dependent on the type of fuels used in the industrial sector. 59% of electricity consumption derives from industrial activities while 39% from private residences only. The public sector accounts for only 2% of the global electricity balance. Currently, the entire area analyzed consumes 107.768 [MWh / year] of electricity annually, which correspond (considering actual renewable and non-renewable supply systems) 33.624 [tCO_2eq/year].
On thermal side, we cannot say with certainty which sector is the most energy-intensive, but we know that the fuel widely used (with rare exceptions) is natural gas. On average, 60% of the thermal demand is covered by this source which is associated with an emission coefficient of 0,202 [tCO_2eq/MWh]. All the emission coefficients estimated according to the International Climate Change Panel are summarized in Figure 93.

Type of biomass	Local	CO$_2$ emission factors	Non-local	CO$_2$ emission factors	Global CO$_2$ emission factors
	[%]	tCO$_2$/MWh	[%]	tCO$_2$/MWh	tCO$_2$/MWh
Average biomass	70%	0,000	30%	0,403	0,121

Electricity	Fossil fuels					Renewable energies		
Local	Natural gas	Liquid gas	Heating oil	Diesel	Gasoline	Other biomass	Local Biomass	Gc Area Biomass
tCO$_2$/MWh								
0,312	0,202	0,227	0,267	0,267	0,249	0,403	0	0,121

Figure 93 – Summary of the emission coefficient used for Deliverable 3.2.

To better compare the future emissive scenario with respect to the current one, we only need to consider non-renewable energy sources of supply.

For electricity we exclude the current sources of solar panels and consider only the consumption covered by the local distributor; for thermal energy we must consider an average coefficient weighed between the actual consumption of the area and the coefficient of each energy carrier. From the preliminary analyses the actual annual consumption is presented in Figure 94 and with them also the weighted coefficient with which we will carry out the analyses.

	[MWh$_{th}$/*year]*	**[tCO$_2$/*year]***
Natural gas	60317	0,202
Diesel fuel	22436	0,267
LPG	13503	0,227

Mean Coeff.	**[tCO2eq/MWh]**	0,220

Figure 94 – Emissive coefficients of non-renewable energy carriers. At the bottom there is also the weighted mean coefficient of the vectors that will be used in comparative analyses.

For define what we are comparing now rather than Deliverable 3.2, we can see figure 95. For each energy vector there are subsequential values for previous and actual emission according to IPCC methodology.

Energy Form	**DL3.2 IPCC values**	**OFF-GRID values**	**ON-GRID values**	**Units**
Electricity	0,312	0,0349	0,312	kgCO2eq/kWh
HVAC	0,220	0	0,011	kgCO2eq/kWh

Figure 95 – Comparison between previous emission and new ones for a correct evaluation of [kgCO$_2$eq/kWh.

6. LIFE TERRITORY SIMULATION SCENARIO

6.1. LIFE TERRITORY SIMULATION SCENARIO

The KPIs already selected in DL 3.2 were applied to the electrical and thermal consumption to evaluate emissions of the entire project territory. The emission simulation is based on two types of configurations: one at the end of the project and another 5 years after the end of the project, both simulations will use the emission factors calculated in this Deliverable 3.4.

The scenario at the end of the project was simulated assuming the following parameters:

- the replacement of 15% of existing traditional wood boilers with high efficiency Wood chip boiler. It was also considered to increase by 20% the use of local biomass from sustainable forest management.
- the replacement of 15% of existing fossil fuel boilers with high efficiency Wood chip boiler. It was also considered to increase by 20% the use of local biomass from sustainable forest management.
- the installation of 3 micro-cogeneration systems (Bagnolo Piemonte, Barge, Sanfront) in the project area with thermal and electrical connection.
- a 2% reduction in general electricity consumption due to a greater awareness of the population after the meetings relating to the energy community.

HVAC consumption and emissions - Simulation - At the end of the project												
Sign	Biomass		Natural gas		Diesel fuel		LPG		Solar thermal panels		Biomass district heating	
	[MWh$_{th}$/year]	*[tCO$_2$/year]*	*[MWh$_{th}$/year]*	*[tCO$_2$/year]*	*[MWh$_{th}$/year]*	*[tCO$_2$/year]*	*[MWh$_{th}$/year]*	*[tCO$_2$/year]*	*[MWh$_{th}$/year]*	*[tCO$_2$/year]*	*[MWh$_{th}$/year]*	*[tCO$_2$/year]*
	Simulation - At the end of the project											
BAP	9.963	699	12.961	2.618	5.112	1.365	4.648	1.055	78		166	1
BAR	19.106	1.341	16.623	3.358	5.288	1.412	3.986	905	81		321	9
BRO	555	39	387	78	86	23	308	70				
CRI	402	28	170	34	321	86	114	26	1			
ENV	3.517	247	2.348	474	1.214	324	1.079	245	14		294	8
GAM	366	26	727	147	121	32	192	44				
MAP	1.280	90	1.999	404	329	88	394	90				
ONC	215	15	143	29	39	11	4	1				
OST	306	21	154	31	102	27	18	4	0			
PAE	5.591	392	5.541	1.119	3.238	864	484	110	38			
PAG	982	69	1.551	313	138	37	102	23	6			
REV	6.884	483	10.764	2.174	4.059	1.084	1.417	322	95		37	1
RIF	1.161	81	1.995	403	653	174	217	49	6			
SAN	2.446	172	4.955	1.001	1.736	463	539	122	31		166	5
TOTAL	52.776	3.703	60.317	12.184	22.436	5.990	13.503	3.065	348		984	24

Figure 96 – Values of emission in the first simulation of the territory at the end of the project.

The scenario beyond 5 years after the end of the project was simulated assuming the following parameters:

- the replacement of 30% of existing traditional wood boilers with condensing high efficiency Wood chip boiler. It was also considered to increase by 20% the use of local biomass from sustainable forest management.
- the replacement of 30% of existing fossil fuel boilers with high efficiency Wood chip boiler. It was also considered to increase by 20% the use of local biomass from sustainable forest management.
- the installation of one micro-cogeneration systems for each municipality and 2 in Bagnolo Piemonte, Barge, and Sanfront, with thermal and electrical connection.
- a 3% reduction in general electricity consumption due to a greater awareness of the population after the meetings relating to the energy community.

HVAC consumption and emissions - Simulation - Beyond 5 years after the end of the project												
Sign	Biomass		Natural gas		Diesel fuel		LPG		Solar thermal panels		Biomass district heating	
	[MWh$_{th}$ /year]	*[tCO$_2$/year]*	*[MWh$_{th}$/ year]*	*[tCO$_2$/year]*	*[MWh$_{th}$/ year]*	*[tCO$_2$/year]*	*[MWh$_{th}$/ year]*	*[tCO$_2$/year]*	*[MWh$_{th}$/year]*	*[tCO$_2$ /year]*	*[MWh$_{th}$/ year]*	*[tCO$_2$/year]*
	Simulation - At the end of the project											
BAP	12.372	868	10.561	2.133	3.709	990	3.362	763	66		498	35
BAR	21.709	1.523	13.628	2.753	3.803	1.015	2.826	642	68		653	46
BRO	628	44	239	48	25	7	191	43			160	11
CRI	454	32	60	12	201	54	45	10	1		160	11
ENV	3.986	280	1.949	394	797	213	696	158	12		454	32
GAM	484	34	519	105	51	14	104	24			160	11
MAP	1.583	111	1.567	316	207	55	256	58			160	11
ONC	232	16	38	8	-10	-3	-37	-8			160	11
OST	329	23	47	9	37	10	-27	-6	0		160	11
PAE	6.527	458	4.483	906	2.388	638	323	73	32		160	11
PAG	1.187	83	1.197	242	64	17	37	8	5		160	11
REV	8.666	608	8.796	1.777	2.995	800	1.013	230	81		197	14
RIF	1.480	104	1.563	316	449	120	123	28	5		160	11
SAN	3.286	231	4.057	820	1.222	326	324	74	26		320	22
TOTAL	62.923	4.415	48.702	9.838	15.937	4.255	9.237	2.097	296		3.562	250

Figure 97 – Values of emission in the second simulation of the territory 5 year after the end of the project.

Inconclusion, the final comparison between the two simulations and the current state confirms an improved environmental balance for the benefit of the community. The evaluations only consider the demand for thermal requirements. In this simulation, reductions reach 20% of [tCO$_2$eq] issued at the end of the project and 33% at five years after.

GC AREA	HVAC energy consumption and related CO2 emissions		HVAC consumption and emissions reduction - Simulation - At the end of the project				HVAC consumption and emissions reduction - Simulation - Beyond 5 years after the end of the project			
Sign	*[MWh$_{th}$/year]*	*[tCO$_2$/year]*	*[MWh$_{th}$/year]*	*[tCO$_2$/year]*	*[%]*	*[%]*	*[MWh$_{th}$/year]*	*[tCO$_2$/year]*	*[%]*	*[%]*
BAP	34.685	7.059	32.928	5.738	5,07%	18,71%	30.568	4.790	11,87%	32,15%
BAR	48.029	9.005	45.405	7.024	5,46%	22,00%	42.687	5.979	11,12%	33,61%
BRO	1.399	265	1.337	210	4,46%	20,63%	1.243	154	11,18%	42,01%
CRI	1.091	229	1.008	174	7,59%	24,05%	921	119	15,58%	48,05%
ENV	8.998	1.703	8.466	1.298	5,91%	23,77%	7.894	1.076	12,27%	36,83%
GAM	1.490	301	1.407	249	5,56%	17,38%	1.318	187	11,53%	37,77%
MAP	4.305	849	4.003	671	7,02%	20,98%	3.772	552	12,39%	35,01%
ONC	413	71	402	55	2,70%	22,28%	383	24	7,32%	66,38%
OST	813	168	580	84	28,68%	50,13%	546	47	32,90%	71,78%
PAE	15.986	3.168	14.891	2.486	6,85%	21,54%	13.914	2.086	12,96%	34,17%
PAG	2.972	555	2.779	442	6,48%	20,34%	2.649	362	10,85%	34,87%
REV	23.910	4.839	23.255	4.064	2,74%	16,03%	21.748	3.428	9,04%	29,16%
RIF	4.138	838	4.032	708	2,57%	15,51%	3.781	579	8,64%	30,94%
SAN	11.100	2.347	9.872	1.763	11,06%	24,89%	9.235	1.472	16,80%	37,27%
TOTAL	**159.328**	**31.399**	**150.366**	**24.967**	**5,63%**	**20,49%**	**140.657**	**20.854**	**11,72%**	**33,58%**

Figure 98 – Final values of emission for both simulation of the territory in comparison with actual emission.

6.2. OFF-GRID AND ON-GRID SIMULATION SCENARIO

If all area of Valle Po intends to convert actual sources of energy gradually and totally with more efficient systems, the total amount of CO$_2$eq will decrease. In this section we have performed the emissive rate of CO$_2$eq that would be reached variating the spread of supply.

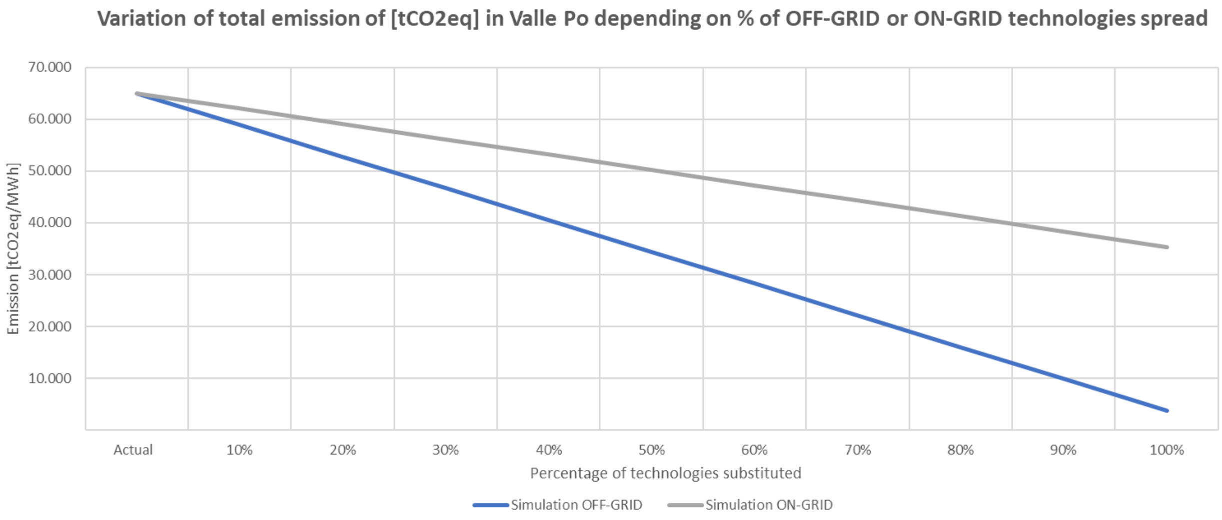
The trend line will be different depending on the system replaced (e.g., OFF-GRID or ON-GRID). Starting from actual situation and keeping constant the consumption values required by the population, we compare the current state of CO$_2$ emitted by replacing the supply with cogeneration biomass systems and 5-stars boilers, both systems are fed by local biomass. Figure 99 shows trends in two cases.

The maximum reduction obtainable is 94% (from 65.023 [tCO$_2$eq/year] to 3764) in the case of OFF-GRID systems and 46% for ON-GRID appliances (from 65.023 [tCO$_2$eq/year] to 35.378). A 100% replacement of the current sources would not be feasible due to landscape constraints, but only replacing the 30% of the area with one of the two system will provide respectively a reduction of 34% and 14%.

As visible, the trend of OFF-GRID emission decreases more rapidly than ON-GRID systems because cogeneration plant guarantees electricity and heat. The heat distributed is obtained by a refrigerating process internal of the plant so, with the same amount of emission, it is possible withdraw two kind of energy demand and decrease remarkably the content of CO$_2$ despite high local consumption.

This discount in environmental aspect is due to the burner. The heat produced is transferred to a working fluid, for example water. The pressure of the confined fluid increases, acquiring mechanical energy. This is captured by a turbine which imprints a rotary motion on an axis and permit the production of electricity. Not all the energy contained in the steam is transferred to the turbine. Part of it remains in the working fluid in the form of thermal energy, which can be transferred, for example, to a hot water circuit, and used for all conceivable uses.

For ON-GRID scenario, instead, the electricity is still supplied by national distributor and only the amount of emission for HVAC demand is reduced. Thermal energy is the only supply and production in these systems.



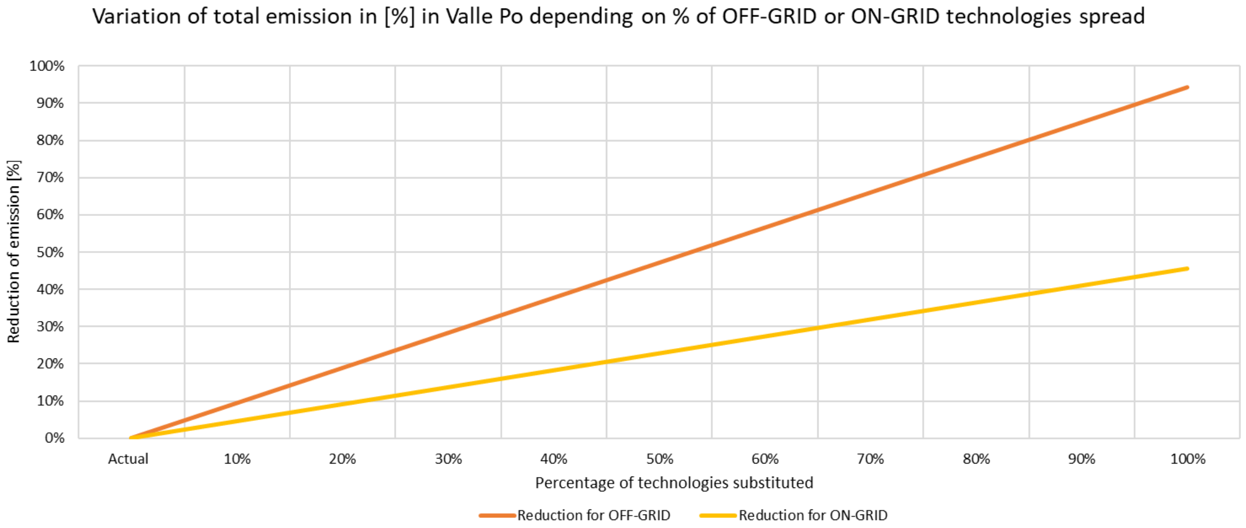


Figure 99 – Representation of local CO_2 reductions if existing energy sources were gradually replaced by OFF-GRID or ON-GRID systems.

7. CONCLUSION AND NEXT ACTIONS

7.1. CONCLUSIONS

The deliverable determines the emission factors of the entire process: biomass cutting (local and non-local), chipping, transport, production of electrical and thermal energy (on-grid and off-grid scenario). Two main methodologies are used to determine the final value: IPCC GWP 20a and ILCD 2011+ Midpoint. The results of the analysis allowed us to arrive at the conclusions listed below.

- Analyses carried out to calculate the emission factors of local and non-local biomass fuel production. We have shown that a local biomass harvest impacts 70% less than an imported product. Local chip generates **0,029** kgCO_2eq/kg of wood chips produced while 1 kg of wood chips imported from 3100 km away produces 0,097 kgCO_2eq/kg. The differences are essentially in the quantities of fossil fuel for the machineries used in the supply chain (transport, chipper etc.).

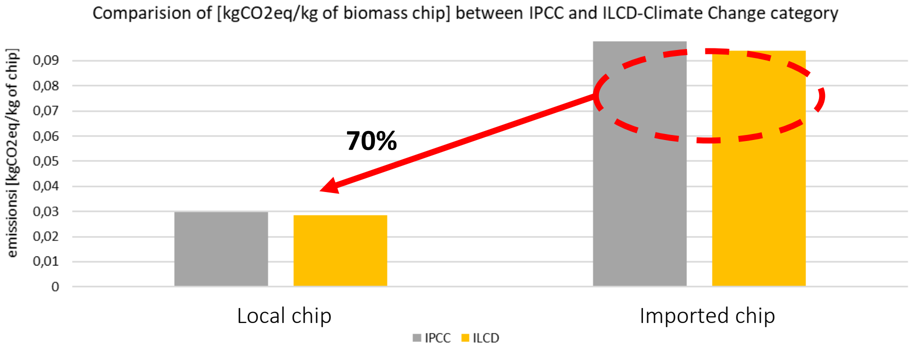


Figure 100 - Comparison of emission [kgCO2eq/kg of biomass chip] between local and imported

In the other impact categories (land use, Ozone, PM, photochemical ozone formation) the results show a decrease in values for the local chip between 60% and 70% compared to the non-local chip (3100 km travel distance).

	Impact category	Reference unit	Result	[%] of reduction rather than importe chip
Local chip	Climate change	kg CO2 eq	0,028	70%
	Land use	kg C deficit	0,072	70%
	Ozone depletion	kg CFC-11 eq	0,000	70%
	Particulate matter	kg PM2.5 eq	0,000	65%
	Photochemical ozone formation	kg NMVOC eq	0,000	62%

Figure 101 - Biomass supply chain: environmental impact results

- The supply chains hypothesized for local and imported chip are qualitatively equal, but quantitatively not. The input data for each system varies according on dimension of machineries used. For imported solutions, the supply chain considers industrial machineries for great quantities productions. This consideration highlights the relevant role of the chipping machine (transport to forest and usage). The impact of its process contributes to the chain heavier than transport influences. In the following graph we can see the weight in percentage for each contribution phase to better quantify every influence.

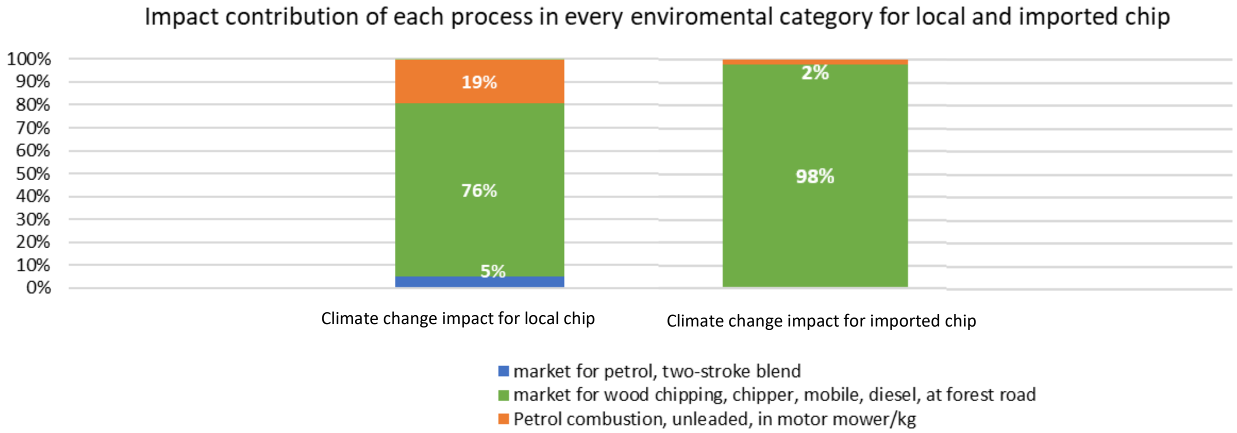


Figure 102 - Impact contribution of each process for local non imported chip

- Subsequently, a comparative analysis was carried out between current emissions (average from fossil sources) and emissions deriving from the production of thermal energy and electricity from local biomass. Two configurations were therefore defined: OFF-grid (combined production of electrical and thermal energy) and ON-Grid (thermal production from a 5-star boiler and electricity production from the national grid). This comparison allows us to demonstrate how biomass thermal production reduces emissions by 90% and biomass electricity production reduces emissions by 95%. With a cogeneration system, thermal emissions are equal to zero as thermal energy is a process energy deriving from the cooling of electrical production systems, therefore the advantage is even greater.

Energy	**Actual IPCC Coefficient**	**OFF-GRID system**	**ON-GRID system**
	kgCO2eq/kWh	kgCO2eq/kWh	
Electricity	0,312 (energy grid)	0,034	0,312
		reduction 90%	
HVAC	0,220 (average value between LPG, Diesel, Natural Gas)	0	0,011
		reduction 100%	reduction 95%

Figure 103 - Comparison between the coefficients of CO2 emissions for the production of 1kWh of thermal and electrical energy between the fossil scenario and the biomass scenario

- By simulating energy efficiency scenarios in the LIFE project area, it emerges that by replacing 50% of the plants (fossil fuel) with biomass systems for thermal energy production (5-star boiler) and cogeneration systems for joint electrical and thermal production, they can have emissions reductions of between 23% and 47% (total emissions sum of thermal + electric).

	Actual configuration	**OFF-GRID system [50%]**	**ON-GRID system [50%]**	**Units**
Emission	65022	34393	50200	$tCO_2eq/year$
Reduction	0%	47%	23%	%

Figure 104 - Reduction of emissions in LIFE area resulting from the replacement of 50% of the fossil plants with high efficiency biomass systems

- There is a high share of old stoves in LIFE area households (most of them are fireplaces o old boiler not checked), there is thus significant potential for improvement in residential wood combustion. Also, for electricity side, the potentiality is high in the region. Most of regional habitants and industries are strongly related to the national grid. Stronger policies will encourage the replacement of old systems, especially financial incentives. This kind of return is possible thanks to "Conto Termico" of GSE (national authority). The GSE procedure facilitates the use of heat pumps, stoves and boilers ecolabelled with financial cover of 65% of initial investment. For OFF-GRID replacement, local authorities or private initiative will count on incentives for High Efficiency Cogeneration plant. GSE provides these types of incentives too.
Then there are the incentives linked to the renewable energy communities (CER) which allow to obtain a premium of 119 € MWH on the electricity produced from renewable sources and self-consumed within the community.

- After considering various solutions suitable for rural/mountainous area we can conclude that both scenarios have optimal aspect to implement.
    - The OFF-GRID solutions is indicated for renewable energy communities (CER) next to accessible transport viability. The system needs a great initial investment and continuous maintenance, it is not affordable by every single citizen;
    - ON-GRID solutions would be perfect for isolated locations that currently use fossil fuels. This solution is a reliable appliance, but it is necessary a correct usage and consciousness from every single owner.

- To allow the diffusion of these technologies using a biomass of local and sustainable origin, it is therefore essential to provide good training to end users, also through information campaigns by the Life project and local authorities. Local authorities need to promote information campaign to allow citizen to recognize the potential, criticalities, and methods of use of individual technologies in order to allow an informed choice.

7.2. NEXT ACTIONS

After those conclusions, the next steps will be:

- upgrade of updated data relating mainly to biomass consumption through the energy tool and automatic loading on the DSS platform (task C4.1);
- support to the creation of energy mapper connected to the DSS platform (task C4.1);
- implementation of territorial SECAP (task C 4.2) starting from the data collected in this deliverable and from the preliminary results of the business cases in order to plan the Monitoring plan;
- support in the Organization of the Logistics related to the Use of residual Biomass for Energy and testing of real biomass and ashes in the GreenPlasma CHP (WP C.7).

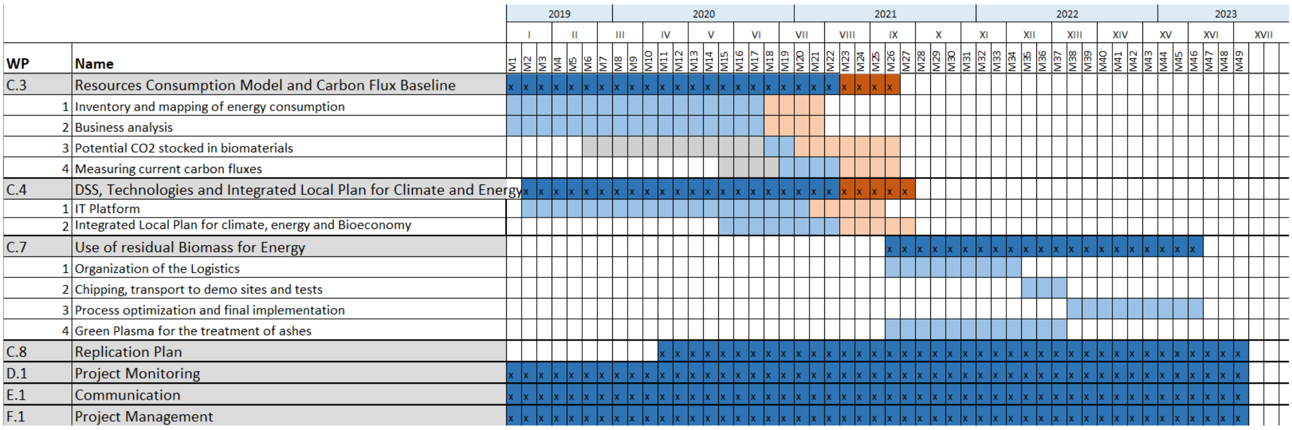


Figure 105 - Gantt related to the WP C.3, C.4, C.7

These actions will be preparatory to the:

- DL4.2 Integrated local plan for climate, energy, and bioeconomy.

8. REFERENCES

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