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XPRESS

Facilitating green public procurement in the energy sector

Deliverable 4.2

Deliverable 4.2

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info@xpress-h2020.eu
www.xpress-h2020.eu

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Deliverable 4.2

Environmental assessment: goal & scope and life cycle inventory of selected case studies

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Authors	…

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Contributors

Name	Organisation
Alberto Sartoretto	eAmbiente
Cristian Soldati	eAmbiente
Ozgur Gundogan	eAmbiente
Koldo Saez de Bikuna Salinas	eAmbiente

Peer Reviews

Name	Organisation
Ozgur Gundogan	eAmbiente
Manfredi Vale	eAmbiente

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1. Introduction

This deliverable builds on and completes previous work, namely the submitted D4.1 *Construction of a specific framework for the assessment of the whole sustainability of RES technology application* and D2.5 *Building a first LCA dataset of best practice examples*. Individual interviews have been carried out and the XPRESS survey has been launched in November, which is being completed by different SMEs and Public Authorities (PA) in Europe.

Based on the TED analysis performed and looking at the SMEs and PAs that have already positively responded or which have been reached now, eAmbiente suggests:

- To focus on a small selection of case-studies (one per RES technology type) from different countries, in order to carry out a few high-quality LCA case-studies with primary data;
- To parameterize each LCA model so as to cover a wide spectrum of possible configurations (e.g., installed capacity, efficiencies…), RES availability (geography dependent) and electricity grid-mix (country dependent).

Life Cycle Thinking (LCT) approach has been used for this analysis. All relevant life cycle stages related to the life cycle of different RE technologies were considered. The analysis was carried out in according to the LCA methodology, which is regulated by the ISO 14040 [1] and 14044 [2] international standards.

For the upcoming deliverables, environmental impacts will be calculated using the software Simapro 9.1 with the support of Ecoinvent databases. The method chosen is ***Environmental Footprint*** v3.0, developed by European Commission JRC. This method includes the following impact categories:

- Climate change;
- Ozone depletion;
- Ecotoxicity for aquatic fresh water;
- Human toxicity, cancer;
- Human toxicity, non – cancer;
- Particulate matter/respiratory inorganics;

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- Ionising radiation;
- Photochemical ozone formation;
- Acidification;
- Eutrophication – terrestrial;
- Eutrophication – fresh water;
- Eutrophication – marine;
- Water use;
- Resource use – mineral and metals;
- Resource use – fossils;
- Land use.

1.1. Covered RE technologies and involved SMEs and public authorities

1.1.1. ATS – Alto Trevigiano Servizi: power generation with a pressure-drop micro-hydroelectric turbine

The objective of this case study is to assess the environmental profile of a micro hydropower plant of Consorzio Schievenin Alto Trevigiano Servizi (ATS). The Pelton turbine exploits hydraulic energy of drinking water distribution systems to produce electricity. Water is supplied from Mares source to Floriani reservoir in the Municipality of Cison di Valmarino.

In general, micro-hydropower plants have negligible impacts due to existing hydro schemes or being adjacent to existing underground or semi-underground storage reservoirs.

Drinking water is drawn from a high source and delivered to users at controlled pressure by means of pressure-reducing valves. The limited overpressure, together with the water flow, represents the share of wasted hydraulic energy. This residual energy, instead of being dissipated, can be transformed into electrical energy by inserting a hydraulic turbine with an associated electrical generator along the pipeline. In addition to the advantage of producing electrical energy, an installation of this type also offers the advantage that the adduction system is already partially constructed: the inlets, pipes and various necessary structures are usually already in place, thus allowing further savings in terms of costs and environmental impacts.

The energy produced in this way can be described practically as 'clean'. Plants of this type are becoming increasingly popular, where the conditions are favourable.

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The type of hydraulic turbine used is a Pelton turbine (**Figure 1**) as it is quite common in micro-hydroelectric power stations due to the efficiency of exploitation of small flow rates. In **Table 1** are listed characteristics about the turbine, the generator and the transformation centre

Figure 1 – Pelton turbine installed in micro-hydropower station

Table 1 – Characteristics of micro-hydropower plant

Turbine	
Model	Pelton
Power	45 kW
Annual production	391 MWh
Tons of CO_2 not emitted in atmosphere	351 t

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1.1.2. Asparrena Municipality: a refurbished mini-hydropower station from an ancient iron smelting factory

The objective of this case study is to assess the environmental profile of a refurbished mini hydropower plant in the Municipality of Asparrena from an ancient iron smelting factory. Iron smelting factory was built in 1848 and operated until 1985. The factory used the water of the Zirauntza River, in particular the hydraulic jump to produce heat for the forge. After the closure of the factory, there reconversion process took place which led to the creation of a mini-hydroelectric power plant in 2003 (**Figure 3**).

Currently a portion of the river flow goes into a small dam, where the water is stored. The water enters the turbine through a 200 m long and 152 m high steel pipe and exits through a drainage channel before being discharged into the river. Within the turbine, water is sent to a shaft that rotates at 600 rpm. A generator produces electricity at a voltage of 380V. Then, electricity is sent to a transformer, which raises the voltage to about 13'000 V. This process causes the temperature of the water to rise by 6°C. As a result of this heating, a cooling period is necessary before re-discharging the water into the Zirautza River to avoid adverse effects on the ecosystem (**Figure 2**). This project allows the citizens of Asparrena to have enough electricity for civil uses. In **Table 2** are listed characteristics about the turbine, the generator and the transformation centre.

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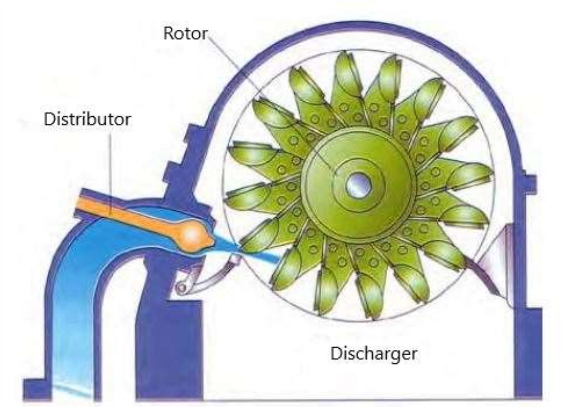

Figure 2 – Pelton turbine installed in mini-hydropower station [3]

Table 2 – Characteristics of mini-hydropower plant

Turbine	
Model	Pelton
Power	967 kW
Jump	152 m
Flow	725 l/s
Velocity	600 round/minute
Generator	
Type	Asynchronous triphasic, horizontal axis
Generator power	970 kW
Velocity synchronous	600 rpm
Voltage	380 V
Transformation centre	
Type	Internal, manoeuvre with SF6 tank and with protective chambers
Power	1250 kVA
Transformation ratio	13200/398-230 V

Figure 3 – Mini-hydropower plant in the Municipality of Asparrena [3]

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1.1.3. Asparrena Municipality: biomass boiler for a mini district-heating plant fuelled with local and sustainably-sourced wood chips

The objective of this case study is to assess the environmental profile of a biomass boiler that was installed in 2015 to heat three public buildings: the public school, the health clinic and the House of Culture (**Figure** *5*). Before that date the heating requirement were met by three natural gas boilers, one for each building. The characteristics of the buildings and the boilers are listed below (**Table 3**):

Table 3 – Characteristics of buildings and natural gas boiler

Building	Characteristics
Public school	• 1200 m^2 • 3 floors • Natural gas boiler with a power of 260 kW • Yield of boiler: 90.8% • Estimated annual hours: 1760 h
Ambulatory	• 325 m^2 • 1 floor • Natural gas boiler with a power of 50 kW • Yield of boiler: 90.8% • Estimated annual hours: 1384 h
House of culture	• 550 m^2 • 3 floors • Natural gas boiler with a power of 100 kW • Yield of boiler: 90.8% • Estimated annual hours: 1592 h

With the aim of reducing the dependence on fossil fuel, in 2013 the Municipality of Asparrena discussed the substitution of the three boilers with a single biomass boiler fuelled by biomass from local forests.

After preliminary studies and projects carried out by HAZI and EVE, it was decided to start the development of biomass boiler in 2014. Lantec and Giros were the companies appointed to develop the biomass boiler. The company operating the biomass boiler is “Central Hidroélectrica San Pedro de Araia S.A”, the same company that operates the three natural gas boilers. There is a mutual agreement between “Central Hidroélectrica San Pedro de Araia S.A” and the Municipality of Asparrena: the municipality provides wood chips and biomass with specific characteristics to the boiler and the company distributes thermal energy to the three buildings.

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In the first year of monitoring, two important results were observed. Firstly, there has been a reactivation of local biomass business as previously there was little interest in the available forest heritage. Secondly, there is an energy saving that can be translated into an economic saving.

The biomass boiler replaces three natural gas boilers; its features are listed below (**Table 4**):

Table 4 – Characteristics of biomass boiler in Asparrena Municipality

Building	Characteristics
Model	Herz Firematic
Power	301 kW
Smoke diameter outlet	250 mm
Volume of ashes in combustion chamber	85 litres
Water content	436 litres
Temperature of wood chips/pellet	150/160°C
Efficiency	93%
Weight	2,264 kg
Annual production	333.7 MWh
Annual wood chips consumption	113.6 t
kg CO_2 reduction	71039 kg

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Figure 4 – Map of the three buildings heated by the biomass system: (1) the public school, (2) public ambulatory and (3) House of Culture. In addition to the boiler, a hexagonal silo was built in which biomass can be stored. [4]

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1.1.4. Suntherm: Smart heat pump system with thermal storage for cost and GHG emissions minimization

Context: Carbon Neutrality pledge for 2040

The Suntherm system is a heat pump coupled with phase change materials (PCM) thermal energy storage: the system functioning is optimised by a smart controller. The role of the PCM tank is to decouple heat pump operation from the heat demand by the dwelling.

The heat pump extracts low grade heat from the outside air. This heat is used to evaporate the refrigerant. The refrigerant is then compressed by the compressor, increasing its pressure and temperature. This high-grade heat is transferred and stored in the PCM tank. The tank releases heat during the peak demand periods. By storing the heat in the storage tank, the pump can operate when there is a surplus of electricity. The system is further optimised by a real time controller operated via cloud. The controller gets real time electricity prices and CO_2 emissions from the Danish grid (DK1, DK2). Using this data and monitoring user habits the controller optimises the heat pump operation with minor electricity cost and CO_2 emissions.

Optionally solar panels can be connected to the storage tank to also store solar energy (Figure 6).

Figure 5 - Smart heat system

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1.1.5. BOFA: decision-support for strategic planning and tendering of organic waste treatment technology options in the island of Bornholm (DK)

The case study focuses on the organic fraction (food waste and green waste) coming from both households and commercial and industrial activities in the island of Bornholm, Denmark (**Figure 6**). The public company BOFA[1] in charge of the waste management system is interested in getting some specific Life Cycle Assessment (LCA) based support for the ongoing public tender around the waste management system.

Figure 6 – Geographical location of Bornholm Island

The last Danish national waste plan requires each municipality to work on new local waste plan proposal pursuing the target of 50% recycling of cardboard, paper, glass, metal, plastic, wood and organic waste from households by 2022. Regional Municipality of Bornholm is involved in the update process of the waste plan, replacing it with a new one, and at the same time Regional Municipality of Bornholm its 2040 Energy Strategy[2] with the aim of turning Bornholm into a carbon-neutral society based on sustainable and renewable energy updating the existing the 2025-target plan which is part of the "Transparent Energy Planning and Implementation", an ongoing energy project commonly referred to as "Transplan". Key points are:

1. Fossil fuel use to be phased out (oil and gas) by 2040.
2. More green electricity produced, including from offshore wind farms, more solar PV and reduction of use of biomass.
3. Utilizing green electricity by electrifying societal infrastructure and storing electricity so that there is electricity available even through production is low.

[1] www.bofa.dk
[2] https://www.brk.dk/Indflydelse-Politik/Politikker/Sider/Energipolitik-2040.aspx

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Two main technologies and three alternatives for bio-waste recycling were considered in this study: dry thermophilic anaerobic digestion (Scenario B), enclosed composting (scenario C), and a combination of the two (Scenario D). The compost produced was assumed to be used in agriculture while the biogas produced from the anaerobic digestion will feed a local CHP unit for electricity and thermal energy production, partly used directly at the site and partly transferred to a district heating network.

To summarize, BOFA expressed its willingness to collaborate with XPRESS in order to carry out a comparative analysis via LCA of three different scenarios (compared with the Reference Scenario A - Incineration):

- A. Incineration: current treatment of unsorted waste (including the organic fraction in the analysis) with heat and electricity production (District Heating) (**Figure 7**).
- B. Anaerobic Digestion (AD) (sorted garden waste + households organic waste) with biogas production used for heating and for its own demand (to replace, partially at least, the current heat production).
- Scenario C. Composting (garden waste + household organic waste) where additional heating and electricity needs to be considered, to substitute the current District Heating consumption. Peat and fertilizers are produced and are considered as positive impacts generated by this treatment technology.
- Scenario D. Anaerobic Digestion + Composting (garden waste + household organic waste) representing a small symbiotic system, where the solid waste is fed into the composting plant and partly recirculated. Soil for plants and organic fertilizer are produced, as well as biogas, which is upgraded to produce electricity and thermal energy by means of CHP (Combined Heat and Power).

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Figure 7 – Incineration plant located in Ronne, Bornholm

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The current incineration plant located in Rønne is receiving unsorted waste, including the organic fraction, from households.

Variations of input waste in quantity and quality over the years can be attributed to fluctuations in the economic cycle, demographics and tourism. And so, the amount of heat produced depends on the amount of input waste and the calorific value of the waste. The calorific value of the waste is naturally very variable and is estimated to be 9.3 GJ/t. As a general rule, all heat produced minus losses is transferred to the district heating network. However, a smaller part is driven to cooling towers during the summer period and a modest quantity is used as frost protection for the cooling towers.

1.1.6. Cascais Municipality: decision-support for strategic planning of the switch to a solar-powered electric vehicle fleet

The goal is to support the Municipality of Cascais (PT) to quantify the renewable energy demand considering the replacement of the current fleet (fuel-based + hybrid + electric vehicles) with a fully renewable energy-based fleet (100% electric vehicles) in the framework of the Carbon Neutrality Target to be achieved by 2040.

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2. Goal & Scope and life cycle inventories

The outcomes from the goal & scope evaluation and the life-cycle inventory phases are presented. In particular, the current deliverable illustrates the general settings, goal and scope, system boundaries, methodology and the data collected for the upcoming assessment phases.

2.1. Hydropower

2.1.1. ATS – Alto Trevigiano Servizi: power generation with a pressure-drop micro-hydroelectric turbine

The aim of this case study is, as said before, the evaluation of the environmental profile of a micro turbine owned by ATS. The function of the system is the generation of electricity through a hydropower micro turbine. The analysis was carried out according to the LCA methodology, which is regulated by the ISO 14040 [11] and 14044 [12] international standards. It includes four phases, namely goal and scope definition, life cycle inventory, life cycle impact assessment (LCIA), and interpretation. Therefore, the functional unit, which is the mathematic relation to which the function of the system is related, was set as 1 MWh of net electricity production.

The system boundaries are "cradle to gate" e include the following processes, namely (**Figure 8**):

- Dismantling and preparation of the site;
- Construction of the hydropower plant;
- Use phase (this process also includes the maintenance).

The end-of-life (EOL), which involves the demolition and recycling of the plant, was omitted considering that the micro-turbine is a recent project and potentially innovative processes will be available for the mitigation of impacts at that stage. In fact, the life span was set at 50 years.

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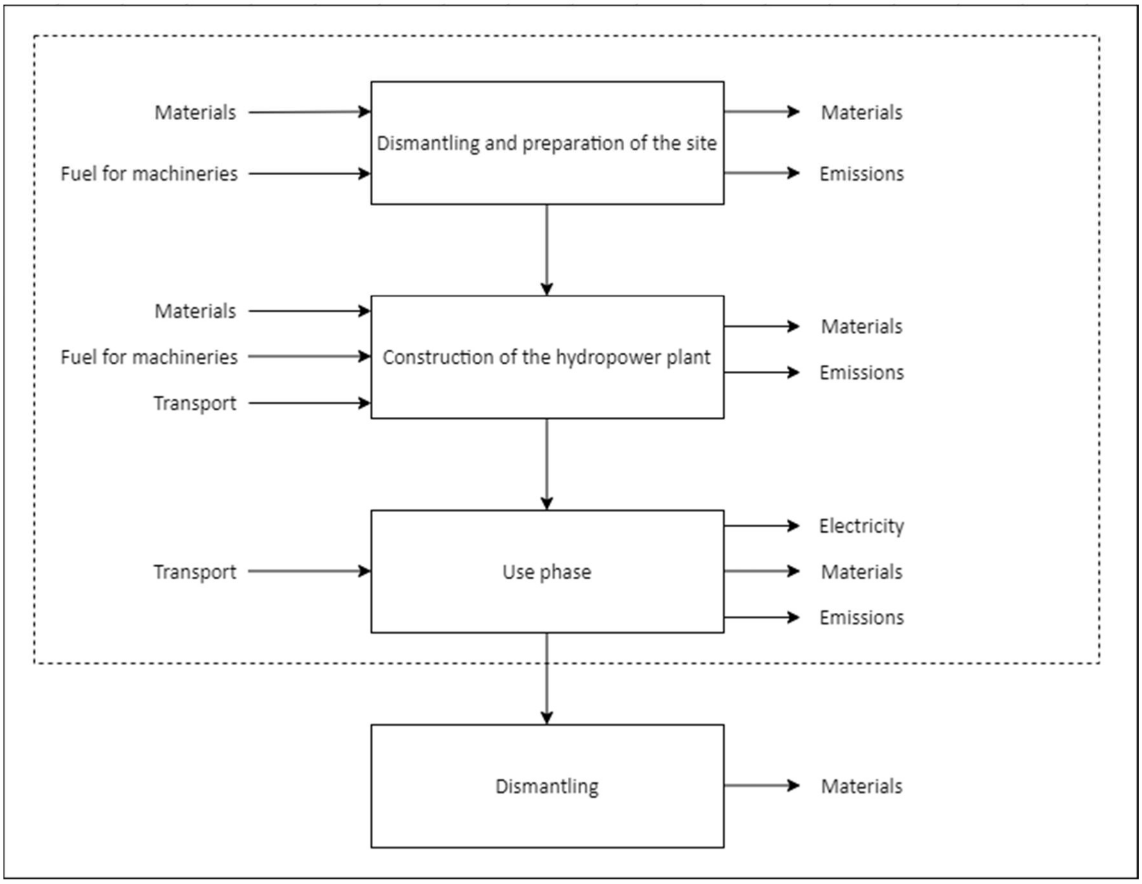

Figure 8 – Mini –hydropower plant System boundaries. The dotted line represents the stages included in the model

Data collection was conducted though documentation provided by the owner for internal use: system specifications, technical reports and presentations. [3], [5], [6]

The following assumptions were taken into account to create the LCI. Firstly, as previously said, the lifespan was estimated in 50 years. The supply of raw materials was set at a distance of 25 km and the transportation to landfill to 45 km; vehicle's characteristics were chosen as "freight, lorry >32 metric ton, EURO4". Some activities were neglected because they were too generic or irrelevant to be converted into LCA activities. For the complete inventory, it remands to the Annex at the end of the present deliverable.

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2.1.2. Asparrena Municipality: a refurbished mini-hydropower station from an ancient iron smelting

The aim of this case study is the evaluation of the environmental profile of a mini turbine owned by ATS. The function of the system is the generation of electricity through a mini turbine Therefore the functional unit was set as 1 MWh of net electricity production.

The system boundaries are "cradle to gate" including the following processes, namely (Figure 9):

- Dismantling and preparation of the site;
- Construction of the hydropower plant;
- Use phase (this process includes also the maintenance).

The end-of-life (EOL), which involves the demolition and recycling of the plant, was omitted considering that the micro-turbine is a recent project and potentially innovative processes will be available for the mitigation of impacts at that stage. In fact, the life span was set at 50 years.

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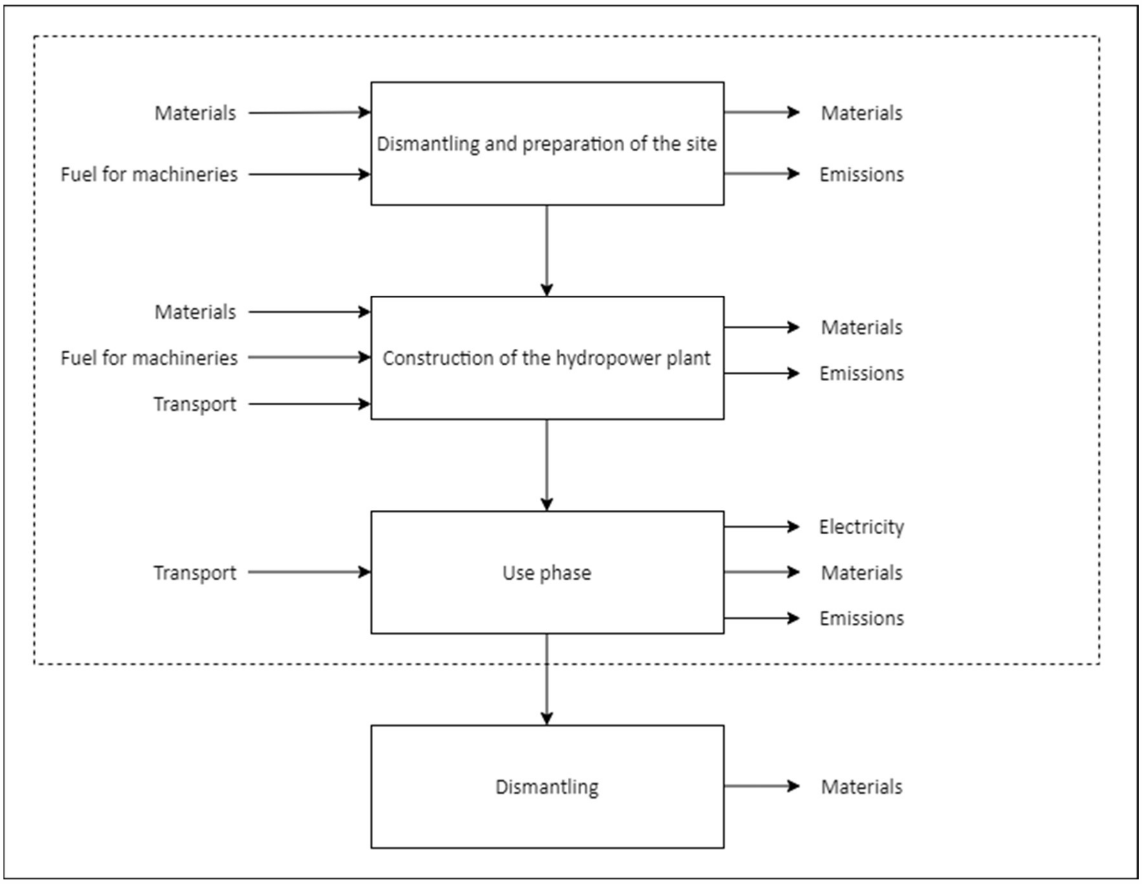

Figure 9 – Mini –hydropower plant system boundaries. The dotted line represents stages that were included in the model

Data collection was conducted through documentation provided by the owner for internal use and with the auxiliary of materials found on the internet such as system specifications, technical reports and presentations [3], [5], [6].

A series of assumptions was taken into account to build the LCI. Firstly, the lifespan was estimated in 20 years, until the end of the concession. The supply of raw materials for construction was set at a distance of 25 km and the transportation to landfill was set at 45 km; the vehicle technology chosen was a "freight, lorry >32 metric ton, EURO4". For the complete inventory, it remands to the Annex at the end of the present deliverable.

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2.2. Bioenergy

The aim of this case study is the evaluation of a biomass boiler fed via wood chips or pellet.

The function of the system is the generation of heat through the combustion of biomass in the new boiler installed. Therefore, the functional unit was set as 1 MWh of thermal energy produced.

The system boundaries are "cradle to gate" and includes the processes, namely (**Figure 10**):

- Dismantling and preparation of the site;
- Construction of the biomass plant;
- Use phase (this process includes also the maintenance).

The end-of-life (EOL), which involves the demolition and recycling of the plant, was omitted considering that the biomass boiler is a recent project and potentially innovative processes will be available for the mitigation of impacts at that stage. In fact, the life span was set at 20 years.

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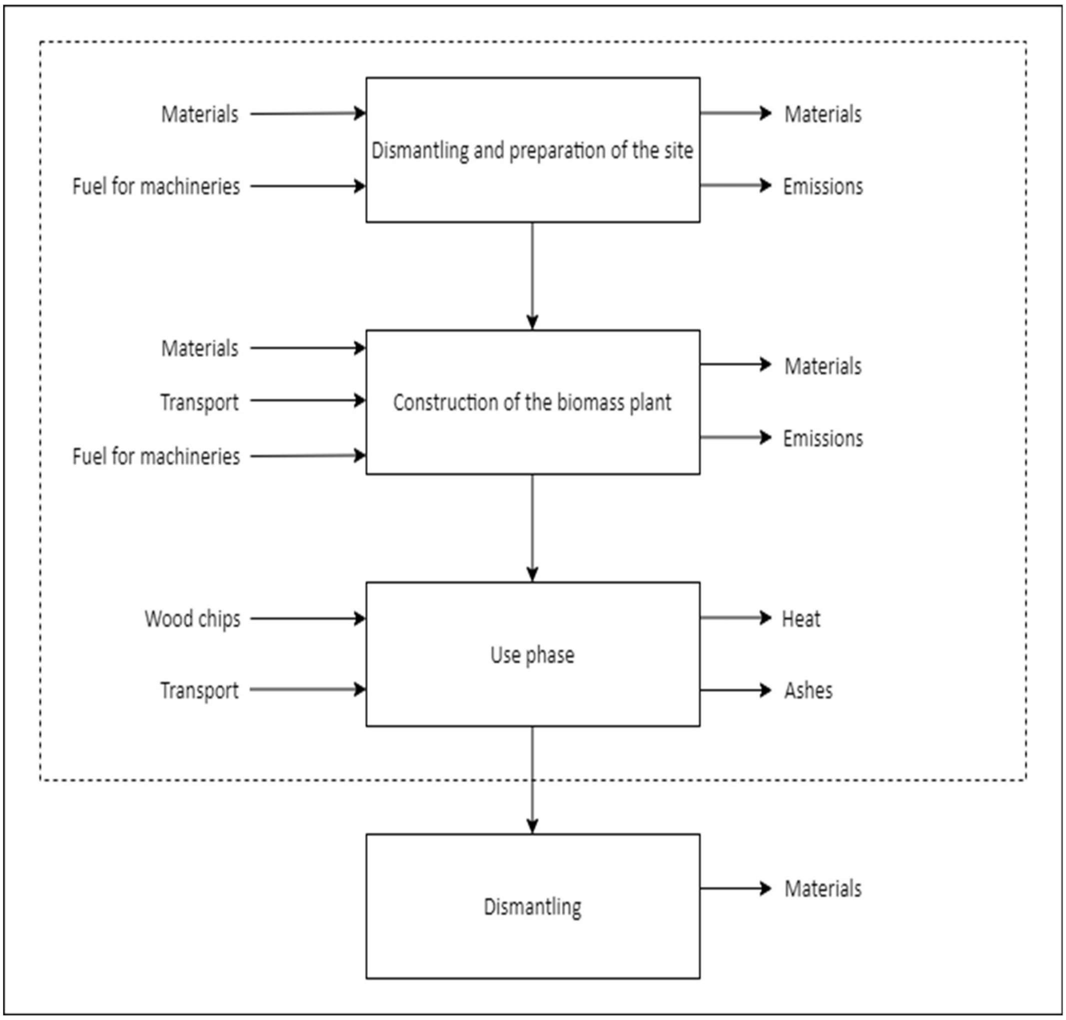

Figure 10 – Biomass boiler system boundaries. The dotted line represents stages included in the model

Data collection was conducted though documentation provided by the owner for internal use and with the auxiliary of materials found on the internet such as system specifications, technical reports and presentations [3], [4], [6], [7].

Due to the lack of available information (e.g., the area of forests, the number of residues), forest management and wood pellet production stages were not considered.

A series of assumptions were taken into account to create the Life Cycle Inventory. Firstly, the lifespan was estimated at 20 years, until the end of the concession. The supply of raw materials was set at 25 km and the transportation to landfill was set at 45 km; the characteristics of the vehicle were chosen as "freight, lorry >32 metric ton, EURO4". For the complete inventory, it remands to the Annex at the end of the present deliverable.

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2.3. Heat pumps

The goal of the case study is to estimate the life cycle environmental impacts of the Smart heat System and the comparison of these heat pump systems with others widely used heating systems in Denmark i.e., oil boilers and district heating.

The system under study is the Smart heat system applied to a single-family dwelling with annual heat demand of 22000 kWh in Denmark.

The functional unit is the generation of 1MWh of thermal energy for domestic heating.

The assumed system lifetime is 20 years without component replacement.

The scope of study is *cradle to gate*. System boundaries are shown in Figure 11.

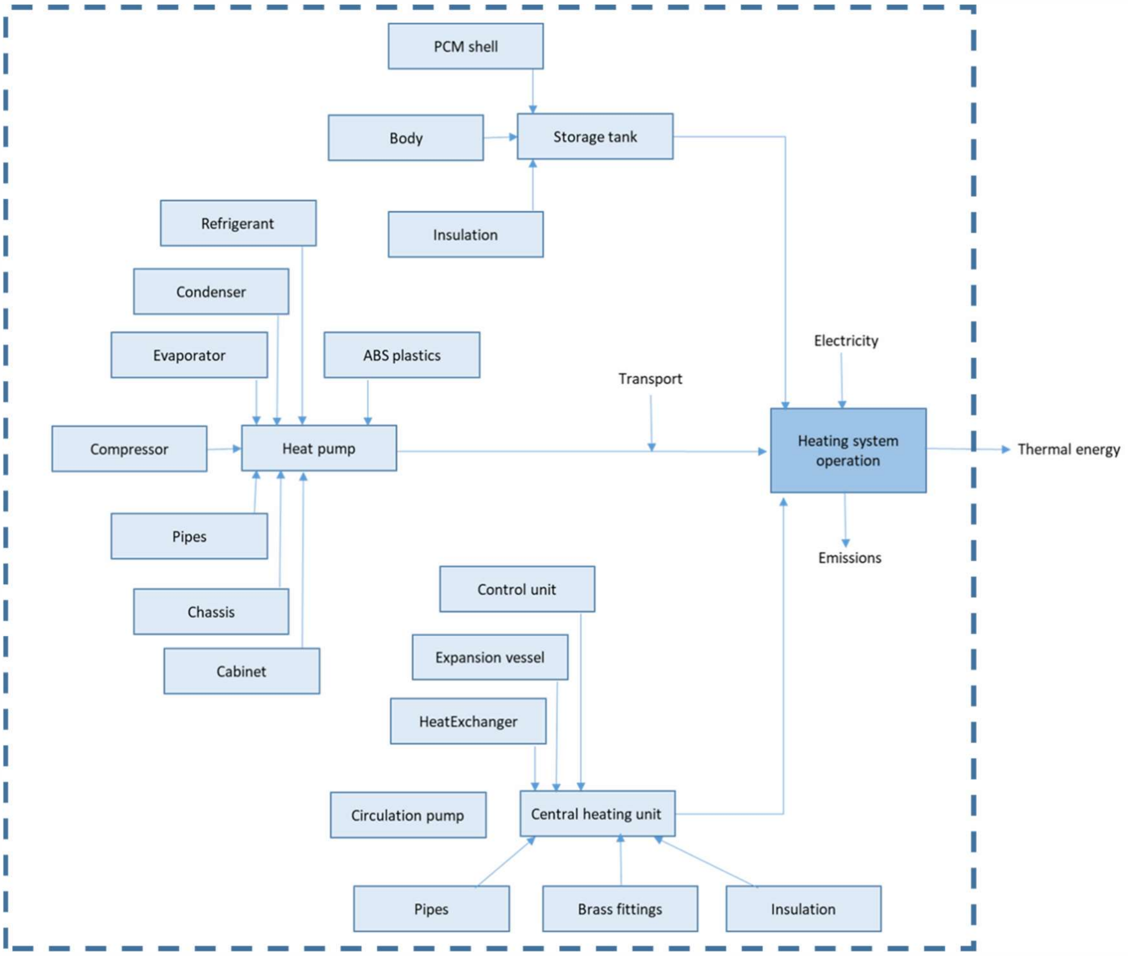

Figure 11 – System boundaries

For the complete inventory, it remands to the Annex at the end of the present deliverable.

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2.4. Municipal Waste Treatment

2.4.1. Goal of the case study

In order to set a reference inventory data, an extensive literature research on composting and anaerobic digestion treatment technologies and the related process outcomes has been performed. The aim is to define the environmental footprint and to compare environmental impacts of anaerobic digestion, composting or a combination of the two with energy and organic fertilizer production against the current scenario: incineration with energy production by CHP.

The double goal of this case study is to define: from one side the environmental impact of different scenarios of organic waste treatment with respect to the current situation, namely "Scenario A. Incineration", thus the goal of the LCA itself is to address an environmental comparison in terms of environmental burdens related to waste management plans and use the study as a decision-making support tool in order to opt for the best sustainable solutions.

On the other side, the waste management plan is aligned with the energy plan of Bornholm with the ambitious goal to reach the carbon neutrality by 2040.

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2.4.2. Functional Unit

The functional unit for this case is not something straightforward as it might happen when carrying out conventional LCA analysis. The complexity stands with the fact that this is a multi-functional process and that different waste treatment technologies are specifically designed to treat waste with specific physical and chemical characteristics (e.g., green waste includes ligneous components hardly biodegradable, thus, anaerobic digestion is not recommended at this scope, even considering the existence of various anaerobic digestion technologies).

The functional unit for the different scenarios is 1 tonne of organic waste treated.

The system boundaries will be "gate to gate" (**Figure 12** and **Figure 13**).

The foreground system consists of the putative incinerator process including waste collection, heat and electricity production. The other scenarios constitute background systems (e.g., the anaerobic digestion system is composed by the treatment and spreading of the digestate on agricultural land as a substitute for inorganic fertilizer, including the materials of construction for the plant). Other related background system for the composting scenarios includes the production of electricity, heat and organic fertilizer.

2.4.3. Systems' boundaries

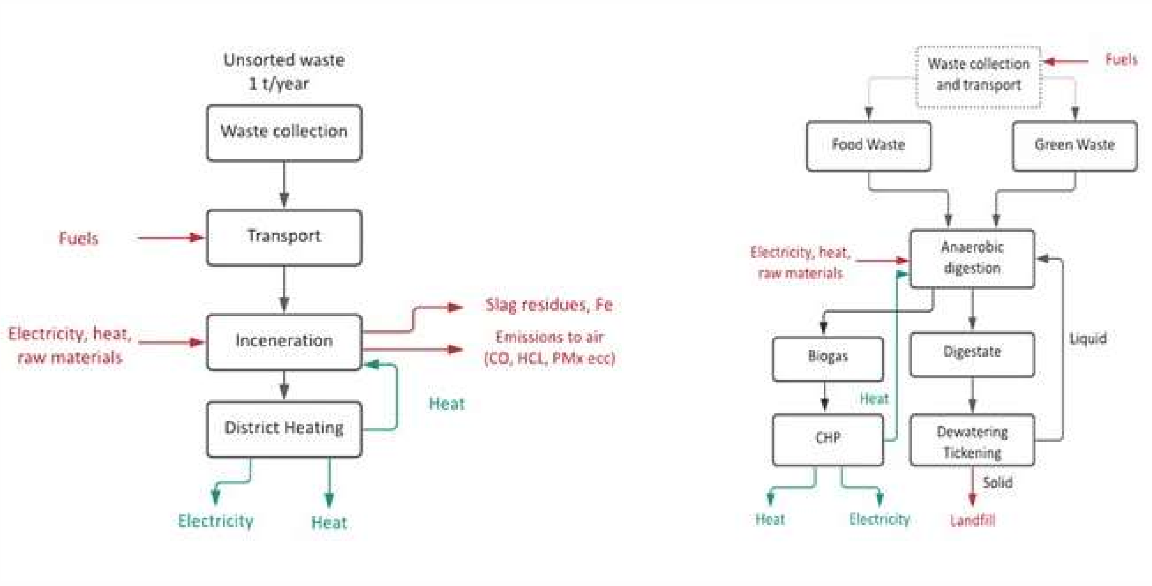

Figure 12 – System boundaries for scenario A – Incineration (left) and scenario B – Anaerobic digestion (right)

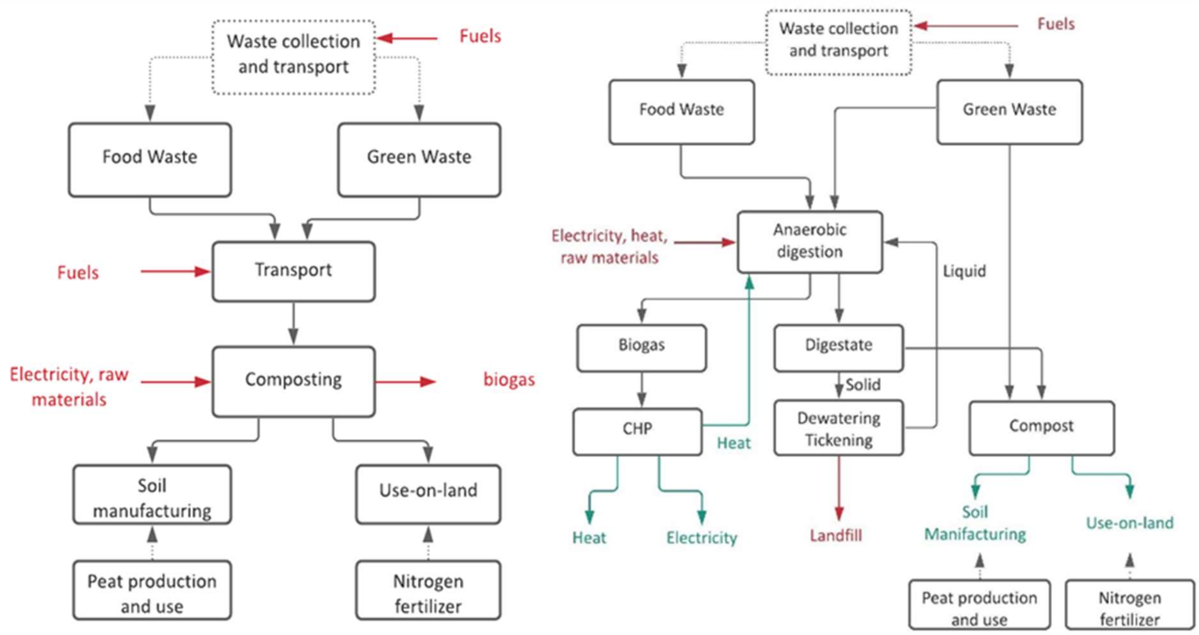

Figure 13 – System boundaries for Scenario C – Incineration (left) and Scenario D – Anaerobic Digestion and Composting (right)

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2.4.4. Generic Assumptions

- In the current scenario waste is not collected separately, and no information on the distances of the collection routes are available, so as a first approximation the distance from the collection bin to the treatment plan has been set at 30 km. This is the maximum distance indeed that can be run on the island.
- There is a lack of information about current waste collection (collection pathways made by the vehicles). Assumptions for the LCA model will be required for this phase.
- Biogas upgrading process is simplified (no de-sulphurisation process is accounted in the model as it was difficult to find either primary or secondary specific-generic data).

For the complete inventory, it remands to the Annex at the end of the present deliverable.

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2.5. Electric Vehicles

The aim of this case study is to support the Municipality of Cascais (PT) to quantify the renewable energy demand considering the replacement of the current fleet (fuel – based, hybrid, electric vehicles) with a fully renewable energy – based fleet (100% electric vehicles) in the framework of the Carbon Neutrality Target to be attained by 2040. To get this aim, the municipality will install a photovoltaic plant, whose dimensions were calculated in relation to the renewable energy demand. The Municipality of Cascais estimates to install 184 MW of solar energy on the rooftops. This ambitious project will permit to generate 213 GWh per year that correspond to 24% of total energy consumption in the municipality.

The function of the system is the generation of electricity through photovoltaic panel installed on the rooftop. Therefore, the functional unit was set as km/fleet. The system boundaries will be "cradle to gate".

The end-of-life (EOL), which involves the demolition and recycling of the plant, was omitted considering that the photovoltaic plant does not exist yet.

Data collection was conducted through datasets sent by the Municipality of Cascais. Documents describe the fleets of cars and other vehicles used by the Municipality of Cascais and give some information about which fuel is used, fuel consumptions and kilometres travelled annually. The following table lists some information about the fleet (Table 5):

Table 5 – Characteristics of Cascais Municipality's fleet

Current fleet	181 diesel, 5 hybrid and 2 plugin hybrid
Annual km (km/y)	3047855
Annual diesel consumption (l/y)	1372960
Annual petrol consumption (l/y)	10564
Current fuel usage for diesel vehicle (l/km)	48/100

For the analysis, the attributional approach will be used, according with the aim of the study. For the inventory phase (LCI) the Ecoinvent database, common in LCA studies, has been used.

For the complete inventory about the fleet, it remands to the Annex at the end of the present deliverable.

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3. Discussion and conclusions

This deliverable was elaborated with the aim to contribute to the definition of the general framework for the whole sustainability assessment of RES Technologies within the XPRESS scope.

The focus of the deliverable is the definition of the goal and scope of the study and the collection of all required information about inputs and outputs of the systems. The following REs technologies are analysed in this deliverable: hydropower, bioenergy, waste treatment, heat pumps and electric vehicles.

3.1. Hydropower plant

For the hydropower technology, both run-of-river (Asparrena case study) and reservoirs (ATS case study) data used to refer to turbines from a mix of typologies of dams contained in the Ecoinvent database built between 1945 and 1970; therefore, they might not be representative of more modern constructions and small- and smallest-scale plants. Despite the limitations of this assumption, this process was chosen, and it was modelled for the two case studies (see Annex A)). All processes are modelled trying to maintain both geographical and temporal representativeness.

Considering the use phase, this RE has no CO_2 emissions: there are emissions in the upstream and downstream phases due to the construction, distribution, and eventually dismantling of the plant (not considered in this case study). We compared CO_2 emissions of 1 kWh of electricity production in each country analysed with the country's technology using the Ecoinvent database.

For the ATS hydropower plant, the emission factor for the production of 1 kWh based on the national electricity grid mix (Italy) is 0.45 $kgCO_{2\text{-}eq}$/kWh. Comparing the ATS plant emission factor with the electricity grid mix of Italy for the production of 1 kWh, there is a saving quantified in 0.45 $kgCO_{2\text{-}eq}$/kWh.

For the Asparrena Municipality, the emission factor for the production of 1 kWh using the national electricity grid mix of Spain is 0.32 $kgCO_{2\text{-}eq}$/kWh. Comparing the emission factor with the electricity grid mix for Spain (production of 1 kWh), there is a saving quantified in 0.32 $kgCO_{2\text{-}q}$/kWh.

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3.2. Bioenergy

For the bioenergy system, a furnace process was chosen and adapted to the case study: it includes several materials such as copper, cast iron, and aluminium. To have more representativeness in geographical, temporal, and technological terms, a process that covers the beginning of the 2000s and Switzerland was chosen (see Annex A). This process is built with some assumptions: the furnace has a life span of 20 years; the chimney has a life span of 80 years; there is a storage silo, an automatic fuel supplier, an automatic controller: the operational time of the furnace is 2100 h/a. For our case study, these assumptions were used. The other processes are modelled trying to maintain both geographical and temporal representativeness.

The emission factors for natural gas are from DEFRA database and they respectively are 0.18 $kgCO_{2-eq}$/kWh for the natural gas boiler and 0.02 gCO_{2-eq}/kWh for the biomass boiler. [8].

Using the biomass boiler there is a reduction of 179.98 gCO_{2-eq}/kWh.

3.3. Heat pumps

In the EU residential sector represents a 26% of final energy consumption, of which 64.1% is for space heating in 2018 (Eurostat). By the EU's climate goals, the demand for heating is expected to fall by 42% by 2050, with a commensurate reduction in CO_2 emissions. Suntherm Smart heat pump system was evaluated for energy performance and CO_2 emissions towards efficient and sustainable heating.

Smartheat produces about 3 units of heat for every unit of electricity consumed (Seasonal performance factor of 2.95) which makes it one of the best options for residential space heating.

Smart heat outperforms a conventional heat pump with a 15% of CO_2 emissions reduction. Compared to an electric heater the reductions are 66% of energy consumption and 71% of CO_2 emissions (equivalent to 2.256 tons CO_2 emissions per year). The comparison with an oil boiler is even more significant with 84% CO_2 emissions reduction (equivalent to 4.776 tons CO_2 emissions per year). When comparing Smartheat and a gas boiler the CO_2 emissions are 71% less (equivalent to 3.016 tons CO_2 emissions per year). These comparisons are based on 100% boiler efficiency, hence the are more applicable to modern boilers. For older boilers, having lower efficiencies, the energy savings and CO_2 emission reductions would be higher (**Figure 14**).

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As the heat pump is powered by electricity, depending on the electricity generation mix, further CO_2 emissions savings can be achieved. For example, if the electricity is generated entirely by renewables, the heat pump system has the potential to fully decarbonize the space heating demand (**Figure 15**).

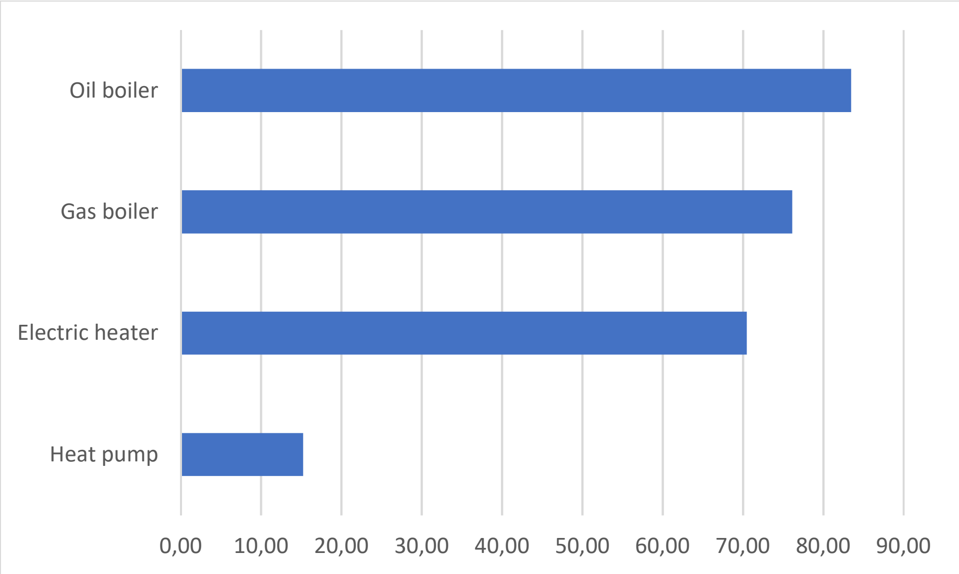

Figure 14 – CO_2 emission reduction in percentage by Smart heat compared to alternative space heating systems

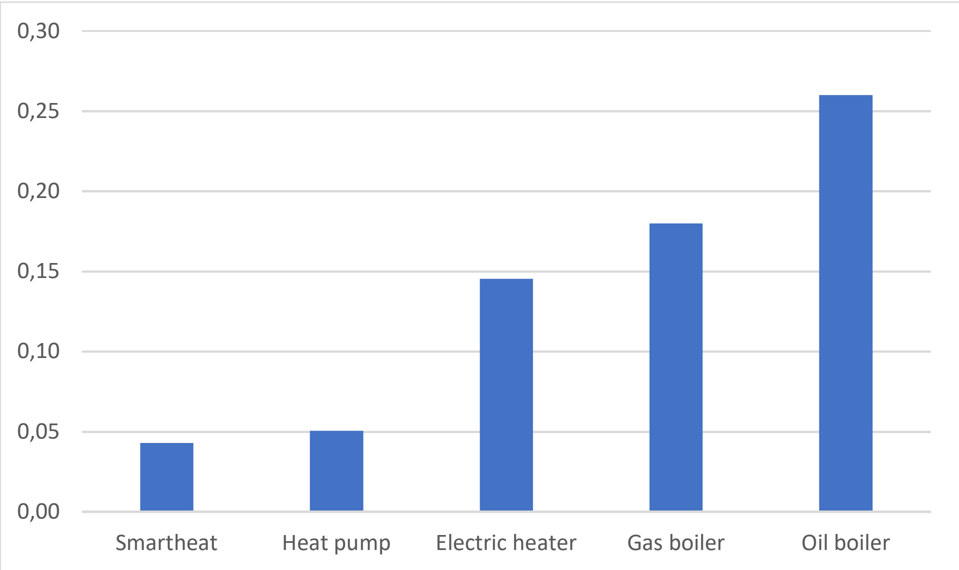

Figure 15 – CO_2 emission intensity (tCO_2/kWh)

3.4. Municipal Waste Treatment

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For the case study of BOFA the KPIs “Renewable Energy Production” and “CO_{2eq} reduction” have been calculated considering a rough comparison between Scenario A (Incineration) and Scenario D (Anaerobic Digestion + Composting):

1. Renewable energy production = 1.84 GWh*e*+ 0.05 GWh*t*=1.89 GWh/y
2. CO_{2eq} reduction = 693.2 tCO_{2eq}/y

To calculate the CO_{2eq} reduction, the Emission Factor from Ecoinvent 3.7 for the production of 1 kWh of Electricity was used (1 kWh Electricity, high voltage {DK}| production mix). The related impact category was determined: Climate change = 0.373 kg CO_{2eq}.

To calculate the energy production for scenario D (best practice) the energy balance has been considered, taking into account net energy consumption (excluding plant internal recirculation of either electric or thermal energy) and the actual production in terms of electric and thermal energy.

In the table below the energy balance from Scenario A – Incineration and Scenario D – Anaerobic Digestion + Composting, are reported.

	SCENARIO A*	SCENARIO D
Net Electric Energy [kWh/ton]	-79.2	146.646
Net Thermal Energy [kWh/ton]	2464.7	3.815

* *Mass balance for scenario A – Incineration is determined considering the unsorted waste currently collected.*

From a first comparison between the two scenarios, we can see how replacing Scenario A with Scenario D, an additional thermal energy supply of 2464.7 kWh/ton of waste is theoretically needed, to fulfil the demand for it. This is the thermal energy that will be supplied by introducing into the system a woodchip furnace, that will be considered in the LCA system, by extending the system boundaries.

For the calculation of the “CO_{2eq} intensity”, only the impacts on climate change related to the production of renewable energy were considered for Scenario D, even though in this case the treatment technology can provide other valuable materials such as fertilizers and compost (see

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flow chart in **Figure 13**). The benefits of these productions and the associated substitution of virgin materials will be accounted for in the LCIA to be delivered in upcoming tasks.

3.5. Electric vehicles

For the case of the *Carbon Neutrality Project* of the Cascais Municipality, we calculated the energy to move from the current vehicles fleet to a completely electric vehicles fleet (see Annex A). The energy required for this transition is 2.42 GWh considering an average of 1.75 kWh/y and consumption of the actual fleet of 0.48 l/km. We considered in Ecoinvent a process of a photovoltaic panel that has 3 kW_p and an estimated lifetime of 30 years. The maximum energy it can produce is 788.4 kWh, so 3070 such panels are necessary to achieve carbon neutrality for the Cascais' fleet. Considering a surface for 3 kW_p panels of 20 m^2, the total surface required corresponds to 61400 m^2.

The emission factor for the actual fleet is 1.53 $kgCO_{2\text{-eq}}$/kWh considering a $CO_{2\text{-eq}}$ emissions of 3704 $kgCO_{2\text{-eq}}$[3] and an annual production of 2.42 GWh[3], while the emission factor considering an electrical fleet fed with renewable energy is supposed not to have any $CO_{2\text{-eq}}$ emissions.

These results can be compared with the emission factor of the electricity grid mix of Portugal. This value is calculated with Ecoinvent database with the process namely "Electricity, medium voltage {PT}| market for" and the emission factor is equal to 0.385 $kgCO_{2\text{-eq}}$/kWh.

[3] Expectation after installation

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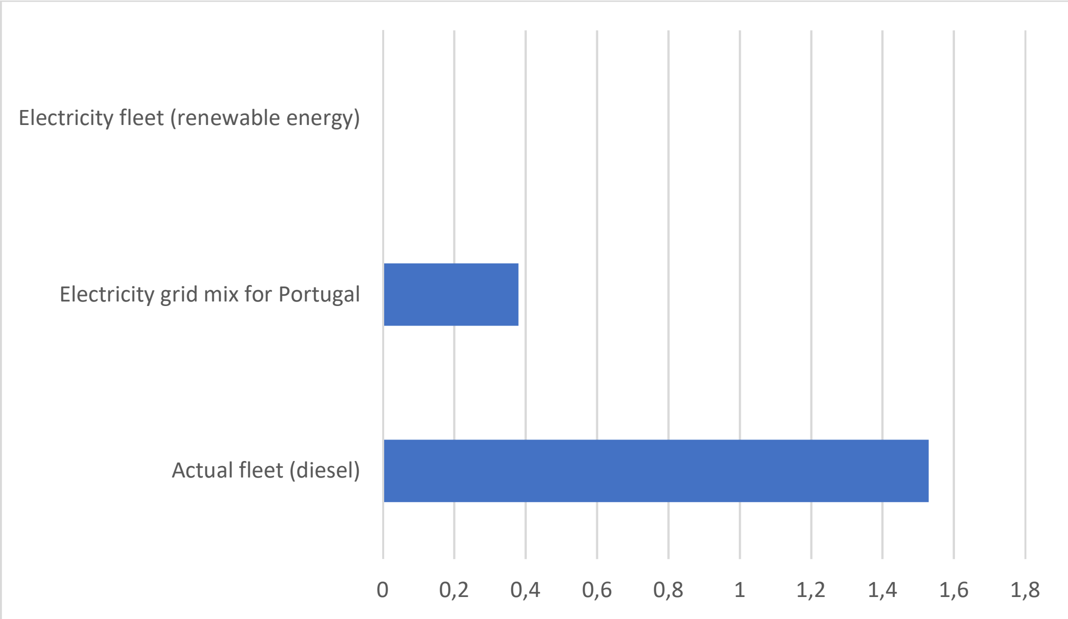

Figure 16 – Comparing emission factors between actual fleet, electric vehicles' fleet and electricity grid mix for Portugal (kg$CO_{2\text{-}eq}$/kWh)

3.6. KPIs

The collected data allows a preliminary estimation of the XPRESS KPIs in the downstream phase (gate to gate). In the next step, KPIs will be enhanced by implementing the LCA methodology. LCA will allow the consideration of the upstream processes and reallocation of the KPIs. These LCA-enhanced KPIs i.e., cradle to gate KPIs will be later quantified from the LCA results. In the next stage, the current set of KPIs will be extended to the indicators derived from the environmental footprint analysis (**Errore. L'origine riferimento non è stata trovata.**). This will permit a detailed comparison of the results deriving from the case studies leading to the ***Life Cycle Screening*** in Deliverable 2.5.

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Table 6 – Effects on KPIs

Case study	Primary energy saving	Renewal energy production	CO_2 intensity
Alto Trevigiano Servizi (IT) Hydropower	Good	Moderate	Moderate
Asparrena Municipality (ES) Hydropower	Poor	Good	Good
Asparrena Municipality (ES) Bioenergy	Poor	Good	Good
Suntherm (DK) Heat pumps	Good	Moderate	Moderate
BOFA (DK) Municipal waste management	Good	Good	Good
Cascais Municipality (PT) Electrical Vehicles & PV	Poor	Good	Good

Small Hydropower

Total electricity generation is 36345 GWh in the XPRESS partner countries excluding Norway in 2019. The estimated economic potential with environmental constraints is 15608 GWh. This equals a potential increase of 43% [9]. As the carbon intensity of hydropower is very low, the potential reduction of direct CO_2 emissions is significant per kWh generated.

Bioenergy

Total electricity and heat generated from biomass correspond to 59% of the entire renewable energy (115694 toe); out of this 59%, 74.6% is used for the heat and cooling sector (86307.7 toe), 13.4% is used for bioelectricity (15503 toe) and 12.0% for biofuels (13883 toe) [10]. Biomass has the highest contribution from forestry and agriculture, while waste has a minor contribution. In 2050, the demand of biomass is supposed to raise from 8162 to 21131 PJ [10]. The biomass boiler considered in our study has no savings in terms of process efficiency since it implies a transition from a feedstock to another one.

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Air/Water Heat Pumps

Total energy generation is 1.E+11 GWh in the XPRESS partner countries in 2019. Total consumption for heating and cooling is 4.E+12 GWh, of which 19% is from RES [11]. As the heat pump market has already witnessed strong growth in sales between 2009 and 2018, the market outlook is slow growth. Air/water heat pumps only account for around 20% of the total heat pumps sold. However, the adoption of the different heat pump technologies varies across the XPRESS partner countries. Air/water heat pumps are the dominant type in Germany and UK. Overall, potential renewable energy generation is significant with moderate direct CO_2 emission reductions. The studied heat pump system also provides moderate energy saving (66%) compared to conventional boilers.[12]

Waste-to-Biogas

The analysis of the data collected on anaerobic digestion and biomethane production practice throughout Europe shows that the number of biomethane plants in 18 EU countries has increased from the by 51% from 2018 to 2020.

In 2018 the 18,202 biogas installations EU ensured an electric capacity (IEC) of 11082 MW, and 63511 GWh of biogas produced. In recent years, however, biomethane has been increasingly in the spotlight. 2018 was no exception, as the European biomethane sector continued its dynamic ascent, reaching a total of 610 plants and producing 2.28 bcm (billion cubic metres) of biomethane.

Committed to reaching carbon neutrality by 2050 and facing the depletion of its gas fields in the North Sea, Denmark has a clear interest in making biogas and biomethane central pillars of its future smart energy system. Likewise, other EU countries' focus on renewable-based electricity generation has led to a robust development of biogas plants with onsite electricity conversion and satellite Combined Heat & Power (CHP) units. This way, Germany became – by far – the largest biogas producing country in the EU, with about 105000 direct jobs in its bioenergy sector. In Italy, the high availability of agricultural feedstock and the widespread use of gas in transport activities have also been strong arguments in favour of biogas production and the upgrade into biomethane, to facilitate the achievement of the renewables expansion target for the transport sector and reduce the country's CO_2 emissions. Investigations of alternative energy strategies

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shows that Waste-to-Energy routes products in place of fossil fuels have an excellent potential for high energy content, such as by anaerobic digestion and biological hydrogen production [13].

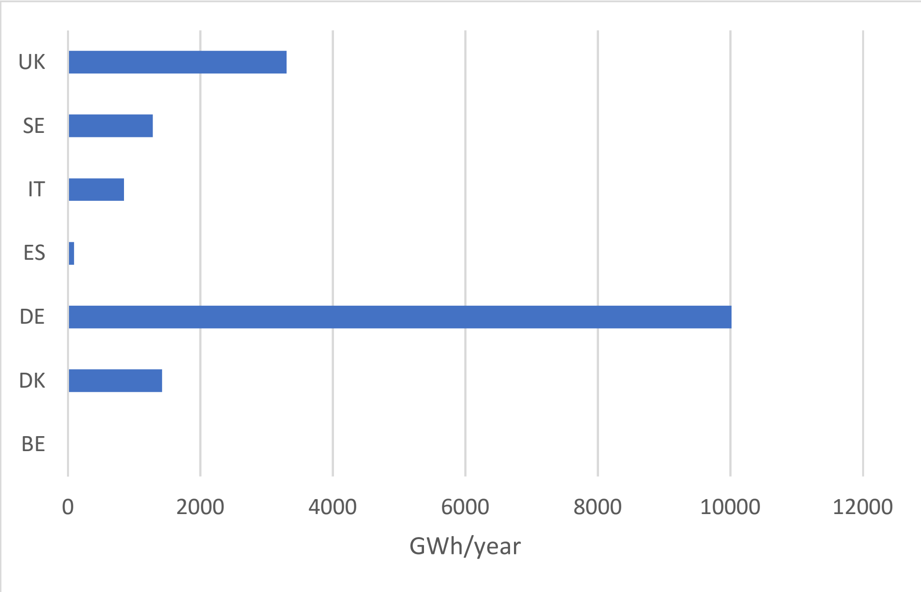

Figure 17 – Biomethane production per country (GWh/year)

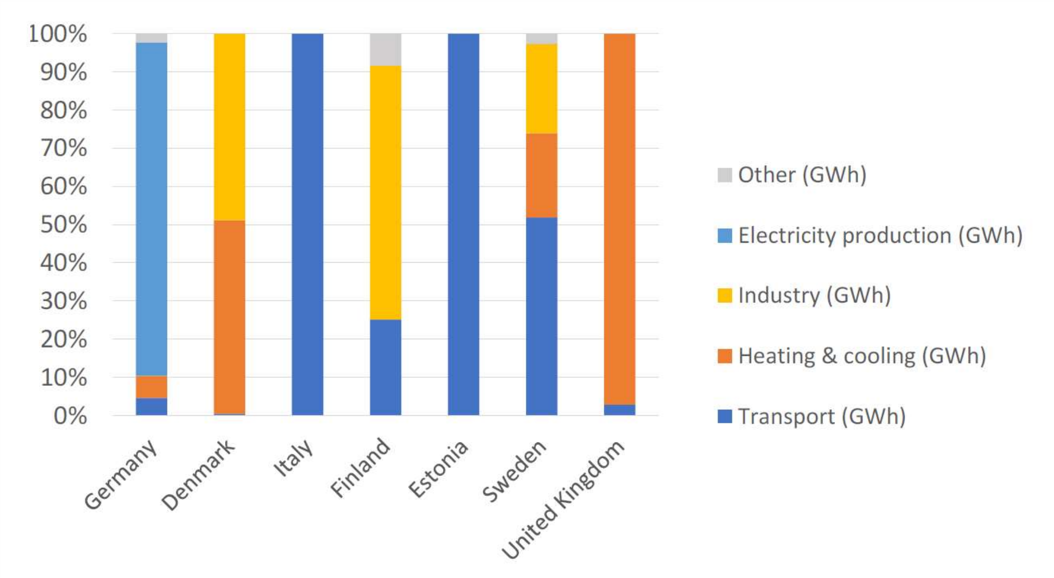

Figure 18 – Consumption of biomethane per sector and per country (for countries where data is available)[14]

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Investigations of alternative energy strategies shows that Waste-to-Energy routes products in place of fossil fuels have an excellent potential for high energy content, such as by anaerobic digestion and biological hydrogen production (high potential in Primary Energy saving, Renewable energy production, as well as Carbon Emissions reduction).[15]

The decision for a PA to integrate Waste-to Energy routes (anaerobic digestion) in its waste management plans, beside indications resulting from the LCSA framework indicators, it is crucial to take into account the potential utilization of the biomethane produced, its general implication and potential demand in the market, and proper infrastructural services in place.

For some countries, end-use pathways are quite clearly defined and regulated, e.g., in Sweden and Italy, the main end-use application is transport, whereas in the United Kingdom this is heating & cooling. Most of Sweden's biomethane is used in the transport sector due to a favourable support system. In Italy, the use of biomethane in the transport sector is facilitated by the fact that there is already both infrastructure and methane vehicle fleet. In 2014, the Italian government introduced the first obligation for the use of biofuels in the transport sector. In Germany, most biomethane is used for electricity production in CHP units. The use of biomethane for electricity production is favoured in Germany by the Feed-in Tariff, which is only granted to the biomethane plant when electricity is generated from the biomethane. In total 2,602 GWh of electricity and 3,608 GWh heat was produced in Germany in CHP units. On the other hand, in Germany, the usage of biomethane as transport fuel is indirectly supported through its inclusion into the list of fuels accepted for the reduction of GHG footprint for fuel distributing companies. [14]

EV and PV

Road transport accounts for the largest energy consumption in the transport sector, of which only 0.06 % is from RES in 2019 [11]. The EU is calling for at least 100 climate-neutral cities in Europe as a milestone on shifting more activity towards more sustainable transport modes [10]. Hence there is a potential of 100 fleet transition to electric vehicles by 2030. If we consider an average fleet size, Cascais fleet size and installation of solar panels to compensate the electricity requirement, it gives significant energy contribution for the transition to renewables and decarbonisation of entire fleet, which is equivalent to 2.42 GWh.

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3.7. Assumptions and critical issues

To conclude, we give an overview of critical parameters that we found while analysing the proposed case studies:

- for the hydropower plant, it is necessary to investigate the system life span and distance of required materials. A life span of 60 has been considered ears for Asparrena and 50 years for ATS, but a hydropower plant can have a very long-life expectancy. Materials supply and demolition wastes are generally of local origin and destination (25 km and 45 km respectively) and they could be delivered not only with lorries. To give an overview about End of Life (EoL), EoL's scenarios can be hypothesized.
- for bioenergy, more understanding is required about the life span and distance of materials. A life span was chosen of 20 years that was an average lifetime of a boiler. Materials supply and demolition waste are generally of local origin and destination (25 km and 45 km respectively) and they could be delivered not only with lorries. To give an overview about End of Life (EoL), EoL's scenarios can be hypothesized.
- for the Municipal Waste Treatment case study, the main criticality stands to select a uniform and standalone functional unit for each scenario to enable a comprehensive comparison between the final unit processes (e.g., Products from DH unit from Scenario A and products from CHP unit from Scenario D, compost and fertilizer production from Scenario B - Composting) to be considered.
- for Cascais, it is important to assess the correct dimensioning for photovoltaic plants. We identified the lower limit, considering peak power and peak energy, but there are some aspects to consider such as solar incidence angle on panels, annual solar radiation, photovoltaic cells and the production of wafer and cells. As results of these assumptions, more panels might be required and consequently a larger surface to install them. In addition to the above, it is important to properly connect photovoltaic plant to the lifetime of the technology. In fact, we transposed the Ecoinvent assumptions, considering a lifetime of 30 years while taking into account the other elements (e.g. inverter) in relation to this period.

These critical issues and assumptions and the other ones highlighted in the Deliverable 2.5 will be analysed through a sensitivity analysis in the Life Cycle Impact Assessment stage.

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Annex A: Inventory of case studies

ATS – Alto Trevigiano Servizi: power generation with a pressure-drop micro-hydroelectric turbine

Activity for plant	Activity in Ecoinvent	Geography	Total amount	Unit of measure	Amount reported to FU	Unit of measure
Building works	market for inert waste	Europe without Switzerland	29610	kg	75.73	kg/MWh
	glass fibre production	RER	370.44	kg	0.95	kg/MWh
	gravel production, crushed	CH	21981.82	kg	56.22	kg/MWh
	market for cement mortar	CH	8.93	kg	0.023	kg/MWh
	market for chromium steel pipe	GLO	1761.31	kg	4.50	kg/MWh
	market for concrete block	DE	251496.75	kg	643.21	kg/MWh
	market for diesel, burned in building machine	GLO	2873.27	MJ	7.35	MJ/MWh
	market for slab and siding, hardwood, wet, measured as dry mass	Europe without Switzerland	128.98	m^2	0.33	m^2/MWh
	polyester fibre production, finished	GLO	110.18	kg	0.28	kg/MWh
	transport, freight, lorry >32 metric ton, EURO4	RER	30137.20	t*km	77.08	t*km/MWh
Machinery	market for steel, chromium steel 18/8 (turbine)	GLO	1564	kg	0.07	kg/MWh
	market for concrete block	DE	187900	kg	8.01	kg/MWh
	transport, freight, lorry >32 metric ton, EURO4	RER	4736.60	t*km	2.02E-01	t*km/MWh
Implants for telecontrol	glass fibre production	RER	260.56	kg	0.67	kg/MWh
	hot rolling, steel	Europe without Austria	52.44	kg	0.13	kg/MWh
	market for electronics, for control units	GLO	6.7	kg	0.02	kg/MWh
	metal working, average for aluminium product manufacturing	RER	5.7	kg	0.01	kg/MWh

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	transport, freight, lorry >32 metric ton, EURO4	RER	8.13	t*km	0.02	t*km/MWh
Maintenance	market for transport, passenger car, medium size, diesel, EURO 4	GLO	30417	km	1.30	km/MWh
	market for lubricating oil	RER	0.76	kg	3.24E-08	kg/MWh
	transport, freight, lorry >32 metric ton, EURO4	RER	0.02	t*km	0.00000081	t*km/MWh
Hydropower energy			**23460**	**MWh**	**1.000E+00**	Reference flow

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Activity for plant	Activity in Ecoinvent	Geography	Total amount	Unit of Measure	Amount reported to FU	Unit of measure
Demolitions	market for cement tile	CH	87.75	kg	0.0004	kg/MWh
	concrete, all types to generic market for concrete, normal strength	GLO	23330.54	m^3	0.11	m^3/MWh
	market for building, hall, steel construction	GLO	48.25	kg	0.0002	kg/MWh
	market for building, hall, wood construction	GLO	7605	kg	0.04	kg/MWh
	market for clay brick	GLO	93213.12	kg	0.45	kg/MWh
	market for electronics scrap	GLO	5	kg	2.4E-05	kg/MWh
	market for electronics, for control units	GLO	3	kg	1.4E-05	kg/MWh
	market for inert waste	Europe without Switzerland	500	kg	0.002	kg/MWh
	transport, freight, lorry >32 metric ton, EURO4	RER	8689.99	t*km	0.04	t*km/MWh
Earthworks	excavation, skid-steer loader	RER	2012.85	MJ	0.01	MJ/MWh
Foundations and structure	concrete, all types to generic market for concrete, normal strength	GLO	41.45	m^3	0.0002	m^3/MWh
	market for hot rolling, steel	GLO	1205.34	kg	0.006	kg/MWh
	transport, freight, lorry >32 metric ton, EURO4	RER	2520.09	t*km	0.01	t*km/MWh
Brickwork	market for cement mortar	CH	11567.70	kg	0.06	kg/MWh
	ceramic tile production	GLO	675	kg	0.003	kg/MWh
	market for concrete block	DE	24609.82	kg	0.12	kg/MWh
Carpentry and metalwork	market for foam glass	GLO	69.18	kg	0.0003	kg/MWh
	market for aluminium alloy, metal matrix composite	GLO	82.70	kg	0.0004	kg/MWh
	market for steel, chromium steel 18/8, hot rolled	GLO	226.67	kg	0.001	kg/MWh
	transport, freight, lorry >32 metric ton, EURO4	RER	9.46	t*km	4. 6E-05	t*km/MWh

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Painting	market for alkyd paint, white, without solvent, in 60% solution state	RER	1437.84	kg	0.01	kg/MWh
	transport, freight, lorry >32 metric ton, EURO4	RER	35.95	t*km	0.0002	t*km/MWh
Urbanisation	concrete, all types to generic market for concrete, normal strength	GLO	250.13	kg	0.001	kg/MWh
	market for diesel, burned in building machine	GLO	3225.07	MJ	0.02	MJ/MWh
	market for inert waste	Europe without Switzerland	745500	kg	3.59	kg/MWh
	market for polyvinylchloride, bulk polymerised	GLO	22.50	kg	0.0001	kg/MWh
	sand quarry operation, extraction from river bed	GLO	210000	kg	1.01	kg/MWh
	transport, freight, lorry >32 metric ton, EURO4	RER	77210.69	t*km	0.37	t*km/MWh
Civil works	market for concrete block	DE	39.07	m^3	0.0002	m^3/MWh
	market for diesel, burned in building machine	GLO	2242.98	MJ	0.01	MJ/MWh
	transport, freight, lorry >32 metric ton, EURO4	RER	138552.93	t*km	0.67	t*km/MWh
Turbine	market for steel, chromium steel 18/8	GLO	13849.79	kg	0.07	kg/MWh
	transport, freight, lorry >32 metric ton, EURO4	RER	346.24	t*km	0.002	t*km/MWh
Generator	market for generator, 200kW electrical	GLO	6.06	unit	2.9E-05	unit/MWh
	transport, freight, lorry >32 metric ton, EURO4	RER	128.78	t*km	0.001	t*km/MWh
Maintenance	market for transport, passenger car, medium size, diesel, EURO 4	GLO	2185920	km	10.52	km/MWh
	market for lubricating oil	RER	6.73	kg	0.00003	kg/MWh
	transport, freight, lorry >32 metric ton, EURO4	RER	0.17	t*km	0.000001	t*km/MWh
Chute and loading chamber	market for concrete block	DE	74.85	m^3	0.0004	m^3/MWh
	market for diesel, burned in building machine	GLO	290.66	MJ	0.001	MJ/MWh
	market for mastic asphalt	GLO	287.62	kg	0.001	kg/MWh
	sand quarry operation, extraction from river bed	GLO	210000	kg	1.01	kg/MWh

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	transport, freight, lorry >32 metric ton, EURO4	RER	13791.01	t*km	0.07	t*km/MWh
Hydropower energy			**207746.9**	**MWh**	**1.000E+00**	Reference flow

Asparrena Municipality: biomass boiler for a mini district-heating plant fuelled with local and sustainably-sourced wood chips

Activity for plant	Activity in Ecoinvent	Geography	Total amount	Unit of measure	Amount reported to FU	Unit of measure
Preparation of the site	market for diesel, burned in building machine	GLO	6628.81	MJ	0.99	MJ/MWh
	transport, freight, lorry >32 metric ton, EURO4	RER	9823.28	t*km	1.47	t*km/MWh
Infrastructure and connections	market for diesel, burned in building machine	GLO	708.67	MJ	0.11	MJ/MWh
	transport, freight, lorry >32 metric ton, EURO4	RER	2498.39	t*km	0.37	t*km/MWh
	market for polyvinylchloride, bulk polymerised	GLO	123.75	kg	0.019	kg/MWh
	extrusion, plastic pipes	RER	7770.97	kg	1.16	kg/MWh
	market for concrete block	DE	3129.61	kg	0.47	kg/MWh
	market for aluminium, primary, ingot	GLO	100.68	kg	0.015	kg/MWh
	market for polyethylene, high density, granulate	GLO	7647.22	kg	1.15	kg/MWh
	clay brick production	RER	2916.94	kg	0.44	kg/MWh
	market for cable, three-conductor cable	GLO	120	m	0.02	m/MWh
	market for cast iron	GLO	957112	kg	143.41	kg/MWh
	market for chromium steel pipe	GLO	48.07	kg	0.01	kg/MWh
	market for compact fluorescent lamp	GLO	60	unit	0.09	unit/MWh
	market for steel, chromium steel 18/8, hot rolled	GLO	9206.26	kg	1.38	kg/MWh
Urbanization	market for gravel, crushed	CH	35737.5	kg	5.35	kg/MWh

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	bitumen adhesive compound, hot	RER	71400	kg	10.70	kg/MWh
	mastic asphalt production	RER	571.5	kg	0.09	kg/MWh
	steel production, chromium steel 18/8, hot rolled	RER	270	kg	0.04	kg/MWh
	transport, freight, lorry >32 metric ton, EURO4	RER	4074.23	t*km	0.61	t*km/MWh
Civil works	transport, freight, lorry >32 metric ton, EURO4	RER	1074.95	t*km	0.16	t*km/MWh
	market for bronze	GLO	0.0046	kg	6.9E-07	kg/MWh
	extrusion, plastic pipes	RER	1.43	kg	0.0002	kg/MWh
	market for brass	CH	1	kg	0.0001	kg/MWh
	market for concrete block	DE	21770.4	kg	3.26	kg/MWh
	market for epoxy resin, liquid	RER	75.2	kg	0.01	kg/MWh
	market for gravel, round	CH	17625	kg	2.64	kg/MWh
	market for sand	CH	3525	kg	0.53	kg/MWh
	polyethylene production, high density, granulate	RER	1.43	kg	0.0002	kg/MWh
Installations	carbon dioxide production, liquid	RER	5	kg	0.001	kg/MWh
	extrusion, plastic pipes	RER	10.93	kg	0.002	kg/MWh
	market for cable, three-conductor cable	GLO	175.00	m	0.03	m/MWh
	market for capacitor, electrolyte type, > 2cm height	GLO	73	kg	0.01	kg/MWh
	market for chromium steel pipe	GLO	262.20	kg	0.04	kg/MWh
	market for compact fluorescent lamp	GLO	6.5	unit	0.001	unit/MWh
	market for electronics, for control units	GLO	45	kg	0.07	kg/MWh
	market for monoammonium phosphate	RER	18	kg	0.003	kg/MWh
	market for polyvinylchloride, bulk polymerised	GLO	4.05	kg	0.001	kg/MWh
	market for sheet rolling, copper	GLO	0.36	kg	5.4E-05	kg/MWh
	market for steel, chromium steel 18/8, hot rolled	GLO	4.98	kg	0.001	kg/MWh
	polyethylene production, high density, granulate	RER	7.13	kg	0.001	kg/MWh
	steel production, chromium steel 18/8, hot rolled	RER	6	kg	0.001	kg/MWh
	transport, freight, lorry >32 metric ton, EURO4	RER	12.94	t*km	0.002	t*km/MWh

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Equipment	furnace production, wood chips, with silo, 300kW	CH	1	unit	0.0001	unit/MWh
	market for electric motor, electric passenger car	GLO	7.16	kg	0.001	kg/MWh
	market for electronics, for control units	GLO	2.5	kg	0.0004	kg/MWh
	transport, freight, lorry >32 metric ton, EURO4	RER	0.30	t*km	4.5E-05	t*km/MWh
Wood chips providing	market for wood chips, wet, measured as dry mass	Europe without Switzerland	2272	t	0.34	t/MWh
	market for diesel, burned in building machine	GLO	1334664	MJ	199.98	MJ/MWh
Grid electricity	market for electricity, high voltage	ES	132145.2	kWh	19.8	kWh/MWh
Maintenance	market for transport, passenger car, medium size, diesel, EURO 4	GLO	65280	km	9.78	Km/MWh
Distribution network	market for stone wool	GLO	213.93	kg	0.03	kg/MWh
	market for bitumen adhesive compound, hot	GLO	133000	kg	19.93	kg/MWh
	market for borehole heat exchanger, 150m	GLO	0.2	unit	3.0E-05	unit/MWh
	market for concrete block	DE	4632	kg	0.69	kg/MWh
	market for diesel, burned in building machine	GLO	455.36	MJ	0.07	MJ/MWh
	market for mastic asphalt	GLO	1150	kg	0.17	kg/MWh
	market for polyethylene, high density, granulate	GLO	120.84	kg	0.02	kg/MWh
	transport, freight, lorry >32 metric ton, EURO4	RER	42700.94	t*km	6.40	t*km/MWh
Wood ashes	treatment of wood ash mixture, pure, sanitary landfill	Europe without Switzerland	3960	kg	0.59	kg/MWh
Thermal energy			6674	MWh	1.000E+00	Reference flow

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Activity for plant	Activity in Ecoinvent	Geography	Total amount	Unit of Measure	Amount reported to FU	Unit of measure
Heat pump	market for sheet rolling, copper	GLO	33.75	kg	7.67E-02	kg/MWh
	market for aluminium, cast alloy	GLO	25	kg	5.68E-02	kg/MWh
	market for steel, low-alloyed, hot rolled	GLO	37.5	kg	8.52E-02	kg/MWh
	market for sheet rolling, chromium steel	GLO	23.75	kg	5.40E-02	kg/MWh
	market for acrylonitrile-butadiene-styrene copolymer	GLO	10	kg	2.27E-02	kg/MWh
	market for electronics, for control units	GLO	10	kg	2.27E-02	kg/MWh
	market for propane	GLO	1.17	kg	2.66E-03	kg/MWh
Heat storage tank	market for reinforcing steel	GLO	180	kg	4.09E-01	kg/MWh
	market for polyurethane, flexible foam	RER	20	kg	4.55E-02	kg/MWh
	market for polypropylene, granulate	GLO	60	kg	1.36E-01	kg/MWh
	market for chromium steel pipe	GLO	10	kg	2.27E-02	kg/MWh
	market for casting, brass	GLO	2	kg	4.55E-03	kg/MWh
	market for polyurethane, flexible foam	RER	3	kg	6.82E-03	kg/MWh
	market for sheet rolling, chromium steel	GLO	4.75	kg	1.08E-02	kg/MWh
	market for sheet rolling, copper	GLO	0.25	kg	5.68E-04	kg/MWh
	market for steel, low-alloyed, hot rolled	GLO	1.5	kg	3.41E-03	kg/MWh
	market for electronics, for control units	GLO	2	kg	4.55E-03	kg/MWh
	market for pump, 40W	GLO	1	unit	2.27E-03	unit/MWh
Transport	transport, freight, lorry 3.5-7.5 metric ton, EURO6	RER	86.2	t*km	1.959E-01	t*km/MWh
Use phase	market for electricity, low voltage	DK	149.6	MWh	3.400E-01	

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	Emissions to air (CO_2)		18879	kg	4.291E+01	
Thermal energy			440.00	MWh	1.000E+00	Reference flow

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Reference 2020	Quantity	Unit/ton$_{waste}$	DB reference
Heat production			
Thermal energy sold	2435,2	kWh	Heat, for reuse in municipal waste incineration only {DK}| market for | APOS, S
Cooling towers (recirculated)	33,7	kWh	Heat, for reuse in municipal waste incineration only {DK}| market for | APOS, S
Electricity consumption			
Electricity Incineration	70985,5	kWh	Electricity, for reuse in municipal waste incineration only
Exchange station	8192,9	kWh	Electricity, for reuse in municipal waste incineration only
Heat consumption			
Thermal energy for own use	3,0	kWh	Heat, district or industrial, natural gas {Europe without Switzerland}| market for heat, district or industrial, natural gas | APOS, U
Stationary heating	1,2	kWh	Heat, district or industrial, natural gas {Europe without Switzerland}| market for heat, district or industrial, natural gas | APOS, U
Water consumption	0,2	m3	
Raw material consumption			
Calcium	10,4	kgCa	Calcium (1,1,3,1,1,na) Emission to air from waste composition and transfer coefficients.
Fuels consumption			
Gasoline			
Administration Toyota I	38,6	l	Transport, passenger car, gasoline powered/person km/RNA
Administration Toyota II	31,5	l	Transport, passenger car, gasoline powered/person km/RNA
Diesel			
Lorry	419,35	l	Waste collection lorry, 21 metric ton {GLO}| market for | APOS, U
Gas			
Incinerator truck	20,81	l	_67 Gas, DK
Emissions to air			

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Flue gas	5950,93	Nm^3	
Carbon monoxide CO	30,67	g	Carbon dioxide, biogenic and fossil. (1,1,3,1,1,na) Emission to air from waste composition and transfer coefficients.
Hydrochloric acid HCL	15,64	g	Hydrogen chloride. (1,1,3,1,1,na) Emission to air from waste composition and transfer coefficients.
Particles dust	0,43	g	Particulates, < 2.5 um (1,1,3,1,1,na) Emission to air from waste composition and transfer coefficients.
Chromo	0,01	g	Chromium. (1,1,3,1,1,na) Emission to air from waste composition and transfer coefficients.
Lead Pb	0,01	g	Lead. (1,1,3,1,1,na) Emission to air from waste composition and transfer coefficients.
Cadmium (Cd) / Mercury (Hg)	0,01	g	Cadmium. (1,1,3,1,1,na) Emission to air from waste composition and transfer coefficients.
Hydrogen fluoride (HF)	1,20	g	Hydrogen fluoride. (1,1,3,1,1,na) Emission to air from waste composition and transfer coefficients.
Sulfur dioxide (SO2)	0,60	g	Sulphur. (1,1,3,1,1,na) Emission to air from waste composition and transfer coefficients.
TOC	0,60	g	TOC, Total Organic Carbon. (1,1,3,1,1,na) Emission to air from waste composition and transfer coefficients.
Residual products			
Slag residues + iron	158,15	kg	Scrap steel {Europe without Switzerland}| treatment of scrap steel, municipal incineration | APOS, U
Other residues from steam	25,05	kg	Scrap copper {Europe without Switzerland}| treatment of scrap copper, municipal incineration | APOS, U

Activity from plant	Activity in Ecoinvent	Geography	Total amount	Unit of measure	Amount reported to FU	Unit of measure

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Electricity used	electricity voltage transformation from high to medium voltage	DK	44.,6	MWh	0,04	MWh/t
Electricity auto-produced	electricity, from municipal waste incineration to generic market for electricity, medium voltage	DK	149.2	MWh	0,01	MWh/t
Water consumption	water, unspecified natural origin, non-agriculture	DK	2451.7	m^3	0,2	m^3/t
Chemicals	market for chemical, organic	GLO	50.9	t	0,004	t/t
Electricity production	electricity voltage transformation from high to medium voltage	DK	2124.5	MWh	0,2	MWh/t
Thermal energy production	market for heat, district or industrial, other than natural gas	Europe without Switzerland	1420.7	MWh	0,1	MWh/t
Biogas production	biogas, heat and power co-generation, gas engine	DK	5000.0	m^3	0, 4	m^3/t
Compost	market for compost	GLO	2080.9	t	0,2	t/t
Input from Technosphere	anaerobic digestion plant construction, for bio-waste	CH	0.008	unit	7E-07	unit/t
	composting facility construction, open	CH	0.08	unit	0,00001	unit/t
	market group for diesel, low-sulphur	RER	0.04	kg	3E-06	kg/t
	market for chemicals, inorganic	GLO	0.06	kg	5E-06	kg/t
	tap water production, conventional treatment	Europe without Switzerland	0.009	kg	8E-07	kg/t
	market for electricity, low voltage	DK	0.04	kg	3E-06	kg/t
Emissions	dinitrogen monoxide		0.003	kg	3E-07	kg/t
	hydrogen sulphide		0.001	kg	1E-07	kg/t
	methane, biogenic		0.005	kg	4E-07	kg/t
	carbon dioxide, biogenic		0.02	kg	2E-06	kg/t
	ammonium, ion		0,0004	kg	3E-08	kg/t
	nitrate		0,0001	kg	1E-08	kg/t

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	nitrite		0,001	kg	5E-08	kg/t
	nitrogen, organic bound		0,003	kg	3E-07	kg/t
	phosphorus		0,0003	kg	3E-08	kg/t
Output to Technosphere	market for digester sludge	GLO	0,3	kg	3E-05	kg/t
	market for wastewater, average	Europe without Switzerland	0,08	l	7E-06	l/t

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Environmental fleet of Cascais													
Nº	Fuel	Cylinder capacity	Make	Model	Vehicle Type	Vehicle Family	Year	Month	Day	Emissions	Age	Km/hh	Lt
1	D	4485	Ravo	540	Machine	Compact Mechanical Sweeper	2012	October		Euro V	7	1339	9665.99
2	Gas		Hyster	H1.50XM	Machine	Stacker	2004	April			15	182	0
3	D	4485	Ravo	540	Machine	Compact Mechanical Sweeper	2011	February		Euro 4	8	1482	11017.94
4	D	4485	Ravo	560	Machine	Compact Mechanical Sweeper	2010	December		Euro 4	9	1375	10127.94
5	D	1248	Opel	Corsa	Light Passenger Vehicle	Small Passengers	2011	October	25		8	22223	1215.97
6	D	1248	Opel	Corsa	Light Passenger Vehicle	Small Passengers	2011	October	25		8	13154	732.21
7	D	1248	Opel	Corsa	Light Passenger Vehicle	Small Passengers	2011	October	25		8	22075	1328.84
8	D	1278	Opel	Corsa	Light Passenger Vehicle	Small Passengers	2011	October	25		8	21551	1149.19
9	D	1364	Toyota	Yaris	Light Passenger Vehicle	Small Passengers	2013	November	11		6	32600	1978.18
10	D	2500	Ford	Ranger	Light Goods Vehicle	Pick-Up 4x4 Double Cab	2005	January	10		14	9366	1292.46
11	D	2500	Ford	Ranger	Light Goods Vehicle	Pick-Up 4x4 Double Cab	2005	January	10		14	6648	1331.55
12	D	2299	Renault	Master	Light Goods Vehicle	Cabin-Chassis Double Cab.	2013	December	13		6	24302	2642.7

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13	D	5480	Volvo	FL-12	Heavy Goods Vehicle	12Ton-Abandoned Waste Collection	2004	October	1	Euro 2	15	26995	5578.57
14	D	2299	Opel	Movano	Light Goods Vehicle	Cabin-Chassis Triple Cab.	2011	December	30		8	22517	2594.92
15	D	1248	Opel	Corsa	Light Passenger Vehicle	Small Passengers	2010	December	2		9	15774	863.07
16	D	1248	Opel	Combo	Light Goods Vehicle	Small Van	2005	December	14		14	13601	1025.86
17	D	2494	Toyota	Dyna	Light Goods Vehicle	Cabin-Chassis Triple Cab.	2005	December	27		14	24475	2446.09
18	D	2299	Opel	Movano	Light Goods Vehicle	Cabin-Chassis Triple Cab.	2013	April	1		6	17839	2045.31
19	D	4613	Toyota	Dyna L	Heavy Goods Vehicle	8Ton-Green Waste Collection	2005	November	10	Euro 2	14	19205	4895.86
20	D	2299	Opel	Movano	Light Goods Vehicle	Cabin-Chassis Triple Cab.	2011	December	30		8	21880	2676.89
21	D	2299	Opel	Movano	Light Goods Vehicle	Cabin-Chassis Triple Cab.	2011	May	4		8	15617	2072.73
22	D	2477	Mitsubishi	L200	Light Goods Vehicle	Pick-Up 4x2 Single Cab	2005	December	9		14	10367	1355.29
23	D	4613	Toyota	Dyna L	Heavy Goods Vehicle	8Ton-Green Waste Collection	2005	November	10	Euro 2	14	14207.5	4317.5
24	D	1248	Opel	Combo	Light Goods Vehicle	Small Van	2005	December	7		14	9424	1041.39
25	D	8480	Scania	P93M	Heavy Goods Vehicle	18Ton-Green Waste Collection	1996	January	4	Euro 1	23	9265	4252.27
26	D	6871	MAN	TGM 18250	HGV Special Urban Cleaning	18Ton-Green Waste Collection	2010	October	26	Euro 4	9	18421.5	8492.57
27	D	5480	Volvo	FL-12	Heavy Goods Vehicle	12Ton-Abandoned Waste Collection	2004	October	1	Euro 2	15	26012	6441.6

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28	D	2477	Mitsubishi	L200	Light Goods Vehicle	Pick-Up 4x2 Single Cab	2005	December	9		14	9525	1347.22
29	D	5480	Volvo	FL-12	Heavy Goods Vehicle	12Ton-Abandoned Waste Collection	2004	October	1	Euro 2	15	32277	7204.3
30	D	1248	Opel	Corsa	Light Passenger Vehicle	Small Passengers	2010	December	2		9	14508	805.32
31	D	9400	Volvo	FM-9	Heavy Goods Vehicle	18Ton-Green Waste Collection	2003	December	3	Euro 2	16	15951.5	10090.68
32	D	5480	Volvo	FL-12	Heavy Goods Vehicle	12Ton-Abandoned Waste Collection	2004	October	1	Euro 2	15	26211	6924.24
33	D	1248	Opel	Corsa	Light Passenger Vehicle	Small Passengers	2010	October	18		9	11334	712.26
34	D	9400	Volvo	FM-9	Heavy Goods Vehicle	18Ton	2004	November	22	Euro 2	15	14618	5373.11
35	D	4485	Case	JX95C4	Machine	Agricultural Tractor	2010	August	2		9	416	0
36	D	6871	MAN	TGM 18250	HGV Special Urban Cleaning	18Ton-Green Waste Collection	2010	October	26	Euro 4	9	12374	5269.36
37	D	2494	Toyota	Hilux	Light Goods Vehicle	Pick-Up 4x4 Double Cab	2007	December	3		12	7347	878.07
38	D	5480	Volvo	FL-12	Heavy Goods Vehicle	12Ton-Abandoned Waste Collection	2004	October	1	Euro 2	15	27116	5884.71
39	D	9400	Volvo	FM-9	Heavy Goods Vehicle	18Ton	2004	November	22	Euro 2	15	10702	4093.41
40	D	2299	Opel	Movano	Light Goods Vehicle	Cabin-Chassis Triple Cab.	2011	May	4		8	18771	2203.8
41	D	9400	Volvo	FM-9	Heavy Goods Vehicle	18Ton-Green Waste Collection	2003	December	3	Euro 2	16	20628	11302.33
42	D	1461	Dacia	Dokker	Light Goods Vehicle	Small Van	2013	October	10		6	9501	909.88

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43	D	9400	Volvo	FM-9	Heavy Goods Vehicle	18Ton-Green Waste Collection	2003	December	3	Euro 2	16	13101	6921.8
44	D	2402	Ford	Transit	Light Goods Vehicle	Cabin-Chassis Triple Cab.	2006	January	26		13	6356	2119.03
45	D	2299	Opel	Movano	Light Goods Vehicle	Cabin-Chassis Triple Cab.	2013	April	1		6	23106	2803.64
46	D	2402	Ford	Transit	Light Goods Vehicle	Cabin-Chassis Triple Cab.	2006	January	26		13	24395	3003.51
47	D	1560	Toyota	Proace	Light Goods Vehicle	Small Van	2013	November	11		6	18729	1707.24
48	D	1248	Opel	Corsa	Light Goods Vehicle	Car Van	2006	January	30		13	10395	545.09
49	D	9400	Volvo	FM-9	Heavy Goods Vehicle	18Ton-Green Waste Collection	2003	December	3	Euro 2	16	26879	14608.18
50	D	1461	Renault	Clio	Light Passenger Vehicle	Small Passengers	2013	October	10		6	49550	2505
51	D	1248	Opel	Corsa	Light Goods Vehicle	Car Van	2006	January	30		13	15192	967
52	D	6374	Mercedes Benz	Atego 1823	Heavy Goods Vehicle	18Ton-Green Waste Collection	2001	February	26	Euro 2	18	41976	9169.39
53	D	1248	Opel	Corsa	Light Passenger Vehicle	Small Passengers	2010	December	2		9	10169	561.74
54	D	1248	Opel	Corsa	Light Goods Vehicle	Car Van	2006	January	30		13	7117	431.44
55	D	1248	Opel	Corsa	Light Goods Vehicle	Car Van	2006	January	30		13	8335	470.56
56	D	2299	Opel	Movano	Light Goods Vehicle	Cabin-Chassis Triple Cab.	2013	April	1		6	29865	3317.2
57	D	4485	Ravo	540	Machine	Compact Mechanical Sweeper	2011	November		Euro 4	8	1039	8360.27

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58	D	4485	Ravo	540	Machine	Compact Mechanical Sweeper	2011	October		Euro 4	8	4299	16032.82
59	D	4485	Ravo	540	Machine	Compact Mechanical Sweeper	2013	September		Euro V	6	1020	9093.98
60	D	4249	Mercedes Benz	1218	HGV Special Urban Cleaning	12Ton-Street Washer	2006	April	10	Euro 3	13	9052	5185.77
61	D	6374	Mercedes Benz	1828	HGV Special Urban Cleaning	12Ton-Street Washer	2006	March	6	Euro 3	13	7523	5449.78
62	D	5900	DAF	FA-55	HGV Special Urban Cleaning	12Ton-Street Washer	2006	April	27	Euro 3	13	10030	4662.46
63	D	9200	DAF	FA-75	HGV Special Urban Cleaning	12Ton-Street Washer	2006	April	27	Euro 3	13	9688	6041.4
64	D	1758	Lamborghini	R1-55 DT	Machine	Agricultural Tractor	2006	June	26		13	184	0
65	D	2800	Mathieu	Aquazura	Machine	Compact Mechanical Sweeper	2006	September		Euro 2	13	49	65.02
66	D	1364	Toyota	Yaris	Light Passenger Vehicle	Small Passengers	2013	November	11		6	26481	1462.07
67	D	7146	Volvo	FES 4x2	HGV Special Urban Cleaning	19Ton-Urban Waste Collection	2010	November	15	Euro 4	9	30907	23914.75
68	D	7146	Volvo	FES 4x2	HGV Special Urban Cleaning	19Ton-Urban Waste Collection	2010	November	15	Euro 4	9	20599	13233.01
69	D	12130	Volvo	FM-12	Heavy Goods Vehicle	26Ton-Selective Waste Collection-Ampliroll	2005	February	9	Euro 2	14	15350	9289.71
70	D	2495	Land Rover	Defender	Light Passenger Vehicle	Jeep	1999	June	6		20	6198	730.83
71	D	8867	Scania	310	HGV Special Urban Waste Collection	19Ton-Selective Waste Collection	2005	October	31	Euro 2	14	14000	12806.3

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72	D	8867	Scania	310	HGV Special Urban Waste Collection	19Ton-Urban Waste Collection	2005	October	31	Euro 2	14	25983	24499.24
73	D	8867	Scania	310	HGV Special Urban Waste Collection	19Ton-Selective Waste Collection	2005	October	31	Euro 2	14	19359	19046.82
74	D	1248	Opel	Corsa	Light Passenger Vehicle	Small Passengers	2007	February	21		12	11253	649.97
75	D	6374	Mercedes Benz	Axor 1829	Heavy Goods Vehicle	26Ton-Selective Waste Collection-Ampliroll	2007	April	23	Euro 3	12	13446	6117.2
76	D	4009	Toyota	Dyna L	HGV Special Urban Waste Collection	8Ton-Urban Waste Collection	2007	July	30	Euro 3	12	22276	4487.73
77	D	4009	Toyota	Dyna L	HGV Special Urban Waste Collection	8Ton-Selective Waste Collection	2007	July	30	Euro 3	12	19648	5243.46
78	D	1248	Opel	Corsa	Light Passenger Vehicle	Small Passengers	2007	September	14		12	16461	464.06
79	D	1248	Opel	Corsa	Light Goods Vehicle	Car Van	2007	October	8		12	16374	864.18
80	D	1995	Opel	Vivaro	Light Goods Vehicle	Passenger Van	2007	November	14		12	11774	1262.35
81	D	1248	Opel	Corsa	Light Passenger Vehicle	Small Passengers	2007	December	18		12	10087	576.59
82	D	9290	Scania	P320	HGV Special Urban Cleaning	19Ton-Selective Waste Collection	2013	December	30	Euro V	6	28427	22958.37
83	D	1248	Opel	Corsa	Light Goods Vehicle	Car Van	2008	March	25		11	9542	476.43
84	D	9290	SCANIA	P320	HGV Special Urban Cleaning	19Ton-Selective Waste Collection	2013	December	30	Euro V	6	19839	16129.79

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85	D	8867	Scania	310	HGV Special Urban Waste Collection	19Ton-Selective Waste Collection	2005	October	31	Euro 2	14	22688	21384.21
86	D	8867	Scania	310	HGV Special Urban Waste Collection	19Ton-Selective Waste Collection	2005	October	31	Euro 2	14	19099	17633.67
87	D	3000	Dulevo	850/Mini	Machine	Compact Mechanical Sweeper	2013	February		Euro V	6	800	2212.2
88	D	6374	Mercedes Benz	Axor 1829	HGV Special Urban Cleaning	19Ton-Selective Waste Collection	2008	May	16	Euro 3	11	21177	10932.18
89	D	6374	Mercedes Benz	Axor 1829	HGV Special Urban Cleaning	19Ton-Selective Waste Collection	2008	May	16	Euro 3	11	8293	5608.28
90	D	6374	Mercedes Benz	Axor 1829	HGV Special Urban Cleaning	19Ton-Urban Waste Collection	2008	July	8	Euro 3	11	14661	10242.85
91	D	1461	Renault	Clio	Light Passenger Vehicle	Small Passengers	2013	December	10		6	29715	1750.8
92	D	2488	Nissan	Pick Up	Light Goods Vehicle	Pick-Up 4x2 Single Cab	2006	August	31		13	11335	1398.04
93	D	1248	Opel	Corsa	Light Passenger Vehicle	Small Passengers	2010	December	2		9	11405	695.55
94	D	1364	Toyota	Yaris	Light Goods Vehicle	Car Van	2006	September	18		13	15721	960.82
95	D	3920	John Deere	2650 A	Machine	Agricultural Tractor	2006	April	21		13	475	0
96	D	6871	MAN	TGM 18250	HGV Special Urban Cleaning	18Ton-Green Waste Collection	2012	November	20	Euro V	7	32741	12687.21
97	D	10837	Volvo	FM-11	HGV Special Urban Cleaning	26Ton-Urban Waste Collection	2012	June	26	Euro V	7	18616	22203.31
98	D	9290	Scania	P320	HGV Special Urban Cleaning	26Ton-Urban Waste Collection	2012	July	19	Euro V	7	34805	34636.53

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99	D	9290	Scania	P320	HGV Special Urban Cleaning	26Ton-Urban Waste Collection	2012	July	19	Euro V	7	31031	32251.56
100	D	10837	Volvo	FM-11	HGV Special Urban Cleaning	26Ton-Urban Waste Collection	2012	June	26	Euro V	7	24256	29510.47
101	D	10518	MAN	TGS 26320	HGV Special Urban Cleaning	26Ton-Urban Waste Collection	2012	May	23	Euro V	7	14302	13995.36
102	D	10518	MAN	TGS 26320	HGV Special Urban Cleaning	26Ton-Urban Waste Collection	2012	May	23	Euro V	7	17646	12708.66
103	D	1248	Opel	Corsa	Light Passenger Vehicle	Small Passengers	2008	September	29		11	11596	695.44
104	D	1248	Opel	Corsa	Light Goods Vehicle	Car Van	2008	September	29		11	10311	540.4
105	E	0	Goupil	G3S	Light Goods Vehicle	Electric Small Vehicle	2009	April	21		10	3352	0
106	D	2800	Mathieu	Aquadyne	Machine	Compact Mechanical Street Washer	2009	May			10	424	1356.42
107	D	2800	Mathieu	Aquazura	Machine	Compact Mechanical Street Washer	2009	May			10	35	132.82
108	D	1248	Opel	Corsa	Light Goods Vehicle	Car Van	2009	May	11		10	13894	749.54
109	D	4485	Ravo	540	Machine	Compact Mechanical Sweeper	2010	January		Euro V		99	677.3
110	D	1248	Opel	Astra	Light Passenger Vehicle	Small Passengers	2012	September	21		7	21843	1311.09
111	D	2299	Opel	Movano	Light Goods Vehicle	Cabin-Chassi Triple Cab.	2013	April	1		6	29028	3224.53
112	D	2982	Toyota	Dyna	Light Goods Vehicle	Cabin-Chassi Triple Cab.	2013	November	4		6	25174	3374.78
113	D	4485	Case	Farmall 95AC	Machine	Agricultural Tractor	2014	June	3	Tier3	5	999.5	5856.59

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114	D	6600	CATERPILLAR	924K	Machine	Wheel Loader	2014	October	3	Tier4; SIIIB	5	336	4298.17
115	GH	1497	Toyota	Prius	Light Passenger Vehicle	Hybrid Medium Passengers	2007	August	30		12	35963	2246.56
116	D	9291	Scania	P320	HGV Special Urban Cleaning	19Ton-Selective Waste Collection	2015	April	9	Euro VI	4	24359	20801.88
117	D	1364	Toyota	Yaris	Light Passenger Vehicle	Small Passengers	2015	June	22		4	6162	351.77
118	D	1364	Toyota	Yaris	Light Passenger Vehicle	Small Passengers	2015	June	22		4	17057	1122.14
119	E		Goupil	G3S	Light Goods Vehicle	Electric Small Vehicle	2015	July	1		4	4298	0
120	D	2198	Peugeot	Boxer	Light Goods Vehicle	Van	2015	June	19		4	31398	3710.99
121	D	2982	Toyota	Dyna	Light Goods Vehicle	Cabin-Chassi Triple Cab.	2015	June	22		4	43811	4989.92
122	D	2494	Toyota	Hilux	Light Goods Vehicle	Pick-Up 4x2 Single Cab	2015	June	22		4	18212	1861.27
123	D	2494	Toyota	Hilux	Light Goods Vehicle	Pick-Up 4x2 Single Cab	2015	June	22		4	13443	1805.05
124	D	4500	Ravo	540	Machine	Compact Mechanical Sweeper	2015	October	1	Euro V	4	2612	21136.54
125	D	4500	Ravo	540	Machine	Compact Mechanical Sweeper	2015	October	1	Euro V	4	1418	9697.13
126	D	3400	Case	695ST	Machine	Backhoe Loader	2015	December	17	Tier IV	4	565	4437.47
127	E		Renault	Kangoo ZE	Light Goods Vehicle	Electric Small Van	2015	December	22		4	8148	0
128	GH	1798	Toyota	Auris	Light Passenger Vehicle	Hybrid Medium Passengers	2016	January	12		3	22802	1531.81

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129	D	9291	Scania	N321	HGV Special Urban Cleaning	19Ton-Green Waste Collection	2016	January	5	Euro VI	3	36106	21846.19
130	D	12742	Scania	N331	Heavy Goods Vehicle	26Ton-Selective Waste Collection-Ampliroll	2016	January	5	Euro VI	3	24624	16559.46
131	D	3400	Case	695ST	Machine	Backhoe Loader	2016	February	4	Tier IV	3	749	5289.55
132	G	125	Keeway	CityBlade	Motorcycle	Scooter	2016	March	24		3	4230	132.02
133	D	4500	Ravo	540	Machine	Compact Mechanical Sweeper	2016	April	18	Euro VI	3	1460.5	10724.52
134	D	4500	Ravo	540	Machine	Compact Mechanical Sweeper	2016	May	27	Euro VI	3	1208	8591.81
135	GHPI	1798	Toyota	Prius	Light Passenger Vehicle	Hybrid Plug-in Medium Passengers	2015	April	17		4	29254	1438.97
136	GHPI	1798	Toyota	Prius	Light Passenger Vehicle	Hybrid Plug-in Medium Passengers	2015	December	29		4	10372	331.53
137	D	9291	Scania	P250	HGV Special Urban Cleaning	19Ton-Sweeper	2016	May	23	Euro VI	3	10836	13103.93
138	D	7698	Volvo	FE 4750	HGV Special Urban Cleaning	19Ton-Green Waste Collection	2016	May	24	Euro VI	3	32750	15511.17
139	D	4500	Ravo	540	Machine	Compact Mechanical Sweeper	2016	June	6	Euro VI	3	1519	11725.67
140	D	4500	Ravo	540	Machine	Compact Mechanical Sweeper	2016	June	27	Euro VI	3	1684.5	11837.55
141	D	7698	Volvo	FE4100	HGV Special Urban Cleaning	19Ton-Selective Waste Collection	2016	July	7	Euro VI	3	26676	19924.08
142	GH	1497	Toyota	Yaris Hybrid	Light Passenger Vehicle	Hybrid Small Passengers	2016	December	13		3	30906	1621.64
143	D	3387	CASE-IH	Farmall 95AC	Machine	Agricultural Tractor	2016	December		Tier IV	3	1005	4829.02

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144	D	2998	Mitsubishi	Canter	Light Goods Vehicle	Cabin-Chassis Double Cab.	2017	March	30		2	10864	1531.09
145	D	2445	Mitsubishi	L200	Light Goods Vehicle	Pick-Up 4x2 Double Cab	2017	March	30		2	24478	2923.31
146	D	2445	Mitsubishi	L200	Light Goods Vehicle	Pick-Up 4x2 Double Cab	2017	March	30		2	24881	2971.74
147	D	9291	Scania	P320	HGV Special Urban Cleaning	26Ton-Urban Waste Collection	2017	April	19	Euro VI	2	50012	42894.69
148	D	9291	Scania	P320	HGV Special Urban Cleaning	26Ton-Urban Waste Collection	2017	April	19	Euro VI	2	29910	28078.67
149	D	9291	Scania	P320	HGV Special Urban Cleaning	26Ton-Urban Waste Collection	2017	April	19	Euro VI	2	36672	36323.81
150	D	9291	Scania	P320	HGV Special Urban Cleaning	26Ton-Urban Waste Collection	2017	April	19	Euro VI	2	32030	31754.31
151	GH	1500	Toyota	Yaris Hybrid	Light Passenger Vehicle	Hybrid Small Passengers	2017	April	24		2	42632	2435.22
152	GH	1500	Toyota	Yaris Hybrid	Light Passenger Vehicle	Hybrid Small Passengers	2017	April	24		2	22821	958.73
153	E		TENAX	TXE2 ELECTRA 2.0	Machine	Compact Electrical Sweeper	2017	May	18		2	59	0
154	D	4500	Ravo	540	Machine	Compact Mechanical Sweeper	2017	January	25	Euro VI	2	1570	11259.93
155	D	4500	Ravo	540	Machine	Compact Mechanical Sweeper	2016	October	27	Euro VI	3	2083.5	14877.15
156	D	2998	Mitsubishi	Canter	Heavy Goods Vehicle	18Ton-Green Waste Collection	2017	March	29	Euro VI	2	29598	6148.07
157	D	2998	Mitsubishi	Canter	Heavy Goods Vehicle	18Ton-Green Waste Collection	2017	March	29	Euro VI	2	27935	6575.79
158	E		Renault	Zoe	Light Passenger Vehicle	Electric Small Passengers	2017	June	1		2	14121	0

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159	D	2442	Renault	Master	Light Goods Vehicle	Van	2017	June	1		2	46791	4897.93
160	D	2998	Mitsubishi	Canter	Light Goods Vehicle	Cabin-Chassis Triple Cab.	2017	June	28	Euro VI	2	20484	2624.6
161	D	2998	Mitsubishi	Canter	Light Goods Vehicle	Cabin-Chassis Triple Cab.	2017	September	27	Euro VI	2	28822	3493.9
162	D	9291	Scania	P320	HGV Special Urban Cleaning	26Ton-Urban Waste Collection	2017	June	22	Euro VI	2	35299	33182.83
163	D	9291	Scania	P320	HGV Special Urban Cleaning	26Ton-Urban Waste Collection	2017	June	22	Euro VI	2	42433	39102.53
164	D	9291	Scania	P320	HGV Special Urban Cleaning	26Ton-Urban Waste Collection	2017	June	22	Euro VI	2	48028	43059.82
165	D	9291	Scania	P320	HGV Special Urban Cleaning	26Ton-Urban Waste Collection	2017	June	22	Euro VI	2	46995	43498.96
166	E		Green Machines	500ze Plus	Machine	Compact Electrical Sweeper	2017	October	4		2	147	0
167	D	2200	CASE-IH	Farmall 50A	Machine	Agricultural Tractor	2017	June	4	Tier IV	2	417	746.25
168	D	3387	CASE-IH	Farmall 95AC	Machine	Agricultural Tractor	2017	December	29	Tier IV	2	557.5	3271.83
169	D	2442	Mitsubishi	L200 4x2	Light Goods Vehicle	Pick-Up 4x2 Double Cab	2018	April	30	Euro VI	1	13414	1482.2
170	D	2998	Mitsubishi	Canter	Light Goods Vehicle	Cabin-Chassi Double Cab.	2018	May	23	Euro VI	1	8359	1326.95
171	E		Renault	Kangoo ZE	Light Goods Vehicle	Electric Small Van	2018	April	23		1	14552	0
172	D	2299	Renault	Master	Light Goods Vehicle	Van	2018	November	26	Euro VI	1	12149	1161.26
173	D	3769	Mathieu	Azura MC210	Machine	Compact Mechanical Street Washer	2018	February	20	Tier IV	1	675	3283.28

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174	D	4500	Ravo	540	Machine	Compact Mechanical Sweeper	2018	June	11	Euro VI	1	1930	19201.38
175	D	4500	Ravo	540	Machine	Compact Mechanical Sweeper	2018	June	11	Euro VI	1	2274	14337.97
176	D	2143	Mercedes Benz	Sprinter	Light Goods Vehicle	Van	2018	June	22	Euro VI	1	9714	1258.74
177	D	2143	Mercedes Benz	Sprinter	Light Goods Vehicle	Van	2018	June	22	Euro VI	1	6469	807.47
178	E		Renault	Zoe	Light Passenger Vehicle	Electric Small Passengers	2018	July	23		1	13963	0
179	E		Renault	Zoe	Light Passenger Vehicle	Electric Small Passengers	2018	July	23		1	18738	0
180	E		Renault	Zoe	Light Passenger Vehicle	Electric Small Passengers	2018	July	23		1	16166	0
181	E		Renault	Zoe	Light Passenger Vehicle	Electric Small Passengers	2018	July	23		1	11281	0
182	E		Renault	Zoe	Light Passenger Vehicle	Electric Small Passengers	2018	July	23		1	15397	0
183	E		Renault	Zoe	Light Passenger Vehicle	Electric Small Passengers	2018	July	23		1	35728	0
184	D	3300	CATERPILLAR	259D	Machine	Compact Track Loader	2018			Tier IV	1	215	906.9
185	D	4400	CATERPILLAR	444F2	Machine	Backhoe Loader	2018	December	4	Tier IV	1	1055	7636.48
186	D	2962	Toyota	Land Cruiser	Light Passenger Vehicle	Jeep	2009	September	30		10	9567	1285.46
187	D	6871	MAN	TGM 18290	Heavy Goods Vehicle	18Ton-Green Waste Collection	2018	Euro VI	3	Euro VI	1	30205	13433.55
188	D	2393	Toyota	Hilux CE 3L	Light Goods Vehicle	Pick-Up 4x4 King Cab	2018	September	27	Euro VI	1	17327	2418.67

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189	D	2393	Toyota	Hilux CD 5L	Light Goods Vehicle	Pick-Up 4x4 Double Cab	2018	September	27	Euro VI	1	7261	808.3
190	D	4500	DAF	LF180	Heavy Goods Vehicle	12Ton-Abandoned Waste Collection	2018	December	26	Euro VI	1	27680	6012.54
191	D	4500	Ravo	540 CD	Machine	Compact Mechanical Sweeper	2019	February	26	Euro VI	0	1172.5	7555.49
192	E		Renault	Zoe	Light Passenger Vehicle	Electric Small Passengers	2019	April	11		0	21012	0
193	E		Renault	Zoe	Light Passenger Vehicle	Electric Small Passengers	2019	April	11		0	8037	0
194	E		Renault	Zoe	Light Passenger Vehicle	Electric Small Passengers	2019	April	11		0	4738	0
195	D	1560	Toyota	Proace	Light Goods Vehicle	Small Van	2019	July	2	Euro VI	0	14488	1166.26
196	D	9291	Scania	P360	HGV Special Urban Cleaning	26Ton-Urban Waste Collection	2019	May	27	Euro VI	0	20369	19661.15
197	D	6700	Scania	P280	Heavy Goods Vehicle	18Ton-Green Waste Collection	2019	April	17	Euro VI	0	13947	5966.64
198	D	6700	Scania	P280	Heavy Goods Vehicle	18Ton-Green Waste Collection	2019	April	17	Euro VI	0	15815	5287.68
199	D	10837	Volvo	FM330	HGV Special Urban Cleaning	26Ton-Urban Waste Collection	2019	April	24	Euro VI	0	6113	5827.24
200	D	9291	Scania	L320	HGV Special Urban Cleaning	19Ton-Selective Waste Collection	2019	June	11	Euro VI	0	1546	155.9
201	D	2998	Mitsubishi	Canter	Light Goods Vehicle	Cabin-Chassis Double Cab.	2019	June	5	Euro VI	0	12772	1538.08
202	E		TENAX	Electra 2 Hydro	Machine	Compact Electrical Street Washer	2019	July	16		0	126	0
203	D	2143	Mercedes Benz	Sprinter	Light Goods Vehicle	Cabin-Chassis Triple Cab.	2019	September	13	Euro VI	0	6017	618.86

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204	D	2143	Mercedes Benz	Sprinter	Light Goods Vehicle	Cabin-Chassi Triple Cab.	2019	September	22	Euro VI	0	6144	579.34
205	D	4500	Ravo	540 CD	Machine	Compact Mechanical Sweeper	2019	August	22	Euro VI	0	249	1852.89
206	D	10837	Volvo		HGV Special Urban Cleaning	26Ton-Selective Waste Collection-Ampliroll	2019	September	27	Euro VI	0	1670	1469
207	E		ALKÉ	ATX340E	Light Goods Vehicle	Electric Small Vehicle	2019	October	31		0	80	0
208	E		ALKÉ	ATX340E	Light Goods Vehicle	Electric Small Vehicle	2019	October	31		0	0	0
209	E		ALKÉ	ATX330E	Light Goods Vehicle	Electric Small Vehicle	2019	October	31		0	35	0
210	E		ADDAX	MT15	Light Goods Vehicle	Electric Small Vehicle	2019	October	1		0	1024	0
211	E		ESAGONO	Gastone	Light Goods Vehicle	Electric Small Vehicle	2019	September	24		0	824	0
212	D	7700	Volvo	FL 8 16	HGV Special Urban Cleaning	12Ton-Urban Waste Collection	2019	December	4	Euro VI	0	5440	0

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