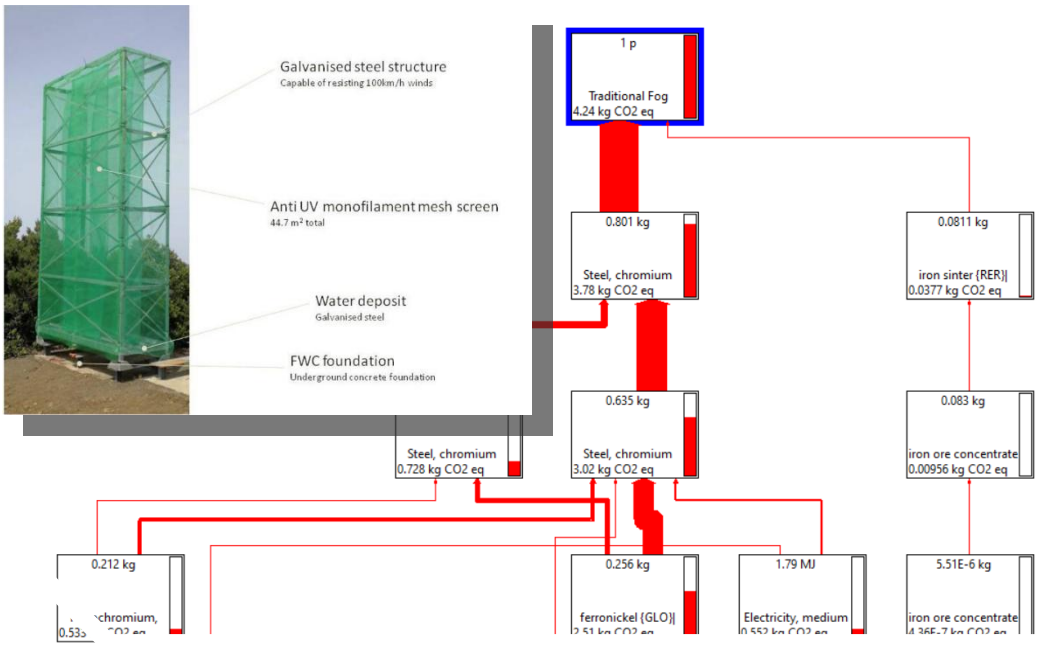
D6. Monitoring of the Impact of the project actions

GHG emissions evaluation by LCA methodology



Compiled by Life-Nieblas team: ITC, GESPLAN.

Delivery date: 10/03/2023

Last revision: 03/2025

Table of content

1. Summary 1
2. Action: D6. Monitoring of the Impact of the project actions 2
3. Objective of the LCA. 3
4. Scope of the study. 3
   4.1 Overview of the system under study 3
   4.2 Traditional fog collectors 3
   4.3 Water tanks 4
   4.4 Autonomous Fluid Discharge System (AFDS) 5
   4.5 Individual Fog Collectors (IFCW) 6
   4.6 Cocoons 7
   4.7 Traditional irrigation system. 8
   4.8 Innovative Fog Water Collector (i-FWC) 8
5. Functional Unit Definition 9
6. System boundaries 9
7. Quality requirements of the system 9
8. Inventory analysis 10
   8.1 Construction phase 10
      8.1.1 AFDS supplied with 3 fog collectors 10
      8.1.2 3 AFDS supplied with pumped water from spring 16
      8.1.3 AFDS supplied with water tank truck from wells 17
      8.1.4 Cocoon with different supplies 17
      8.1.5 Traditional irrigation with different supplies 19
      8.1.6 Individual fog water collector (IFWC) 21
      8.1.7 Innovative Fog Water Collector (i-FWC) 22
   8.2 Exploration and maintenance phase 23
9. Impact assessment of the systems studied 30
   9.1 Impact assessment in the first assembly phase. 31
      9.1.1 AFDS supplied with 3 fog collectors (500 surviving trees, 100%) 31
      9.1.2 AFDS supplied with 3 fog collectors (400 surviving trees, 80%) 32
      9.1.3 3 AFDS supplied with pumped water from spring (1,200 trees, 80%) 33
      9.1.4 AFDS supplied with water tank truck (400 trees, 80%) 34

9.1.5 Cocoon emissions (LCA assessment) 35
9.1.6 Cocoon supplied with tank and three fog collectors (400 trees, 80%) 36
9.1.7 Cocoon supplied with pumped water form spring (400 trees, 80%) 37
9.1.8 Cocoon supplied with water tank truck (400 trees, 80%) 38
9.1.9 Individual fog water collector (IFWC) 39
9.1.10 Innovative Fog Water Collector (i-FWC), total emissions. 40
9.1.11 Comparison in first Assembly Phase 41
9.2 Impact Assessment of the operation and maintenance phase (1 year). 45
9.2.1 AFDS 2 supplied with 3 fog collectors with spring pump support in August. 45
9.2.2 AFDS 1 supplied with pumped water from spring (July – Sep, irrigation regime) 46
9.2.3 AFDS 3 supplied with pumped water from spring (May –Sep irrigation regime) 47
9.2.4 AFDS2 (400) fog collectors supply with water truck support In August. 48
9.2.5 AFDS1 (400) water truck support (July – Sep, irrigation regime) 49
9.2.6 AFDS3 (400) water truck support (May – Sep, irrigation regime) 50
9.2.7 Cocoon Sector 1 fog collectors support 51
9.2.8 Cocoon Sector 2 fog support 52
9.2.9 Cocoon Sector 3 fog support 53
9.2.10 Cocoon Sector 1 pump support 54
9.2.11 Cocoon Sector 2 pump support 55
9.2.12 Cocoon Sector 3 pump support 56
9.2.13 Comparison between different systems and irrigation regimes 57
9.3 Relationships between initial assembly phase (without reusing materials) and operation phase (1 year). 59
10. Global contribution to climate objectives 60
11. Conclusions of the study 64
12. Annex: Ecoinvent v3.7.1 database references 66
12.1 Diesel {Europe without Switzerland}| market for | Cut-off, U 66
12.2 Transport, passenger car, médium size, diésel, EURO 4 67
12.3 Electricity, low voltage {ES}| market for | Cut-off, U 68
12.4 Electricity, medium voltage {ES}| market for | Cut-off, U 70
12.5 Transport, freight, lorry 7.5-16 metric ton, EURO4 {RER}| transport, freight, lorry 7.5-16 metric ton, EURO4 | Cut-off, U 71
13. Authors: 76

1. Summary

This document is part of the set of studies carried out by the Department of Water of the Technological Institute of the Canary Islands (ITC) within the framework of the project to monitor the installed equipment and its impact. The information collected for the study has been provided by ITC, GESPLAN and ICIA technicians.

As an addition to the project, not considered in the initial application form, It was considered to carry out a life cycle analysis (LCA) of the equipment installed for the development of the LIFE NIEBLAS Project, with the objective of determine the carbon footprint (GHG) of the different irrigation systems and to provide useful background information for the development of Action D6 Monitoring of LIFE KPI.

The main objective of this LCA is to obtain an estimate of the environmental impact generated in the hole life cycle of the different irrigation and fog collection systems installed by the LIFE NIEBLAS project.

A complete stroke is performed, cradle to gate, that is, it is considered the reception of the materials necessary for the construction of the different systems and the operation and maintenance of them.

This LCA can contribute to the development of a guide for decision-making in the planning of reforestation models in areas with characteristics similar to those raised in the study.

It is important to highlight that, in the case of water transported from wells outside La Finca El Pinillo, the emissions impact from the manufacturing of the tanker trucks and the construction of the underground water wells was not considered. Only the emissions cost of pumping and transportation was taken into account. However, for water collection within the estate, whether from fog catchers or the spring, the emissions from the manufacturing of all components and materials are considered. This aspect is crucial for evaluating and comparing the different systems and drawing conclusions.

2. Action: D6. Monitoring of the Impact of the project actions

A number of indicators were planned to be monitored during, at the end and five years after the completion of this project that will demonstrate the feasibility of the methodology used and/or highlight opportunities for improvements.

Life Nieblas in line with EU commitment to contribute to the Paris Agreement goals tested innovative reforestation methodologies which are particularly looking into their replication and transferability potential. For such task, data collected has been analysed within the monitoring actions of this project. Life Nieblas expects to contribute to gas emissions mitigation target set by the Paris Agreement for non-ETS sectors. In this regards, the project, as an additional contribution, developed a Life Cycle Assessment (LCA) that conclude whether the techniques and methods proposed could positively contribute to the aforementioned agreement and other regulation such as Effort Sharing Regulation (EU) 2018/842 and the Land Use, Land Use Change and Forestry (LULUCF) Regulation (EU) 2018/841. All in all with the methods tested in this project, the innovation in technology developed by our engineers and the detailed analyses in potential biomass generation and CO2 fluxes in developed Laurisilva forests, Life Nieblas is looking into data that would conclude whether such developments would work as source, sink or CO2 sequestration hubs. Furthermore, the LCA will help throw some light into economic and carbon footprint feasibility of the project.[1]

Four methods were used in the development of this project:

1- Traditional reforestation by direct irrigation.
2- Reforestation through the use of 'Cocoons' (a self-managed, biodegradable breeding system, which was developed by a previous 'Life Green Link' project)
3- Reforestation by individual fog collectors. The plants are covered with a square metal mesh for wind protection and large herbivores that in turn have the ability to capture moisture from the air.
4- Automatic Fluid Dischargue System (AFDS) with an irrigation network.

Independently of the reforestation system, another key aspect to consider in the evaluation of this project is the different possible water sources and the irrigation regimes applied, both during the establishment phase of the plantations and in the monitoring and consolidation phases.

The following water sources have been considered:

1. Water sourced from outside the reforestation area, extracted from underground wells and transported by tanker trucks to the irrigation zone[2].
2. Water collected from various types of fog collectors.
3. Water from spring water accumulated in the cave reservoir located in “La Finca El Pinillo”.

Finally, the different reforestation systems are combined with the various irrigation regimes and water sources to evaluate their performance and draw conclusions.

This document contains the information necessary to perform the LCA of the different systems and combinations through the process collected by the UNE 14040:

- Definition of objectives and scope.
- Analysis of inventory.

[1] LIFENIEBLAS Mid-term report.
[2] This is the most commonly used traditional system, which, in the case of the LIFE NIEBLAS project, has not been necessary due to local water collection or the presence of a natural spring in *La Finca El Pinillo*.

- Impact assessment.
- Interpretation of the LCA.

This order was followed to facilitate further analysis.

3. Objective of the LCA.

The main objective of this LCA is to obtain an estimate of the environmental impact generated (GHG emissions) in the life cycle of the different irrigation and fog collection systems installed by the LIFE NIEBLAS project.

A complete stroke is performed, from the cradle to the gate, that is, it is considered the reception of the materials necessary for the construction[3] and installation of the different systems and the operation and maintenance of them.

This LCA can contribute to the development of a guide for decision making in the planning of reforestation models in areas with characteristics similar to those raised in the study.

4. Scope of the study.

4.1 Overview of the system under study

The study system uses fog collectors that capture water for later use in irrigation and maintenance of reforested areas. Reforestation methods will take the form of different technologies that have been observed to be beneficial or have the potential to be further developed, including: individual fog water collectors, Cocoons (developed in another Life 'The Green Link' project), AFDS (Autonomous Fluid Discharge System) and finally traditional reforestation, included water form external wells and transported by water trucks, as a control group. Each of the different irrigation systems and collectors is described below.

4.2 Traditional fog collectors

One of the local source of water to evaluate comes from the traditional "fog collectors" that have been supplied through public procurement by Nieblagua. In total there are 15 fog collectors water located at the top of a hill in the case of "*La Finca El Pinillo*". It was established that this area is the best as wind conditions favor the uptake of fog at this point. In order to cope with such conditions, these collectors must have certain structural characteristics such as being able to withstand sustained winds of up to 100 km/h.

[3] In the case of water transported from wells outside La Finca El Pinillo, the emissions impact from the manufacturing of the tanker trucks and the construction of the underground water wells was not considered.

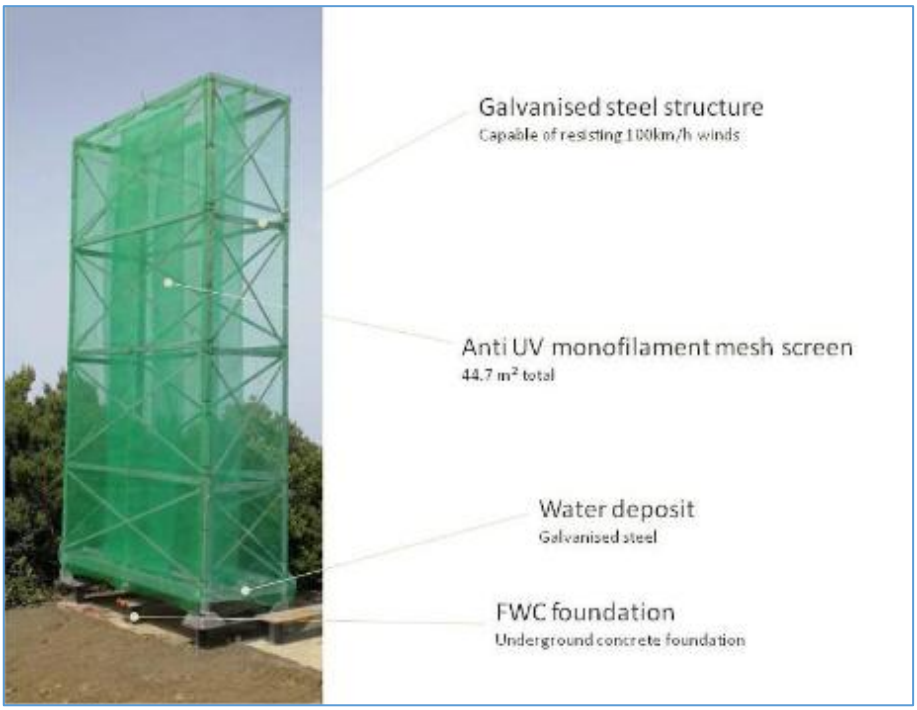


Figure 1 Traditional fog collector diagram

4.3 Water tanks

At the beginning of the project, it was estimated that approximately 215,000 litres of water will be consumed for the total area of the plot. It would be necessary to supply irrigation in summer with about 3 litres per plant except for the Cocoons that would consume 20 litres. Therefore, water tanks had to meet the following requirements:

- Have the ability to be connected in battery
- Be compatible with AFDS developed by ITC
- Have a minimum capacity of 2,000-5,000 litres.

The tanks installed are as follows:

Figure 2 Typology of installed water tanks

4.4 Autonomous Fluid Discharge System (AFDS)

The Autonomous Fluid Discharge System is a device that is based on the Archimedes principle and the Gauss curve, allows to discharge a fluid automatically, autonomous and controlled in a tank without any power supply or electronic control device. AFDS reforestation systems will be designed to supply water through a drip irrigation system.

Each AFDS reforestation system shall consist of the following basic elements:

- Traditional fog collectors (or other water source).
- Water storage tank (5,000 litres)
- Autonomous fluid discharge system.
- Irrigation network.

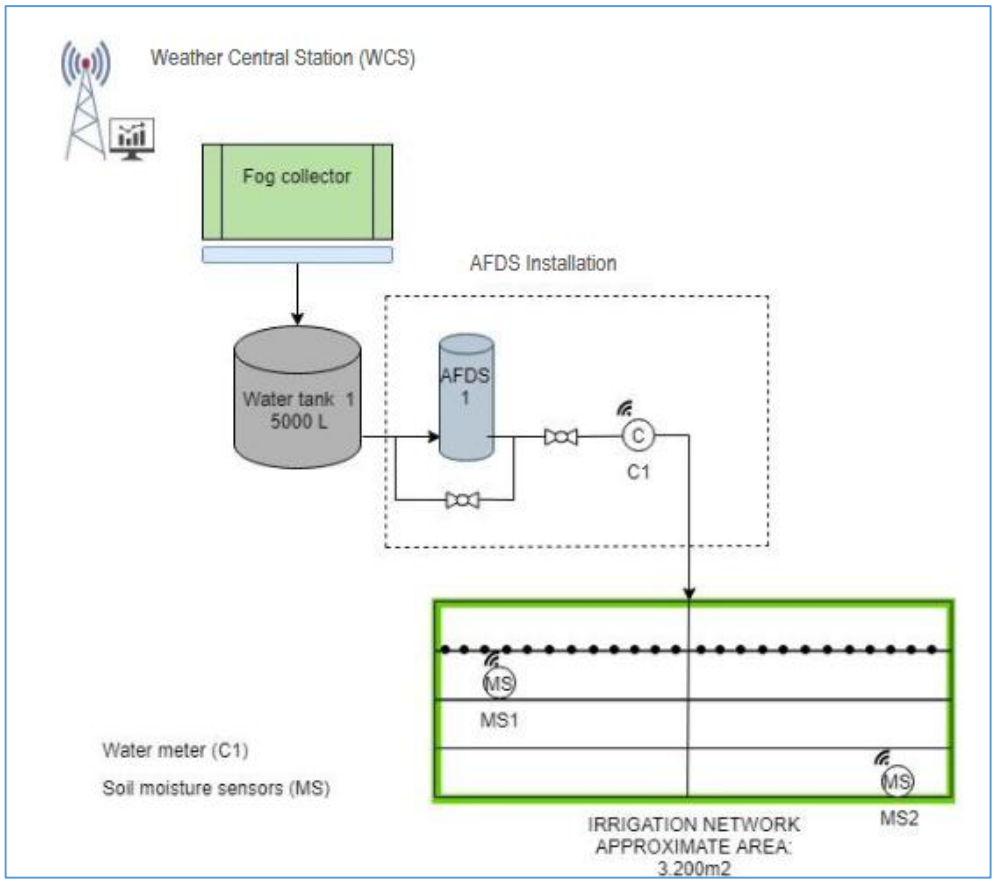


Figure 3 Overview of each AFDS installation

Figure 4 AFDS's and water tanks

4.5 Individual Fog Collectors (IFCW)

Through an earlier case study, the Life-GuGuy project, scientific observation suggested that the individual protective metal mesh helps to capture fog water or light rain. Consequently, drops captured drips directly onto the root area of the seedlings by gravity, providing a direct and natural irrigation system. For this irrigation method a metal mesh of 25x25mm has been used.

Figure 5 Individual fog collector

4.6 Cocoons

The Cocoons system is an autonomous and biodegradable nutrition system that is installed by digging under each tree. This not only provides a cool and humid environment to the plant but also protects the environment. Cocoons deposits are capable of containing 20 litres of water that will slowly dissolve in the soil with very little rate of evaporation as they are isolated underground. This method of irrigation and nursery was developed by a previous project Life (The Life Green Link) which was also tested in Gran Canaria at high risk of drought in the south of the island.

One advantage (and perhaps the most relevant) of this system is that they do not require constant monitoring or regular irrigation, reducing recurrent human action and economic investment (less water use, no irrigation systems, etc.). Another advantage of Cocoons is that through their natural degradation, they will provide a source of nutrients throughout the first years of plant development by increasing the success rate and encouraging the full establishment of the forest.

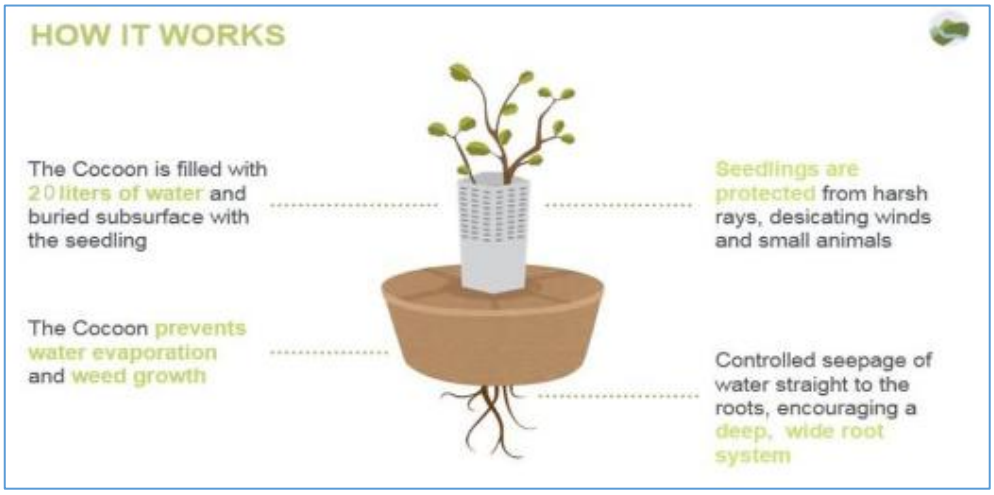


Figure 6 Cocoon system

Figure 7 Cocoon system installed

4.7 Traditional irrigation system.

The traditional irrigation technique consists of supplying water to each plant manually through a hose connected to the water tanks. This form of irrigation, which is already used daily in several areas, can be used to compare the different newer methods. It must be combined with different source of water.

4.8 Innovative Fog Water Collector (i-FWC)

Within the framework of the LIFE-NIEBLAS Project, an innovative fog collector has been developed by ICIA. This new system improves the conditions of fog water collection than traditional systems.

Figure 8 Innovative fog water collector

5. Functional Unit Definition

The objective of the functional unit is to provide a reference for system inputs and outputs. In this case, 1 surviving tree has been chosen as a functional unit since this way the different irrigation systems and source of water can be compared, since not all of them supply the same number of trees. Likewise, considerations will be made between the water collection capacities of the fog collectors and the quantities necessary to ensure the survival of each tree.

6. System boundaries

The stages taken into account in this analysis are as follows:

- Construction materials for the facilities and their transport (except external wells and water trucks).
- Construction of the installation taking into account the required energy/fuel consumption.
- Maintenance and operation of irrigation regimes and irrigation systems.

The stage excluded from the analysis is the dismantling of equipment and the impact of the treatment and final disposal of waste in landfill or to be treated as by-products. Also, emissions related to the manufacture of machinery and infrastructure necessary for the extraction and transport of any raw material, water or material used in the construction of the systems are not included, wastes or by-products resulting from their maintenance.

7. Quality requirements of the system

- Geographical boundary: The study system is located in Barranco de La Virgen, Valleseco, composed of 35.8ha. The selected hill is partially located within the Special Conservation Area (SAC) ES7010038 being, in turn, part of the Natura 2000 network included in the priority 4050 habitat 'Macaronesian Heath'
- Time boundaires: This project started in 2020 and has a planned duration of four years plus one year after performance monitoring. For the realization of the LCA a time limit of one year is proposed since it is the time necessary for the plants to stabilize and the irrigation system is transferred to other areas. In addition, this period coincides with the time that the system has been installed so we have real data from this first year of study.
- Data validity range: The service life of each system varies. Certain materials under optimal conditions will be reused like AFDS systems and irrigation networks, Fog collectors or water tanks, etc. Others like Cocoons cannot be reused.
- Data Cutting Rules: It is necessary to establish equal cutting rules for all cases. For this reason, only components weighing more than 10 kg are analysed, provided the important parts of each system are not omitted.

8. Inventory analysis

In this section, the inventory analysis of each of the study systems must be performed. To do this, it is necessary to describe the facilities and know all the processes that compose it.

The inventory will consist of two parts; one associated with the construction phase, where all the materials and processes necessary for the construction of the systems will be collected and another phase of maintenance and operation. The latter shall take into account the maintenance processes, the costs involved, the necessary personnel, their transfer to the workplace, the mobilization and transport of water if necessary or the associated energy consumption in each case.

For the correct development of the LCA methodology, it is necessary to use a software tool to save time and achieve reliable results. The basic function of these is to perform the material and energy balances on the specific process and to allocate emissions, energy uses, etc., normalised on a common basis. In this case, the tool **SimaPro version 9.1.1** is used.

For this LCA, we work with the **Ecoinvent v3.7.1** database with more than 4,000 processes from different sectors. The materials and processes used in **Ecoinvent v3.7.1** database for each of the equipment are detailed in annexes.

8.1 Construction phase

Information is collected from the necessary materials and their weight used for the manufacture of each of the systems under study.

The data used have been provided by project technicians who have knowledge of the quantities and materials used.

8.1.1 AFDS supplied with 3 fog collectors

In this case, the inventory of the irrigation system must be made, consisting of the following stages:

- 3 Fog collectors
- Connecting pipes between collectors and water storage tank
- Water storage tank.
- AFDS.
- Irrigation network.

In Table 2 the materials and quantities necessary for the construction and installation of the fog collectors are shown. These are secured to the ground by buried concrete anchors and iron. The structure is made of galvanized steel and is covered by a high density polyethylene mesh.

The data relating to the actions carried out have been calculated taking into account the transport of the necessary persons from a point of reference to the facilities. To do this, we know the consumption of cars and machinery used in each case as well as the total time it has taken to install the equipment.

Transport of persons:

- 4 specialized operators
- Travel distance: 20.4km (Tafira-Valleseco) = 40.8km daily (round trip)

- Car used by crew: Mitsubishi L200, D/C220 DI-D engine, M-PRO finish
- WLTP fuel consumption (l/100km): 8.5 l/100km

Excavation of land (dimensions and machinery used):

- Trenching of 0.12m^3 * 2 trenches/catcher (FWC) = 0.24m^3/FWC
- 0.24m^3 * 15 = 3.6m^3 total excavation
- Auger model: DRILL 932SG-V20 GARLAND
- Consumption: 1.72 l/h for 6 days.

Job definition	Amount	Num. labourers	Start date	Finish date	Time (days)
FWC foundation	15	2	26/03/2021	02/04/2021	6
FWC transport	15	4	05/04/2021	07/10/2021	2
FWC assembling	15	4	08/04/2021	13/04/2021	3,5
FWC mounting	15	5	13/04/2021	19/04/2021	4
				TOTAL days	15,5

Table 1 Days to install the traditional fog collectors

Components	Materials for each traditional fog water collector	Quantities for each FWC
Structure	Steel, chromium steel 18/8 {GLO}| market for | Cut-off, U	400kg
Foundation	Iron sinter {RER}| iron sinter production | Cut-off, U	19.81kg*2=39.62kg
Foundation	Concrete, medium strength {CO}| market for concrete, medium strength | Cut-off, U	(0.12m^3)=288.8kg 288.8kg*2= 577.6kg
Monofilament mesh screen	Polyethylene, high density, granulate {Europe without Switzerland}	44.7m^2/FWC * 84 g/m^2 = 3.75kg/FWC
Fuel consumption for transport (workers)	Diesel {Europe without Switzerland}| market for | Cut-off, U	53.7 litres /15 FWC = 3.58 litres
Fuel consumption for machinery		82.5 litres /15 FWC = 5.5 litres

Table 2 Materials inventory for traditional fog collectors

For the calculation of the material quantity used in interconnection pipelines, the necessary pipe meters were taken into account to make the connection between the FWC area and the tanks associated with the AFDS, as well as the density of the material used. (Table 3).

It was estimated one day to install each AFDS tank, taking into account that it is prefabricated and has to be transported to the area. The transport of the tank has not been considered but of the personnel required for its placement.

The material from which the tank is made is high density polyethylene and the weight is estimated by consulting its technical data sheets.

The actions taken for the installation of tanks are evaluated as follows:

Transport of persons:

- 4 specialized operators
- Travel distance: 20.4km (Tafira-Valleseco) = 40.8km daily (round trip)
- Car used by crew: Mitsubishi L200, D/C220 DI-D engine, M-PRO finish
- WLTP fuel consumption (l/100km): 8.5 l/100km

Excavation of land (dimensions and machinery used):

4 specialized operators using hoe and other non-motorized hand tools → 1 working day per tank.

Components	Materials	Quantity
Pipe fog collectors to AFDS tanks	HDPE pipes E	52,1 kg
5,000 litres AFDS tank	Polyethylene, high density, granulate {Europe without Switzerland}| polyethylene, high density, granulate, recycled to generic market for high density PE granulate | Cut-off, U	145 kg
Fuel consumption for each tank installation	Diesel {Europe without Switzerland}| market for | Cut-off, U	3.5 litres

Table 3 Materials inventory for pipes and tanks

Watermeters and soil moisture sensors were not included in the study since their weight is less than 10 kg. Likewise, were considered to be PVC pressure fittings necessary for AFDS which do not reach this weight but which are considered essential for manufacture.

Finally, the irrigation network had to be pre-prepared. Subsequently, pipes, drippers and micro-irrigation hoses were installed. The latter two elements were not considered in the study as their weight is less than 10 kg. The pipes used are polyethylene.

The actions taken for the installation of tanks are evaluated as follows:

Transport of persons:

- 4 specialized operators
- Travel distance: 20.4km (Tafira-Valleseco) = 40.8km daily (round trip)
- Car used by crew: Mitsubishi L200, D/C220 DI-D engine, M-PRO finish
- WLTP fuel consumption (l/100km): 8.5 l/100km

Time for AFDS irrigation network installation with devices and valves:

- AFDS installation: 8 days
- AFDS hoses: 10 days
- Plantation: 5 days.

Components	Materials for each AFDS irrigation system	Quantities for AFDS irrigation system (500 drippers)
AFDS external protection and foundation	Polyvinylidenchloride, granulate {RER}| market for polyvinylidenchloride, granulate | Cut-off, U Concrete, medium strength {RoW}| market for concrete, medium strength | Cut-off, U	PVC pipe 315 mm * 2 meters high *9 kg/meter (PVC density) = 18 kg 0,0036 m^3 *1,800 kg/m^3 (concrete density) = 65 kg
Floating vessel and accessories	Polyvinylidenchloride, granulate {RER}| market for polyvinylidenchloride, granulate | Cut-off, U	9 kg
AFDS pipelines and connections	Brass {RoW}| market for brass | Cut-off, U (connections) Polyvinylidenchloride, granulate {RER}| market for polyvinylidenchloride, granulate | Cut-off, U (DN 40)	4 kg 5 meters flexible PVC pipe (DN40) * 0.6 kg/meter = 3 kg
Watermeters	Brass {RoW}| market for brass | Cut-off, U	0.5 kg (not considered)
Irrigation network	HDPE pipes E 40mm (external diameter) 2.4 mm thickness – 4PN HDPE pipes spinal branch 32 mm (external diameter) 2 mm thickness – 4PN Branching HDPE pipes 16 mm (external diameter) 1.2 mm thickness – 2.5PN Micro irrigation drippers	209m* 0.290kg/m= 60.61kg 217 m*0.205 kg/m= 44.5 kg 4900 m * 0.058 kg/m= 204.2 kg Not considered
Fuel consumption for AFDS installation (workers)	Diesel {Europe without Switzerland}| market for | Cut-off, U	62.4 litres (1,500 drippers)
Fuel consumption for plantations (workers)		17.3 litres (1,500 trees)

Table 4 Materials inventory for AFDS irrigation network installation with devices and valves

The system evaluated in this case is that of 3 fog collectors, an interconnection pipe and 1 AFDS associated with an irrigation network with 500 plants. For research purposes the installation has been carried out with three fog collectors in order to assess whether it is sufficient for irrigation, taking into account that there are contributions of rain.

One of the tasks to be carried out in the future would be to estimate the quantity of collectors needed to supply the total plants in these specific meteorological conditions. It is estimated that about 50 litres per year and per tree is required. Since the total number of plants per AFDS is approximately 500, the water requirement is 25,000 litres/year. Depending on the measurements to be made of fog water collection, rainfall, evapotranspiration, etc., it will be necessary to estimate how many collectors will actually be necessary in practice, in this specific location.

All measured quantities should be referenced to the functional unit (tree planted and survivor). At the beginning of the work it has been estimated a survival of 400 trees compared to 500, consistent with the established irrigation plan. This data should be reviewed with actual survival data.

Components	Materials for 3 Fog collectors (500 trees)	
Structure	Steel, chromium steel 18/8 {GLO}| market for | Cut-off, U	400 kg*3/500 **2.4 kg/tree**
Foundation	Iron sinter {RER}| iron sinter production | Cut-off, U	39.62 kg*3/500 **0,23 kg/tree**
Foundation	Concrete, medium strength {CO}| market for concrete, medium strength | Cut-off, U	0.12m^3*3= 0.36 m^3 **0.00072 m^3/tree**
Monofilament mesh screen	Polyethylene, high density, granulate {Europe without Switzerland}	3.75kg*3/500 **0.022 kg/tree**
Fuel consumption for transport (workers)	Diesel {Europe without Switzerland}| market for | Cut-off, U	9.08*3/500= 0,054 litres /tree
Fuel consumption for machinery		**0.046 kg/tree**
	Materials for pipe fog collectors to AFDS tanks	
Pipe fog collectors to AFDS tanks	HDPE pipes E	52,1 kg /500 **0.1 Kg/tree**
	Materials for 5000 litres AFDS tank	
5000 litres AFDS tank	Polyethylene, high density, granulate {Europe without Switzerland}| polyethylene, high density, granulate, recycled to generic market for high density PE granulate | Cut-off, U	145 kg/500 **0.29 kg/tree**
Fuel consumption for each tank installation	Diesel {Europe without Switzerland}| market for | Cut-off, U	**0.00595 kg/tree**
	Materials for AFDS and irrigation network	
AFDS external protection and foundation	Polyvinylidenchloride, granulate {RER}| market for polyvinylidenchloride, granulate | Cut-off, U	**0.036 kg / tree**
	Concrete, medium strength {RoW}| market for concrete, medium	**0.000007 m^3 / tree**

	strength | Cut-off, U	
Floating vessel and accessories	Polyvinylidenchloride, granulate {RER}| market for polyvinylidenchloride, granulate | Cut-off, U	**0.018 kg / tree**
AFDS pipelines and connections	Brass {RoW}| (connections) Polyvinylidenchloride, granulate {(DN 40)	**0.008 kg / tree** **0.006 kg/tree**
Watermeters	Brass {RoW}| market for brass | Cut-off, U	0.001 kg/tree (not considered)
Irrigation network	HDPE pipes E 40mm (external diameter) 2.4 mm thickness – 4PN HDPE pipes spinal branch 32 mm (external diameter) 2 mm thickness – 4PN Branching HDPE pipes 16 mm (external diameter) 1.2 mm thickness – 2.5PN Micro irrigation system and drippers	**0.12kg/tree** **0.089 kg/tree** **0.4 kg/tree** Not considered
Fuel consumption for AFDS hoses and installation (workers)	Diesel {Europe without Switzerland}| market for | Cut-off, U	**0.084 kg/tree**
Fuel consumption for plantations (workers)		**0.013 kg/tree**

Table 5 Materials materials according to functional unit for 3 Fog collectors with 1 AFDS system for 500 trees

Fog Collectors + pipe + reservoir + AFDS + net	Ning.	
Materiales/Ensamblajes	Cantidad	Ud.
3 Traditional Fog collector (500 tree)	1	p
Pipe fog collectors to AFDS watertank (500)	1	p
5000L Water tank	1	p
AFDS and irrigation network (500)	1	p

Table 6 Assembly summary: 3 Fog collectors with 1 AFDS system for 500 trees

Finally, we are using a reference of 400 surviving trees (80% of survival).

3_AFDS supplied with 3 fog collectors	None	
Materials/Assemblies	Amount	Unit
3 Traditional Fog collector (400 tree)	1	p
Pipe fog collectors to AFDS watertank (400)	1	p
5000L Water tank (400)	1	p
AFDS and irrigation network (400)	1	p

Table 7 Assembly summary: 3 Fog collectors with 1 AFDS system for 400 surviving trees

8.1.2 3 AFDS supplied with pumped water from spring

The second of the options is based on obtaining the water from the spring and pond -cave that exists in the Finca El Pinillo that would be pumped to the AFDS tanks. The stages to be considered in this case would be:

- Motor pump water extraction
- Connecting pipes between spring and general water storage tank.
- 3 AFDS water storage tank (5000 litres)
- 3 AFDS + Irrigation network.
- Planting 1,500 trees

Components	Material for Pump	Quantities for each pump
Structure	Steel, chromium steel 18/8 {GLO}| market for | Cut-off, U	215 kg[4]
Fuel consumption for transport (workers)	Diesel {Europe without Switzerland}| market for | Cut-off, U (1 day)	3.4 litres = 2.89 kg

Table 8 Materials inventory for pump installation

Components	Materials	Quantity
Pipe from pump to AFDS	HDPE pipes E (500 meters)	130 kg
5000 litres AFDS tank	Polyethylene, high density, granulate {Europe without Switzerland}| polyethylene, high density, granulate, recycled to generic market for high density PE granulate | Cut-off, U	145 kg
Fuel consumption for each tank installation	Diesel {Europe without Switzerland}| market for | Cut-off, U	3.5 litres

Table 9 Materials inventory for pipes and tanks

Initially it is hypothesized that the pump is only installed for 3 AFDS with 1500 plants (1200 surviving trees). In practice, the pump is installed for all the systems; therefore, the impact is overestimated.

[4] NK 65-125/144 AA2F2AESBQQENW1 - 98973459 | Grundfos Pump reference. Other materials than Steel have been neglected due to the complexity of the cutting. To be evaluated Honda engine.

Name	Status	
2_AFDS*3 with pumped water from spring	None	
Materials/Assemblies	**Amount**	**Unit**
Pump from spring to general tanks (1200)	1	p
Pipe from pump to AFDS watertanks (1200)	1	p
5000L Water tank (400)	3	p
AFDS and irrigation network (400)	3	p

Table 10 Assembly summary: Pump with 3 AFDS system for 1,200 surviving trees (80% of survival).

8.1.3 AFDS supplied with water tank truck from wells

Finally the last consideration with AFDS would be to consider that water tanks are filled by tankers from external sources (wells). In this case, the manufacture of these means of transport is not taken into account. The extraction and transport of water to the site must be considered during the exploitation phase.

It is included in this case:

- AFDS water storage tank.
- AFDS.
- Irrigation network.
- Planting

Name	Status	Cor
1_AFDS supplied with water tank truck	None	
Materials/Assemblies	**Amount**	**Unit**
5000L Water tank (400)	1	p
AFDS and irrigation network (400)	1	p

Table 11 Assembly summary: AFDS system for 400 surviving trees

8.1.4 Cocoon with different supplies

The technique of irrigation through Cocoon requires that biodegradable deposits are filled as soon as they are empty, therefore, it is necessary to have a system to store the water and take into account the different ways of obtaining it. As for the AFDS, three scenarios will arise. The first one where the water is obtained from the fog collectors, the second one where the tank is recharged by water extracted from the spring and finally, the third case that would be to recharge the tank with water transported by a tanker truck.

For the installation of the Cocoons, the land had to be prepared first by hoe. Later the devices and plants were installed. The weights of the individual Cocoon elements were also obtained.

The actions taken for the installation of Cocoons are evaluated as follows:

Transport of persons:

- 4 specialized operators
- Travel distance: 20.4km (Tafira-Valleseco) = 40.8km daily (round trip)
- Car used by crew: Mitsubishi L200, D/C220 DI-D engine, M-PRO finish
- WLTP fuel consumption (l/100km): 8.5 l/100km

Excavation of land (dimensions and machinery used):

4 specialized operators using hoe. Holes dimensions: 60cm Ø *30cm (h)

Components	Materials for each Cocoon	Quantity for each Cocoon
Contentor	Corrugated board box {RER}| production | Cut-off, U	0.644 kg
Tapa	Corrugated board box {RER}| production | Cut-off, U	0.340 kg
Protector	kraft paper {RER}| market for kraft paper | Cut-off, U	0.067 kg
Fuel consumption for Cocoon installation (workers)	Diesel {Europe without Switzerland}| market for | Cut-off, U	62.4 litres (1,500 holes) 0.0416 litres/Cocoon
Fuel consumption for plantations (workers)		17.3 litres (1,500 holes) 0.0115 litres/Cocoon

Table 12 Materials inventory for Cocoon

Below are the stages for the case in which water is obtained from the collectors, from the pump and through tanker truck.

Name	Status	Co
6_Cocoon supplied with tank and fog collectors	None	

Materials/Assemblies	Amount	Unit
3 Traditional Fog collector (400 tree)	1	p
Pipe fog collectors to Cocoon watertank (400)	1	p
5000L Water tank (400)	1	p
Cocoon	1	p

Name	Status	Co
5_Cocoon supplied with pumped water from spring	None	

Materials/Assemblies	Amount	Unit
Pump from spring to general tanks (1200)	1	p
Pipe from pump to Traditional watertanks (1940)	1	p
5000L Water tank (400)	1	p
Cocoon	1	p

Cocoons supplied with water tank truck		Ning.
Materiales/Ensamblajes	Cantidad	Ud.
5000L Water tank	1	p
Cocoon	1	p

Table 13 Assembly summary: Cocoons with different supplies.

8.1.5 Traditional irrigation with different supplies

For traditional irrigation, it is necessary to have a water tank to irrigate and hoses to get the water to the different irrigation points. In the same way as in the first two techniques, the water used may come from three different sources: from fog collectors, from the natural spring or from the transport of water by means of a tank truck.

For the traditional planting, the land had to be prepared first by hoe. Later the holes were made and the trees were planted.

The actions taken for the Traditional reforestation are evaluated as follows:

Transport of persons:

- 4 specialized operators
- Travel distance: 20.4km (Tafira-Valleseco) = 40.8km daily (round trip)
- Car used by crew: Mitsubishi L200, D/C220 DI-D engine, M-PRO finish
- WLTP fuel consumption (l/100km): 8.5 l/100km

Excavation of land (dimensions and machinery used):

4 specialized operators using hoe. Holes dimensions: 60cm Ø *30cm (h)
Time spent: 28 days for 1,940 trees

Table 14 reflects materials and inputs used for planting about 1,940 trees.

Components	Materials for traditional irrigation	Quantity
Hoses	HDPE hose PE 40mm (external diameter) 2.4 mm thickness – 4PN HDPE hoses branching PE 32mm (external diameter) 2 mm thickness – 4PN HDPE hoses branching PE 20 mm (external diameter) 2 mm thickness – 4PN	280 meters*0.290 kg/meter = 81.2 kg → **0.041 kg/tree** 300 meters* .205kg/meter= 61.5kg → **0.032 kg/tree** 300 meters * 0.120kg/meter= 36kg → **0.018 kg/tree**
Fuel consumption for plantations (workers)	Diesel {Europe without Switzerland}| market for | Cut-off, U	(28 days * 40.8 km/day*8.5 litres/100 km)/ 100 km= 97 litres (1,940 trees) 0.05 litres/tree **0.042 kg/tree**

5,000 litres tank	Polyethylene, high density, granulate {Europe without Switzerland}| polyethylene, high density, granulate, recycled to generic market for high density PE granulate | Cut-off, U	145 kg *4/1940 **0.29 kg/tree**
Fuel consumption for each tank installation	Diesel {Europe without Switzerland}| market for | Cut-off, U	**0.00595 kg/tree**

Table 14 Materials inventory for traditional irrigarion

The necessary equipment will be different depending on the water source used.

	Materials for pump from spring to traditional reforestation tanks	
Pump structure	Steel, chromium steel 18/8 {GLO}| market for | Cut-off, U	215 kg/1940 **0.11 kg/tree**
Fuel consumption for transport to install pump and pipe (workers)	Diesel {Europe without Switzerland}| market for | Cut-off, U	2.89 kg/1940 **0.0015 kg/tree**
Pipe pump to traditional reforestation tanks	HDPE pipes E	130 kg /1940 **0.07 Kg/tree**

Table 15 Materials for pump from spring to traditional reforestation tanks

	Materials for fog collectors to traditional reforestation tanks	
Fog collectors structure	Steel, chromium steel 18/8 {GLO}| market for | Cut-off, U	400 kg*12/2000 **2.4 kg/tree**
Fog collectors Foundation	Iron sinter {RER}| iron sinter production | Cut-off, U	39.62 kg*12/2000 **0,23 kg/tree**
	Concrete, medium strength {CO}| market for concrete, medium strength | Cut-off, U	0.12m^3*12/2000 **0.00072 m^3/tree**
Fog collectors monofilament mesh screen	Polyethylene, high density, granulate {Europe without Switzerland}	3.75kg*12/2000 **0.022 kg/tree**
Fuel consumption for transport (workers)	Diesel {Europe without Switzerland}| market for | Cut-off, U	9.08*3/500= 0,054 litres /tree
Fuel consumption for machinery		**0.046 kg/tree**
	Materials for pipe fog collectors to tanks	
Pipe fog collectors to tanks	HDPE pipes E	52,1 kg /2000 **0.026 kg/tree**
Fuel consumption for transport to install pipe (workers)	Diesel {Europe without Switzerland}| market for | Cut-off, U	2.89 kg/1940 **0.0015 kg/tree**

Table 16 Materials for pump from spring to traditional reforestation tanks

7_Traditional irrigation with water tank truck	None	
Materials/Assemblies	Amount	Unit
5000L Water tank (400)	1	p
Plantation for traditional irrigation (1940 trees)	1	p
Hoses for traditional irrigation (1940 trees)	1	p

8_Traditional irrigation with spring pump	None	
Materials/Assemblies	Amount	Unit
Pump from spring to general tanks (1940)	1	p
Pipe from pump to Traditional watertanks (1940)	1	p
5000L Water tank (400)	1	p
Hoses for traditional irrigation (1940 trees)	1	p
Plantation for traditional irrigation (1940 trees)	1	p

9_Traditional irrigation with fog collectors	None	
Materials/Assemblies	Amount	Unit
3 Traditional Fog collector (400 tree)	1	p
Pipe fog collectors to watertanks (1940)	1	p
5000L Water tank (400)	1	p
Hoses for traditional irrigation (1940 trees)	1	p
Plantation for traditional irrigation (1940 trees)	1	p

Table 17 Assembly summary: Traditional irrigation with different supplies.

8.1.6 Individual fog water collector (IFWC)

This is one of the simplest techniques. By placing the individual collectors around the plant, they are expected to obtain enough water to survive without providing water from other sources.

Table 18 reflects the materials and inputs used for the preparation of planting with IFWC for about 2,680 trees. The installation of hoses for settelment irrigation has not been considered.

Components	Materials for IFWC	Quantity
Protective mesh	Polyethylene, high density, granulate {Europe without Switzerland}| polyethylene, high density, granulate, recycled to generic market for high density PE granulate | Cut-off, U	1.56 m^2/IFWC * 84g/m^2 = 131.04g/IFWC → **0.13 kg/tree**
Metal mesh	Steel electrogalvanized steel/EU	1 m^2/IFWC * 475 g/m^2 = 1887g/IFWC → **0.48 kg/tree**
Corrugated bars 10mm Ø	Steel, chromium steel 18/8 {GLO}| market for | Cut-off, U	2m/IFWC * 640 g/m = 1851g/IFWC → **1.28 kg/tree**
Fuel consumption	Diesel {Europe without Switzerland}|	(20 days * 40.8 km/day*8.5

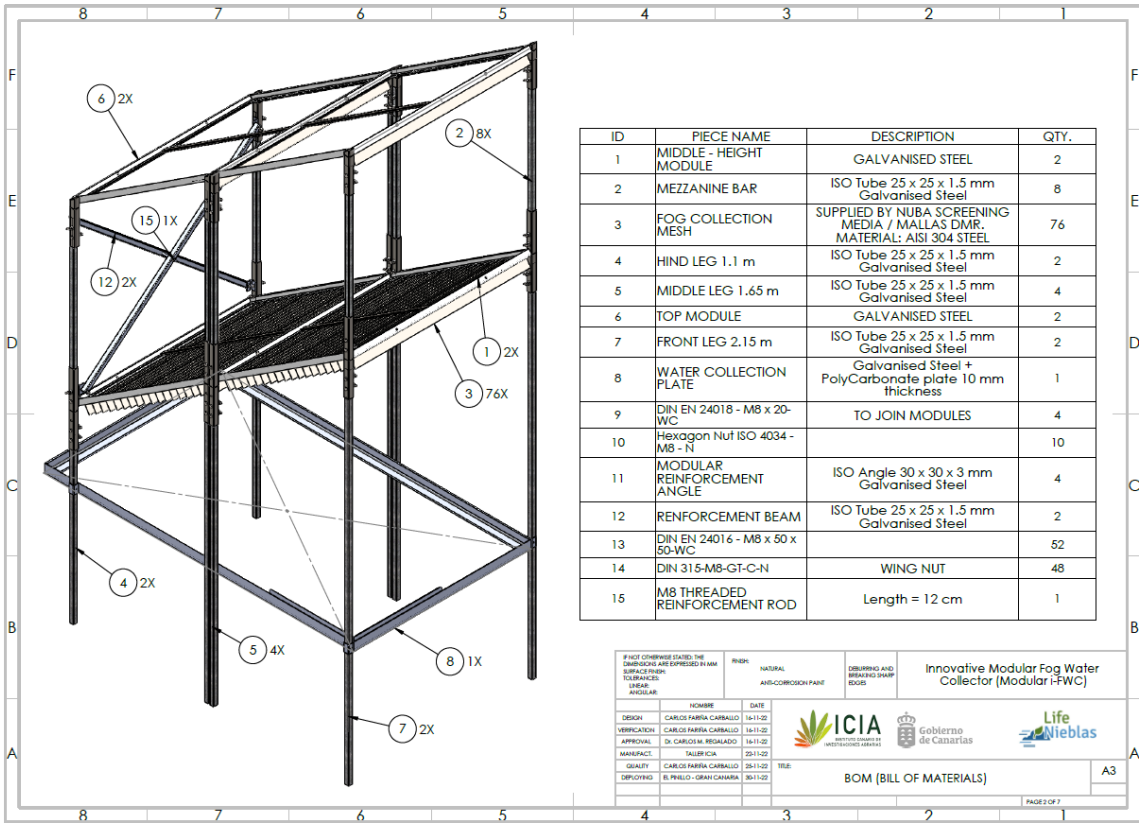
Components	Materials for IFWC	Quantity
for plantations (workers)	market for | Cut-off, U	litres/100 km)/ 100 km= 69 litres (2,680 trees) 0.026 litres/tree **0.023 kg/tree**

Table 18 Materials inventory for IFWC installation

8.1.7 Innovative Fog Water Collector (i-FWC)

The materials used for each i-FWC are as follows: (information provided by ICIA)

- Galvanized steel (Profile L 30x30x3 mm) = 8 meters = 0.696 8 = 5.568 kg
- Galvanized steel (Standard profile 25x25x1.5 mm)= 2*1.65 m + = 2*1.83 kg + 2*1.22 kg= 6.1 kg
- Galvanized steel (Standard 30x30x1.5 mm) = 4*20 cm = 4*0.27 kg = 1.08 kg
- Galvanized steel (rectangular 30x10x1.5 mm)= 1 m = 0.9 kg
- Polycarbonate 10 mm thickness = 1.3 kg
- Screws DIN 933 8x50 = 12
- Nut DIN 933 8 x 50 = 12 unidades
- Corrugated bars 12 mm = 4 m = 1.7 kg
- Stainless steel mesh (Nuba Screening Media - Móstoles) = 1 m x 1 m = 4.12 kg
- Cable ties 7/8" galvanized steel = 4



ID	PIECE NAME	DESCRIPTION	QTY.
1	MIDDLE - HEIGHT MODULE	GALVANISED STEEL	2
2	MEZZANINE BAR	ISO Tube 25 x 25 x 1.5 mm Galvanised Steel	8
3	FOG COLLECTION MESH	SUPPLIED BY NUBA SCREENING MEDIA / MALLAS DMR. MATERIAL: AISI 304 STEEL	76
4	HIND LEG 1.1 m	ISO Tube 25 x 25 x 1.5 mm Galvanised Steel	2
5	MIDDLE LEG 1.65 m	ISO Tube 25 x 25 x 1.5 mm Galvanised Steel	4
6	TOP MODULE	GALVANISED STEEL	2
7	FRONT LEG 2.15 m	ISO Tube 25 x 25 x 1.5 mm Galvanised Steel	2
8	WATER COLLECTION PLATE	Galvanised Steel + PolyCarbonate plate 10 mm thickness	1
9	DIN EN 24018 - M8 x 20-WC	TO JOIN MODULES	4
10	Hexagon Nut ISO 4034 - M8 - N		10
11	MODULAR REINFORCEMENT ANGLE	ISO Angle 30 x 30 x 3 mm Galvanised Steel	4
12	RENFORCEMENT BEAM	ISO Tube 25 x 25 x 1.5 mm Galvanised Steel	2
13	DIN EN 24016 - M8 x 50 x 50-WC		52
14	DIN 315-M8-GT-C-N	WING NUT	48
15	M8 THREADED REINFORCEMENT ROD	Length = 12 cm	1

Figure 9 Materials for i-FWC

Components	Materials for IFWC	Quantity
Polycarbonate 10 mm thickness	Polycarbonate {GLO}| market for | Cut-off, U	1.3 kg
Galvanized steel (L 30x30x3 mm)	Steel electrogalvanized steel/EU	8 meters = 0.696·8= 5.568 kg
Galvanized steel (25x25x1.5 mm)	Steel electrogalvanized steel/EU	2*1.65 m + = 2*1.83 kg + 2·1.22 kg= 6.1 kg
Galvanized steel (30x30x1.5 mm)	Steel electrogalvanized steel/EU	4*20 cm = 4*0.27 kg= 1.08 kg
Galvanized steel (30x10x1.5 mm)	Steel electrogalvanized steel/EU	1 m = 0.9 kg
Stainless steel mesh	Steel, chromium steel 18/8 {GLO}| market for | Cut-off, U	1 m x 1 m = 4.12 kg
Corrugated bars 12mm Ø	Steel rebar/EU	4 m = 1.7 kg
Fuel consumption for installation (workers)	Diesel {Europe without Switzerland}| market for | Cut-off, U	(2 day * 40.8 km/day*8.5 litres/100 km)/ 100 km

Table 19 Materials inventory for IFWC installation

8.2 Exploration and maintenance phase.

At this stage, the different operating and maintenance tasks carried out in each system should be considered. Also, there are tasks such as clearing and land conditioning that were carried out globally without taking into account what type of technology would be implanted in that plot. Therefore, the associated impact for clearing and conditioning is an aspect that can be assessed globally, regardless of the type of technology implemented in each plot space, therefore, it is not used in the process of comparing different reforestation systems.

To carry out the analysis and comparisons of the different reforestation systems, irrigation plans and water sources it has been necessary to investigate and know different details of the activities carried out. For example, know how often operators need to come to the work area and what kind of tasks they perform. In addition, know the possible emissions associated with different processes such as water transport or energy consumption in pumping. In this way, the impacts generated can be compared according to the type of technology and the water source used for the maintenance of reforestation. Although multiple environmental impact categories can be analyzed through the LCA method, this study focuses on a very specific category that are the equivalent emissions of GHG (kg CO2 eq) that affect Global warming 20a.

The reference data used to assess the impact of the transport of workers (and water where applicable) are as follows:

• Travel distance: 20.4km (Tafira-Valleseco) = 40.8km daily (round trip).

The impact of each activity can be determined on a monthly basis, depending on the type of technology involved. The necessary data would be:

- The fuel consumption carried out by the water pump from the spring to the tanks.

- The consumption of the tank truck that supplies the tanks when the water is brought from the outside.
- The energy consumption required to pump water from a medium-deep well in the area for subsequent transport by tanker truck.

Maintenance and irrigation tasks (according to the irrigation plan established in Action A2: Environmental, social and economic indicators selection. Monitoring and evolution protocol in which every plot was divided in 3 parts: sector 1, 2 and 3, and the number of visits to the area with the operators.

The data would be evaluated by annual period. The reference processes used in the Ecoinvent database are expressed in the Table 20 and is described in the *Based on the previous tables* and graphs, the conclusion is confirmed that systems with a higher initial investment in local water collection and automated irrigation generate the lowest emissions during the operational and maintenance phases. In this regard, the IFWC and AFDS systems stand out, particularly when supplied exclusively with fog or rainwater collected through TFWC units. However, in these cases, the survival of the reforestation will be highly dependent on meteorological conditions during the operational years.

Nevertheless, the LIFE NIEBLAS experience has demonstrated that even in particularly dry years (2023 and 2024), IFWC and AFDS systems associated with TFWCs have achieved survival rates exceeding 80%. Additionally, these systems have been shown to be reusable at least once, significantly reducing emissions per functional unit of initial implementation, as their operational emissions are very low.

9. Global contribution to climate objectives

One of the Indicators related to the "LIFE Key project level indicators Call 2019" is the reduction of CO_2 green house gas emissions per year.

There are two Indicators related to climate objectives and CO_2 emissions expressed in Table 25. The LCA analysis helps to compare different options of reforestation and take into account all the items, not only the ones proposed in the project.

Indicators	Estimated Impact (absolute values)
CO_2 emissions annual reduction comparison between the water captured with fog collectors respect to its obtention from water wells and its transport by road to the field	254.33 tons of CO_2
CO_2 emissions annual reduction comparison between the water captured with fog collectors respect to its transportation by road to the field	100 tons of CO_2

Table 25 LIFE NIEBLAS project indicators related to climate objectives and CO_2 emissions

For the first period of the project (April 2021 - February 2023) the water collected by fog water collectors were **86,500 litres**. With this frame we can calculate the CO_2 with different scenario.

As was explained in point Exploration and maintenance phase.carry out the analysis and it has been necessary to investigate and know different details of the activities carried out.

The necessary data would be:

- The consumption of the tank truck that supplies the tanks when the water is brought from the outside.
- The energy consumption required to pump water from a medium-deep well in the area for subsequent transport by tanker truck.

The conditions used were that the well is 150 or 300 meters deep (average in Gran Canaria) and the transportation is by water tank truck for approximately 20.4 kilometres.

The reference data used to assess the impact of the transport of water are as follows:

- Travel distance: 25km (Well in Arucas – Finca el Pinillo - Valleseco) = 50 km daily (round trip).
- Well water pumping, the following conditions are taken into consideration:
  - Q=10l/s =32 m^3/h
  - Well deep =150 – 300 meters
  - Power pump = 26 kW
  - In this scenario to pump each 1,000 litres is needed 0.78 – 1.56 kWh

Also, if it is considered we can take into account the visits to the area with the operators to receive the water tank truck. The reference processes used in the Ecoinvent database are expressed in the Table 20.

To asses this case the **SimaPro version 9.1.1** is used, with the **Ecoinvent v3.7.1** database. And the methodology used for the calculation of the carbon footprint has been the **IPCC 2013 GWP 20a V1.03**., which was developed by the Intergovernmental Panel on Climate Change. It contains the climate change factors of IPCC with a timeframe of 20 years. According with we create different scenario to calculate the CO_2 emissions saved: 150 and 300 meters deep of the well, transport from the well and transport from a water body.

Name	Status	Comment
Global estimated saved water by fog Feb23_300	None	

Assembly	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
	0		Undefined				

Processes	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
Transport, passenger car, EURO 4 {RER}| transport, passe	0	km	Undefined				Not considered
Transport, freight, lorry 7.5-16 metric ton, euro4 {RoW}|	(86.5*25) = 2.16E3	tkm					86,500 litres collected by fog water collectors (TFWC+i-FWC+V-FWC) till February 2023 and not transported to El Pinillo (25 kms)
Electricity, medium voltage {ES}| market for | Cut-off, U	1.56*86.5 = 135	kWh					86,500 collected by fog water collectors (TFWC+i-FWC+V-FWC) till February 2023 and not pumped from a well 300 meters deep
Transport, freight, lorry 7.5-16 metric ton, euro4 {RER}| r	(10*20.4) = 204	tkm					10 empty return journey

Table 26 Scenario used to calculate CO_2 emissions reduction comparison between water collected by fog water collectors (86.5 m3) in respect to obtaining water through wells (300 meters deep) and its transport by road to the field.

In the case described in Table 26 the results are as follows:

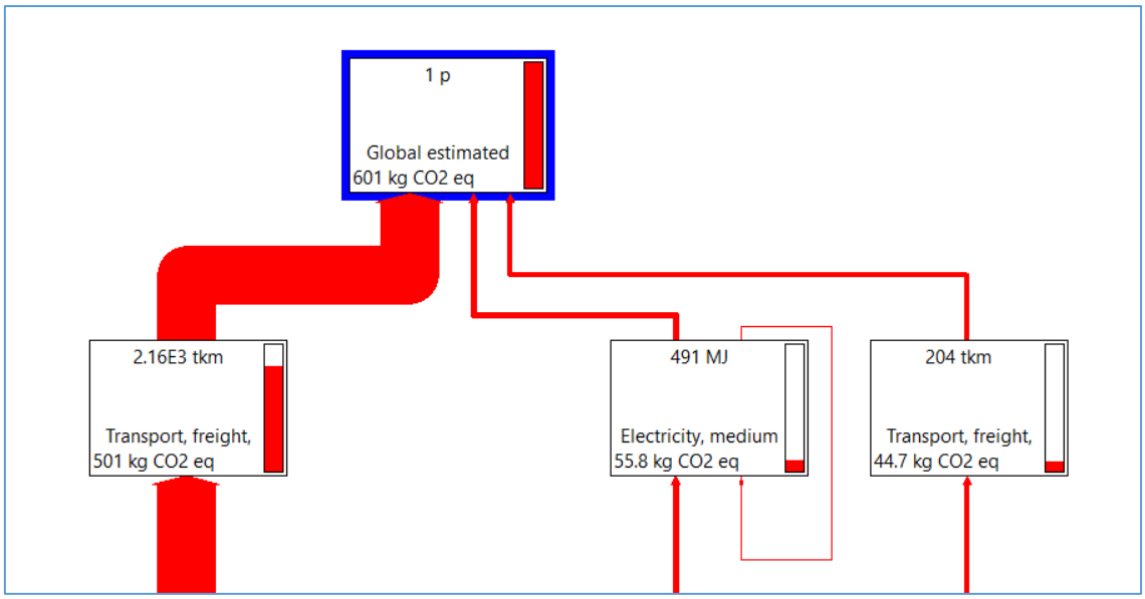


Figure 10 CO_2 emissions reduction comparison between water collected by fog water collectors (86.5 m3) in respect to obtaining water through wells (300 meters deep) and its transport by road to the field.

With these data the results till February 2023 the results (Table 27) are far from estimated.

Indicators	CO_2 emissions reduction from April 2021 till February 2023
CO_2 emissions reduction comparison between water collected by fog water collectors (86.5 m^3) in respect to obtaining water through wells and its transport by road to the field	601 kg of CO_2
CO_2 emissions annual reduction comparison between the water captured with fog collectors respect to its transportation by road to the field (without well pumping)	545.2 kg of CO_2

Table 27 LIFE NIEBLAS project indicators related to climate objectives and CO2 emissions with 86.5 m^3 fog water collected and using LCA method.

In fact, during this first period of the project more emissions have been saved, since all the water that has not been collected from mist has been pumped from the spring located in the area. To calculate this we evaluate the savings regarding using the spring water.

Name	Status	Comment
Global savings for use spring water till Feb23	None	

Assembly	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
	0		Undefined				

Processes	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
Transport, passenger car, EURO 4 {RER}| transport, passe	0	km	Undefined				Not considered
Transport, freight, lorry 7.5-16 metric ton, euro4 {RoW}|	(303.5*25) = 7.59E3	tkm					303,500 litres collected by spring and pumped till February 2023 and not transported to El Pinillo (25 kms)
Electricity, medium voltage {ES}| market for | Cut-off, U	1.56*303.5 = 473	kWh					303,500 collected by spring and pumped till February 2023 and not pumped from a 300 meters deep well
Transport, freight, lorry 7.5-16 metric ton, euro4 {RER}|	(38*20.4) = 775	tkm					38 empty return journey

Table 28 Scenario used to calculate CO_2 emissions reduction comparison between water collected by spring (303 m^3) in respect to obtaining water through wells (300 meters deep) and its transport by road to the field.

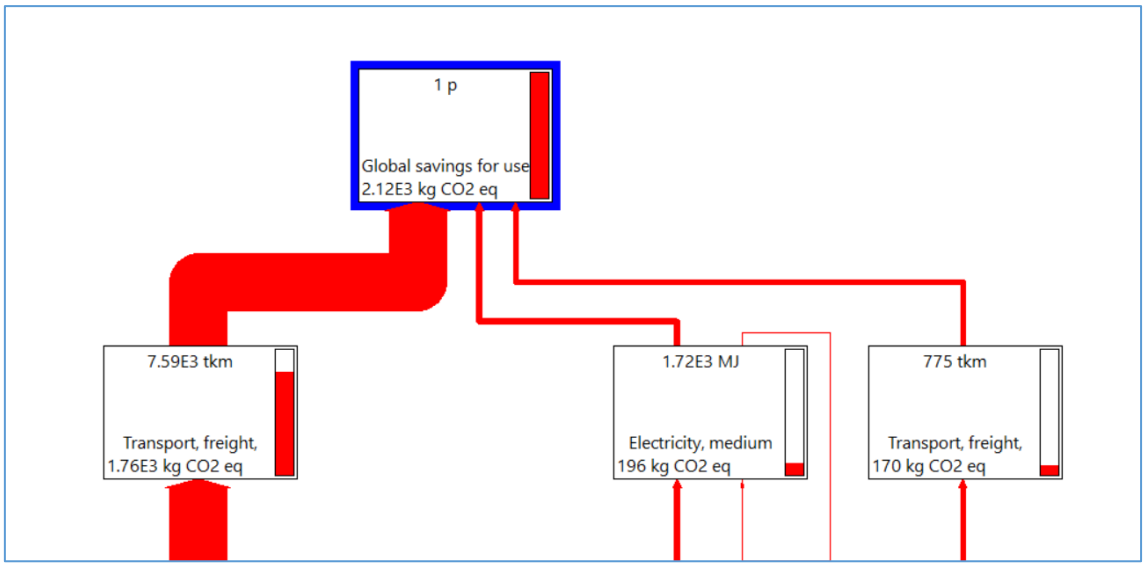


Figure 11 CO_2 emissions reduction comparison between water collected form the spring and pumped (303.5 m^3, 50 meters) in respect to obtaining water through wells (300 meters deep) and its transport by road to the field.

In Table 29 we can see the real savings in CO_2 emissions.

Indicators	CO_2 emissions reduction till February 2023
CO_2 emissions reduction comparison between water collected by fog water collectors (86.5 m^3) and by local spring (303.5 m^3) respect to obtaining water through wells and its transport by road to the field	601 kg + 2,120 kg – 38.8 kg= **2,682.8 kg of CO_2**
CO_2 emissions annual reduction comparison between the water captured with fog collectors and by local spring respect to its transportation by road to the field (without well pumping)	545.2 kg +1,760 kg – 38.8 kg = **2,266.4 kg of CO_2**

Table 29 LIFE NIEBLAS project indicators related to climate objectives and CO2 emissions with 86.5 m^3 fog water collected and 303.5 m^3 spring water, using LCA method.

We also can calculate the emissions reduction with more simple methodologies, for example, with emissions factors and calculating the fuel consumption of the water tank trucks and for production electricity in Gran Canaria.

Typically, under normal heavy truck operation, such a vehicle would achieve a fuel consumption of **30 liters/100km**. We can estimate 8 tons of water transported in each journey. The emission factor differentiated by type of fuel. From 2019 onwards, petrol and diesel fuels are referred to by letters E and B respectively, adding the proportion of biofuel they contain (RD 639/2016). For example (7% biodiesel): **B7 ($kgCO_2$/liter): 2.467**

To obtain the emission factor associated with electricity consumption we can consult the reports published by Red Eléctrica de España for Canary Islands (https://www.ree.es/es/generacion/no-renewable-detalle-emisions-CO2), as well as the percentage of renewable energy in the electricity mix without emissions. In Table 30 we can see the emissions for 2022 I Canary Islands.

Sources of generation with emissions	**Tons CO_2 equivalents (2022)**
Diesel engines	1.193.564

Gas turbine	292.321
Steam turbine	1.094.300
Combined cycle	2.154.006
tCO_2 eq./MWh	**0,55**

Table 30 CO_2 EMISSIONS AND EMISSION FACTOR (tCO_2 eq./MWh) | Electrical system: Canary Islands (2022).

That year the percentage for renewable energies was 20%. The final emissions factor applicable would be **0.44 kg CO_2 eq./kWh**.

In Table 31 we can see the savings in CO_2 emissions calculated with this method.

Indicators	CO_2 emissions reduction till February 2023
CO_2 emissions reduction comparison between water collected by fog water collectors (86.5 m^3) and by local spring (303.5 m^3) respect to obtaining water through wells and its transport by road to the field	Transport by road: 50 km/journey * (30 litres fuel/100 km)*(9 +38) journey * 2.467 $kgCO_2$/litre 333 kg of CO_2 (saved by fog water collectors) 1,406 kg of CO_2 (saved by local spring) Well pumping: 135 kWh (59.4 kg CO_2 eq saved by fog water collectors) 473 kWh – 91kWh = 382 kWh (168 kg CO_2 eq saved by local spring) 517 kWh*0.44 kg CO_2 eq./kWh 227.5 kg CO_2 eq Total emissions reduced: **1,966.5 kg CO_2 eq**
CO_2 emissions annual reduction comparison between the water captured with fog collectors and by local spring respect to its transportation by road to the field (without well pumping)	**1,739 kg of CO_2**

Table 31 LIFE NIEBLAS project indicators related to climate objectives and CO_2 emissions calculated with emission factor method.

The differences in the results from the two methods are not relevant and consistent, taking into account that the LCA method takes into account aspects that are not taken into account by the emission factor method.

With this data, we believe that the estimated value of emissions reduction per year, in the project sheet had some error of calculation. For example, to emit 254.33 tons of CO_2 we have pump form a well and transport by road more than 46.000 m^3 of water per year when the real necessities are around 400 m^3/year (100 times less).

In practice, during the project (April 2021 - December 2024) the water collected by all fog water collectors were **128,260 litres** and used form the spring were **584,423 litres**.

In Table 32 we can see the total savings in CO_2 emissions.

Indicators	CO_2 emissions reduction till December 2024
CO_2 emissions reduction comparison between water collected by fog water collectors (128.26 m^3) and by local spring (584.42 m^3) respect to obtaining water through wells and its transport by road to the field	**4,900 kg of CO_2**
CO_2 emissions annual reduction comparison between the water captured with fog collectors and by local	**3,387.5 kg of CO_2**

spring respect to its transportation by road to the field (without well pumping)	

Table 32 LIFE NIEBLAS project indicators related to climate objectives and CO_2 emissions using LCA method.

10. Conclusions of the study

After the analysis of the data, some conclusions of the study can be established.

- The use of metal materials (galvanized steel, iron bars, etc.) in the construction of the elements that constitute the fog collection and the irrigation systems represents a significant increase in the equivalent CO_2 emissions associated with the life cycle of the installations. → This can be improved by using alternative materials. For example, in the replication on Brava Island (Cape Verde), wooden stakes were used to support the IFWC.
- As systems incorporate more elements to ensure their autonomy from operation and maintenance, equivalent emissions are higher at the first assembly stage. → As the initial installations are used in new reforestations, the impact of these emissions per functional unit (surviving tree) decreases. Therefore, it is important to assess this aspect in the long term and maximize the reuse of initial materials.
- The system with the highest equivalent emissions per tree planted is the one that incorporates 3 FWCT, a 5,000 liter tank, an AFDS and a drip irrigation network for 500 trees (15 kg CO_2 equivalent/tree). In this case, 77.4% of the emissions are due to fog collectors, 18.4% to AFDS and irrigation network, and 2.5% to interconnection pipelines between the fog water collection area and the reservoir for AFDS. This deposit accounts for 1.6% of emissions. On the contrary, this same system in the operation and maintenance phase is the one with the least associated emissions. Considering a survival rate of 80%, emissions would be 0.1 kg of equiv/surviving tree CO_2, taking into account that an emergency irrigation is carried out in August (in this case with water pumped from the spring). → Clearly, the TFWCs will be used in the long term to produce water and continue promoting reforestation. Likewise, it has been demonstrated that the AFDS and the irrigation network can be dismantled and reused in new areas. Therefore, these systems must be designed with a long-term vision, distributing the emissions from the initial installation over the entire lifespan of the equipment rather than only considering their first use for reforestation. In this regard, a promising application of this configuration is the development of permanent irrigation systems in remote areas, as they will help reduce emissions in the long run.
- The system that incorporates less emissions in the assembly phase is the traditional irrigation system that will later be irrigated in the exploitation phase by transporting water tanks from the outside (0.4 kg CO_2 equv/tree). It requires the installation of minimal infrastructure in the field, basically water storage tank and hoses. On the contrary, it would be one of the systems that would generate more emissions in the exploitation phase, depending on the irrigation system, with about 0.6 kg of equiv/tree CO_2. → In practice, this shows that the traditional system can generate up to six times more emissions during the operational phase compared to systems that require more initial infrastructure. As mentioned, the final decision on which model to follow depends on the long-term reuse of the initial installations.
- The system with the highest emissions associated in the operation and maintenance phase is the Cocoon system in sector 3 with Cocoon fillers from May to September, and with water transport from the outside 1.3 kg of equiv/tree CO_2. This is because it is

the system that requires the most water transported and more visits by operators to carry out irrigation.

- The system with the least emissions in the maintenance phase is associated with the IFWC and use of fog water as a support irrigation. → This system has also achieved the highest survival rates; however, it is highly dependent on the specific meteorological conditions of the site. The most significant conclusion is that, regardless of the use of other irrigation methods or supplementary water sources, this system should be implemented in all cases. Care must be taken to remove the mosquito screen mesh and stakes after a reasonable period, once the reforestation has been successfully established.
- More than 96 % of the emissions associated with traditional FWC correspond to the metal elements of which they are composed. In the case of IFWC, it accounts for 98% and 76% in the i-FWC. Any innovation involving replacing metallic materials with others will significantly reduce the installation's carbon footprint.

Annex: Ecoinvent v3.7.1 database references.

Process	Task	Details
Transport, passenger car, médium size, diésel, EURO 4	Visits of workers to plots for irrigation or supervision	Included activities start: From combustion of fuel in the engine. The dataset takes as input the infrastructure of the car and road network, the materials and efforts needed for maintenance of these and the fuel consumed in the vehicle for the journey
Electricity, low voltage {ES}| market for | Cut-off, U	Equivalent energy for water pumping from spring.	This dataset includes: - electricity inputs produced in this country and from imports and transformed to low voltage - the transmission network - electricity losses during transmission
Electricity, medium voltage {ES}| market for | Cut-off, U	Equivalent energy for water pumping from well.	This dataset includes: - electricity inputs produced in this country and from imports and transformed to medium voltage - the transmission network - electricity losses during transmission
Transport, freight, lorry 7.5-16 metric ton, EURO4	Water transport with tank truck	Included activities start: From combustion of fuel in the engine. The dataset takes as input the infrastructure of the lorry and road network, the materials and efforts needed for maintenance of these and the fuel consumed in the vehicle for the journey. Included activities end: The activity ends with the transport service of 1tkm and the emissions of exhaust and non-exhaust

		emissions into air, water and soil.

Table 20 Ecoinvent v3[5] processes used in this study.

In the case of well water pumping, the following scenario is taken into consideration:

- Q = 10l/s = 32 m^3/h
- High = 150m
- P = 26 kW
- To pump each 1,000 litres is needed 0.78 kWh

In the case of pumping water from the spring, the following scenario is taken into consideration:

- Q = 1l/s = 3,2 m^3/h
- High = 50m
- P = 0,9 kW
- To pump each 1,000 litres is needed 0.3 kWh.

Table 21 and Table 22 presents the data used to carry out this part of the study and a preliminary assessment of the impact in terms of CO_2 equivalent emissions.

Water supply system	Maintenance tasks	Period	Consumption in transport and pumping	Process
AFDS 2 supplied with 3 fog collectors, 400 trees **AFDS2 (400) fog collectors supply, pump support_re**	Settlement watering of 5 litres per plant at the time of planting: 2,000 litres Installation check and Emergency irrigation 4,000 litres	2 visits August 2022	Fuel consumption for transport (workers) with Mitsubishi L200 40.8 km*3 visits/year One visit for emergency irrigation Energy needed for pumping 6,000 litres, 50 metres = 1.8 kWh	Transport, passenger car, médium size, diésel, EURO 4 Electricity, low voltage {ES}| market for | Cut-off, U

[5] The Ecoinvent v3 database contains LCI data from various sectors such as energy production, transport, building materials, production of chemicals, metal production and fruit and vegetables. The entire database consists of over 10,000 interlinked datasets, each of which describes a life cycle inventory on a process level. SimaPro provides six libraries that each contain all the processes that are found in the ecoinvent database, but use different system models and contain either unit or system processes.

Water supply system	Maintenance tasks	Period	Consumption in transport and pumping	Process
AFDS 1 supplied with pumped water from spring **400 trees**	Settlement watering of 5 litres per plant at the time of planting Installation check and pump activation	2 visits One visit / month (July - September) pumping and unloading of 4,000 litres.	40.8 km*5 visits/year = Three visits for irrigation Settlement watering = 2,000 litres Energy required for pumping 14,000 litres, 50 metros = 4.2 kWh	Transport, passenger car, médium size, diésel, EURO 4 Electricity, low voltage {ES}| market for | Cut-off, U
AFDS 3 supplied with pumped water from spring **400 trees**	Settlement watering of 5 litres per plant at the time of planting Installation check and pump activation	2 visits One visit / month (May - September) pumping and unloading of 4,000 litres.	40.8 km*7 visits/year = Three visits for irrigation Settlement watering = 2,000 litres Energy required for pumping 22,000 litres, 50 metros = 4.2 kWh	Transport, passenger car, médium size, diésel, EURO 4 Electricity, low voltage {ES}| market for | Cut-off, U
AFDS2 supplied with fog collectors, 400 trees. **AFDS2 (400) fog collectors supply, truck support**	Settlement watering of 5 litres per plant at the time of planting. Installation check and Emergency irrigation	2 visits August 2022, 4000 litres	40.8 km*3 visits/year Transporting 6 tonnes of water by tanker truck (20.4 km, 2 empty return journeys) Pumping of 6,000 litres of water from the aquifer by means of a pump in a well (150 metres deep).	Transport, passenger car, EURO 4 Transport, freight, lorry 7.5-16 metric ton, EURO4 Electricity, medium voltage {ES}| market for | Cut-off, U
AFDS1 supplied with water truck, 400 trees **AFDS1 (400) water truck support (July - Sep)**	Settlement watering of 5 litres per plant at the time of planting Installation check Tank filling	2 visits / year July - Sep: 4,000 l irrigation/month + 2,000 settelment irrigation (14 tons transported and pumped from a well, 150 meters, 10 litres/second)	40.8 km*5 visits/year Transporting 14 tonnes of water by tanker truck (20.4 km, 4 empty return journeys) Pumping of 14,000 litres of water from the aquifer by means of a pump in a well (150 metres deep).[6]	Transport, passenger car, EURO 4 Transport, freight, lorry 7.5-16 metric ton, EURO4 Electricity, medium voltage {ES}| market for | Cut-off, U

[6] Groundwater extraction will strongly depend on the depth of the piezometric level of the aquifer and the efficiency of the pump/motor assembly. An approximation is given here, to be determined on a case-by-case basis. In this case to pump each 1,000 liters is needed 0.78 kWh.

Water supply system	Maintenance tasks	Period	Consumption in transport and pumping	Process
AFDS3 supplied with water truck, 400 trees **AFDS31 (400) water truck support (May - Sep)**	Settlement watering of 5 litres per plant at the time of planting Installation check Tank filling	2 visits / year May - Sep: 4,000 l irrigation/month + 2,000 settelment irrigation (22 tons transported and pumped from a well, 150 meters, 10 litres/second)	40.8 km*7 visits/year Transporting 22 tonnes of water by tanker truck (20.4 km, 6 empty return journeys) Pumping of 22,000 litres of water from the aquifer by means of a pump in a well (150 metres deep).	Transport, passenger car, EURO 4 Transport, freight, lorry 7.5-16 metric ton, EURO4 Electricity, medium voltage {ES}| market for | Cut-off, U

Table 21 Data used to carry out to evaluate AFDS 1, 2 and 3 and different irrigation regime.

Water supply system	Maintenance tasks	Period	Consumption in transport and pumping	Process
Cocoon[7] supplied with fog collectors **Cocoon Sector 1 fog support**	Filling in 4 days for settlement irrigation 110 Coccon/day Overhaul and/or cocoon replacement and/or cocoon filling. Overhauls between May and September	4 visits for settlement irrigation 5 visits for overhaul.	40.8 km*4 visits/year 40.8 km*5 visits/year	Transport, passenger car, EURO 4
Cocoon supplied with fog collectors **Cocoon Sector 2 fog support**	Filling in 4 days for settlement irrigation 110 Coccon/day Overhaul and/or cocoon replacement and/or cocoon filling. Refill between July and September	4 visits for settlement irrigation 12 visits for refill	40.8 km*4 visits/year 40.8 km*12 visits/year	Transport, passenger car, EURO 4

[7] Each cocoon needs 25L.

Water supply system	Maintenance tasks	Period	Consumption in transport and pumping	Process
Cocoon supplied with fog collectors **Cocoon Sector 3 fog support**	Filling in 4 days for settlement irrigation 110 Coccon/day Overhaul and/or cocoon replacement and/or cocoon filling. Refill between May and September	4 visits for settlement irrigation 16 visits for refill	40.8 km*4 visits/year 40.8 km*16 visits/year	Transport, passenger car, EURO 4
Cocoon supplied with pumped water from spring **400 trees** **Cocoon Sector 1 pump support**	Filling in 4 days for settlement irrigation 110 Coccon/day Overhaul and/or cocoon replacement and/or cocoon filling. Overhauls between May and September	4 visits for settlement irrigation 5 visits for overhaul. Pumping of 10,000 litres for initial filling	40.8 km*9 visits/year Settlement watering = 10,000 litres Energy required for pumping 10,000 litres, 50 metros = 3 kWh	Transport, passenger car, médium size, diésel, EURO 4 Electricity, low voltage {ES}| market for | Cut-off, U
Cocoon supplied with pumped water from spring **400 trees** **Cocoon Sector 2 pump support**	Filling in 4 days for settlement irrigation 110 Coccon/day Overhaul and/or cocoon replacement and/or cocoon filling. Refill between July and September	4 visits for settlement irrigation 12 visits for refill. Pumping of 10,000 litres for initial filling Pumping of 28,000 litres for refilling	40.8 km*16 visits/year Settlement watering = 10,000 litres Energy required for pumping 38,000 litres, 50 metros = 11.4 kWh	Transport, passenger car, médium size, diésel, EURO 4 Electricity, low voltage {ES}| market for | Cut-off, U

Water supply system	Maintenance tasks	Period	Consumption in transport and pumping	Process
Cocoon supplied with pumped water from spring **400 trees** **Cocoon Sector 3 pump support**	Filling in 4 days for settlement irrigation 110 Cocoon/day Overhaul and/or cocoon replacement and/or cocoon filling. Refill between May and September	4 visits for settlement irrigation 16 visits for refill. Pumping of 10,000 litres for initial filling Pumping of 36,000 litres for refilling	40.8 km*20 visits/year Settlement watering = 10,000 litres Energy required for pumping 46,000 litres, 50 metros = 13.8 kWh	Transport, passenger car, médium size, diésel, EURO 4 Electricity, low voltage {ES}| market for | Cut-off, U

Table 22 Operation and maintenance work. Data used to carry out to evaluate Cocoons in sectors 1, 2 and 3 with different irrigation regime[8] (fog collectors and spring water)

Cocoon Sector 1 truck support	None						
Assembly	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
5_Cocoon supplied with pumped water from spring	0	p	Undefined				

Processes	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
Transport, passenger car, EURO 4 {RER}| transport, passe	40.8*4/400 = 0.408	km					4 visits for settelment irrigation
Transport, freight, lorry 7.5-16 metric ton, euro4 {RoW}|	(10*20.8)/400 = 0.52	tkm					10,000 for settelment irrigation (25 liter/plant)
Electricity, medium voltage {ES}| market for | Cut-off, U	(0.78*10)/400 = 0.0195	kWh					10,000 for settelment irrigation (25 liter/plant) pumped from a well
Transport, freight, lorry 7.5-16 metric ton, euro4 {RER}| r	(1*20.4)/400 = 0.051	tkm					1 empty return journey

Cocoon Sector 2 truck support	None						
Assembly	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
5_Cocoon supplied with pumped water from spring	0	p	Undefined				

Processes	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
Transport, passenger car, EURO 4 {RER}| transport, passe	40.8*16/400 = 1.63	km					4 visits for settelment irrigation + 12 visists to refill
Transport, freight, lorry 7.5-16 metric ton, euro4 {RoW}|	(38*20.4)/400 = 1.94	tkm					10,000 for settelment irrigation (25 liter/plant) +28,000
Electricity, medium voltage {ES}| market for | Cut-off, U	(0.78*38)/400 = 0.0741	kWh					10,000 for settelment irrigation (25 liter/plant) +28,000 pumped from a well
Transport, freight, lorry 7.5-16 metric ton, euro4 {RER}| r	(4*20.4)/400 = 0.204	tkm					4 empty return journey

Cocoon Sector 3 truck support	None						
Assembly	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
5_Cocoon supplied with pumped water from spring	0	p	Undefined				

Processes	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
Transport, passenger car, EURO 4 {RER}| transport, passe	40.8*20/400 = 2.04	km					4 visits for settelment irrigation + 14 visists to refill
Transport, freight, lorry 7.5-16 metric ton, euro4 {RoW}|	(46*20.4)/400 = 2.35	tkm					10,000 for settelment irrigation (25 liter/plant) +36,000
Electricity, medium voltage {ES}| market for | Cut-off, U	0.78*46/400 = 0.0897	kWh					46,000 pumped from a well +
Transport, freight, lorry 7.5-16 metric ton, euro4 {RER}| r	(5*20.4)/400 = 0.255	tkm					5 empty return journey

Table 23 Data used in SimaPro to evaluate Cocoons in secotr 1, 2 and 3 with water tank truck support.

Table 24 shows all the parameterised operating systems in SimaPro.

[8] Irrigation regime: All new reforestation will receive a settlement watering of 5L per plant at the time of planting. Sector 1 will only receive the settlement irrigation, except for the traditional reforestation method that will receive 5L watering per plant, twice a month from May to September (both inclusive). Sector 2 plants with individual FWC and AFDS treatments will receive 5L watering per plant, twice a month from July to September (both inclusive). Cocoon system treatment will receive two tanks refill during summer. Traditional reforestation method will receive 5L watering per plant, twice a month, from May to September (both inclusive). In 'Sector 3' all plants will receive 5L watering per plant, twice a month from May to September (both inclusive) – At exemption of Cocoon system method which will require two tanks refill during summer. The typology that will take the most water is Cocoon, however we must account for the nature of its own testing methodology. Cocoons will be closely followed by the 'Traditional method', working as control group for the whole experiment. Finally, Individual FWCs and the AFDS system will take the least amount of support irrigation.

Name	Project	Assembly
AFDS1 (400) pump support (July - Sep)_rev	LIFE NIEBLAS_GHG emissions	2_AFDS*3 with pumped water from spring
AFDS1 (400) water truck support (July - Sep)_rev	LIFE NIEBLAS_GHG emissions	1_AFDS supplied with water tank truck
AFDS2 (400) fog collectors supply, pump support_re	LIFE NIEBLAS_GHG emissions	3_AFDS supplied with 3 fog collectors
AFDS2 (400) fog collectors supply, truck support_r	LIFE NIEBLAS_GHG emissions	3_AFDS supplied with 3 fog collectors
AFDS3 (400) pump support (May - Sep)_rev	LIFE NIEBLAS_GHG emissions	2_AFDS*3 with pumped water from spring
AFDS3 (400) water truck support (May - Sep)_rev	LIFE NIEBLAS_GHG emissions	1_AFDS supplied with water tank truck
Cocoon Sector 1 fog support	LIFE NIEBLAS_GHG emissions	6_Cocoon supplied with tank and fog collectors
Cocoon Sector 1 pump support_rev	LIFE NIEBLAS_GHG emissions	5_Cocoon supplied with pumped water from spring
Cocoon Sector 1 truck support	LIFE NIEBLAS_GHG emissions	5_Cocoon supplied with pumped water from spring
Cocoon Sector 2 fog support	LIFE NIEBLAS_GHG emissions	6_Cocoon supplied with tank and fog collectors
Cocoon Sector 2 pump support_rev	LIFE NIEBLAS_GHG emissions	5_Cocoon supplied with pumped water from spring
Cocoon Sector 2 truck support	LIFE NIEBLAS_GHG emissions	5_Cocoon supplied with pumped water from spring
Cocoon Sector 3 fog support	LIFE NIEBLAS_GHG emissions	6_Cocoon supplied with tank and fog collectors
Cocoon Sector 3 pump support_rev	LIFE NIEBLAS_GHG emissions	5_Cocoon supplied with pumped water from spring
Cocoon Sector 3 truck support	LIFE NIEBLAS_GHG emissions	5_Cocoon supplied with pumped water from spring
Individual FWC Sector 1, fog support	LIFE NIEBLAS_GHG emissions	Individual Fog Collector
Individual FWC Sector 1, pump support_rev	LIFE NIEBLAS_GHG emissions	Individual Fog Collector
Individual FWC Sector 1, truck support_rev	LIFE NIEBLAS_GHG emissions	Individual Fog Collector
Individual FWC Sector 2, fog support (July-Sep)	LIFE NIEBLAS_GHG emissions	Individual Fog Collector
Individual FWC Sector 2, pump support (July-Sep)_r	LIFE NIEBLAS_GHG emissions	Individual Fog Collector
Individual FWC Sector 2, truck support (July-Sep)	LIFE NIEBLAS_GHG emissions	Individual Fog Collector
Individual FWC Sector 3, fog support (May - Sep)	LIFE NIEBLAS_GHG emissions	Individual Fog Collector
Individual FWC Sector 3, pump support (May - Sep)	LIFE NIEBLAS_GHG emissions	Individual Fog Collector
Individual FWC Sector 3, truck support (May - Sep)	LIFE NIEBLAS_GHG emissions	Individual Fog Collector
Traditional Sectors fog support	LIFE NIEBLAS_GHG emissions	9_Traditional irrigation with fog collectors
Traditional Sectors pump support	LIFE NIEBLAS_GHG emissions	8_Traditional irrigation with spring pump
Traditional Sectors truck support	LIFE NIEBLAS_GHG emissions	7_Traditional irrigation with water tank truck

Table 24 Irrigation systems and strategies parameterised in SimaPro to assess CO_2 equivalent emissions in the operation and maintenance phase.

11. Impact assessment of the systems studied

For the correct development of the LCA methodology, it is necessary to use a software tool to save time and achieve reliable results. The basic function of these is to perform the material and energy balances on the specific process and to allocate emissions, energy uses, etc., normalised on a common basis. In this case, the tool **SimaPro version 9.1.1** is used.

For this LCA, we work with the **Ecoinvent v3.7.1** database with more than 4,000 processes from different sectors.

The methodology used for the calculation of the carbon footprint has been the **IPCC 2013 GWP 20a V1.03**. IPCC 2013 is the successor of the IPCC 2007 method, which was developed by the Intergovernmental Panel on Climate Change. It contains the climate change factors of IPCC with a timeframe of 20 years.

To asses other impact categories we used the method **CML-IA non-baseline V3.04 / World, 2000**. CML-IA is a LCA methodology developed by the Center of Environmental Science (CML) of Leiden University in The Netherlands.

In addition to the type of technology, the type of water abstraction will be taken into account in the assessment and interpretation of the impacts.

The following sections of the document set out the results of applying the methodology. Initially for the first construction and assembly phase and then for the first year of the operation phase taking into account the different irrigation regimes.

To accurately interpret these results, it is essential to consider that some of the infrastructures established in the reforestation area are not designed for single use. When comparing each infrastructure and reforestation system during its initial implementation, the evaluation should

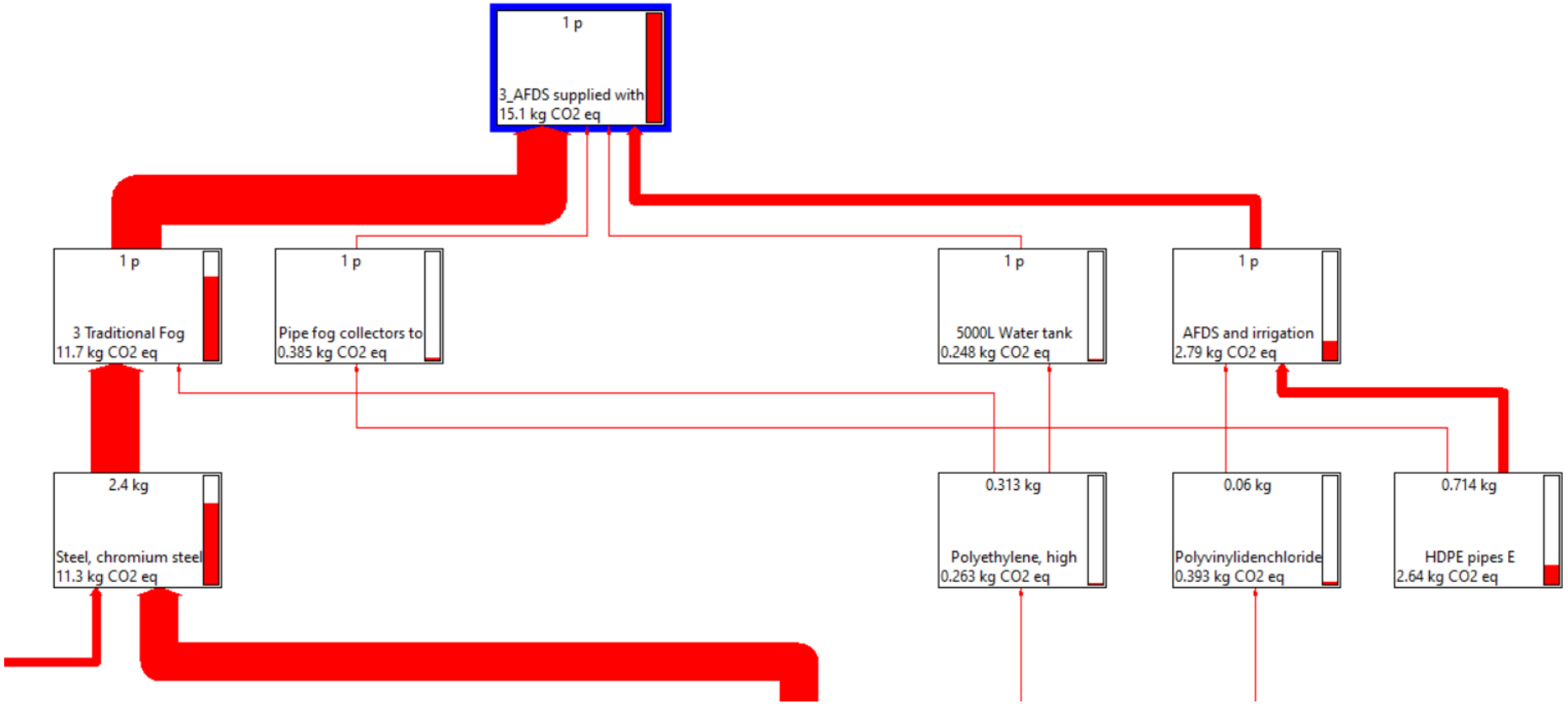
follow the defined methodology. However, in the long term, it is crucial to take into account the capacity of each system to recover and reuse materials and infrastructures throughout its lifespan. This aspect will be further discussed in the conclusions of this study.

A specific section is dedicated to the Innovative Fog Water Collector (i-FWC). In this study, the total emissions associated with its initial installation have been evaluated, but not in relation to a functional unit, as has been done with the other systems to allow for comparison.

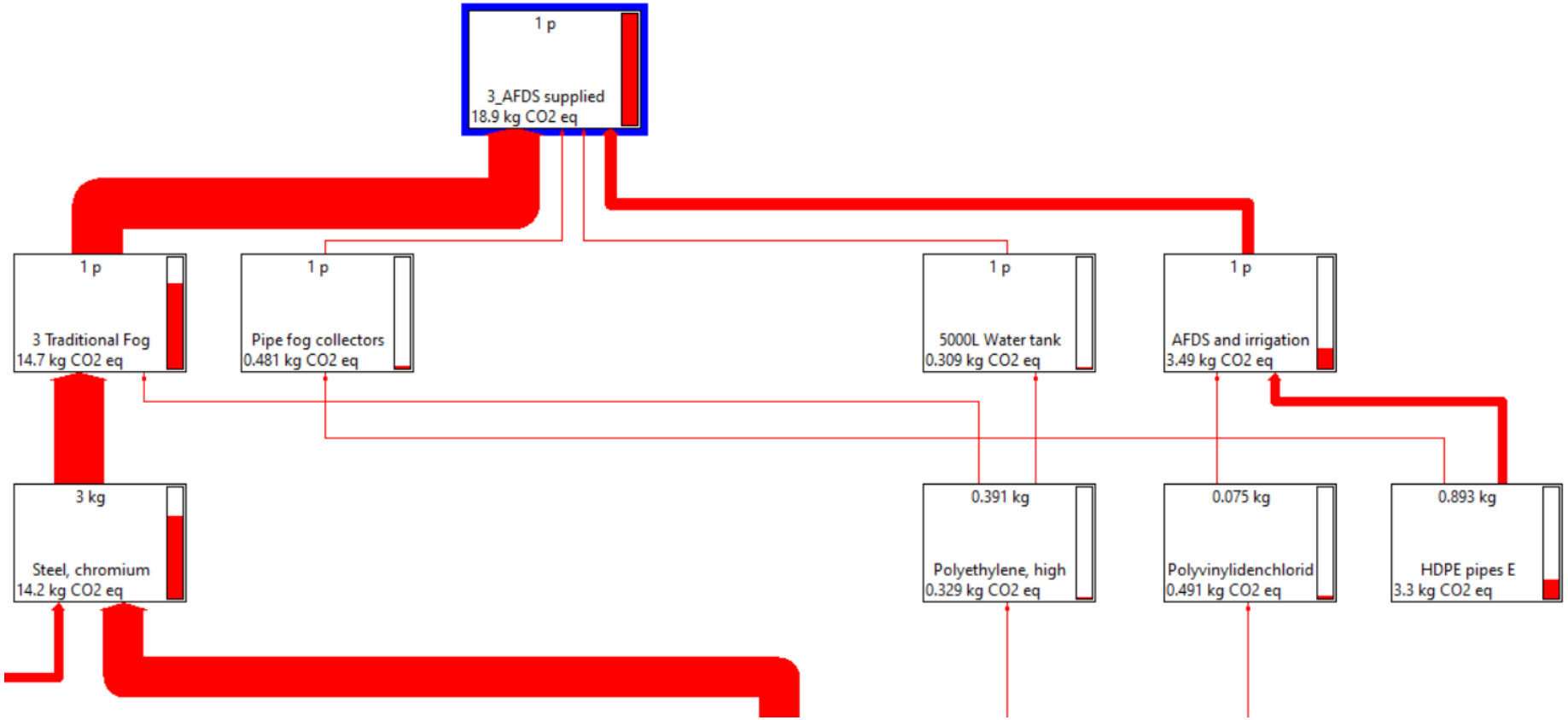
To compare the systems both during the installation phase and in their long-term operation, the chosen functional unit has been the number of surviving trees after the installation process and one year of operation. In the case of the Innovative Fog Water Collector (i-FWC) or other types of fog water collectors, alternative functional units could be used, such as the litres of water produced per square meter of impact area of the dispositive, throughout the meteorological conditions of the project. This aspect will be analysed in a separate chapter.

11.1 Impact assessment in the first assembly phase.

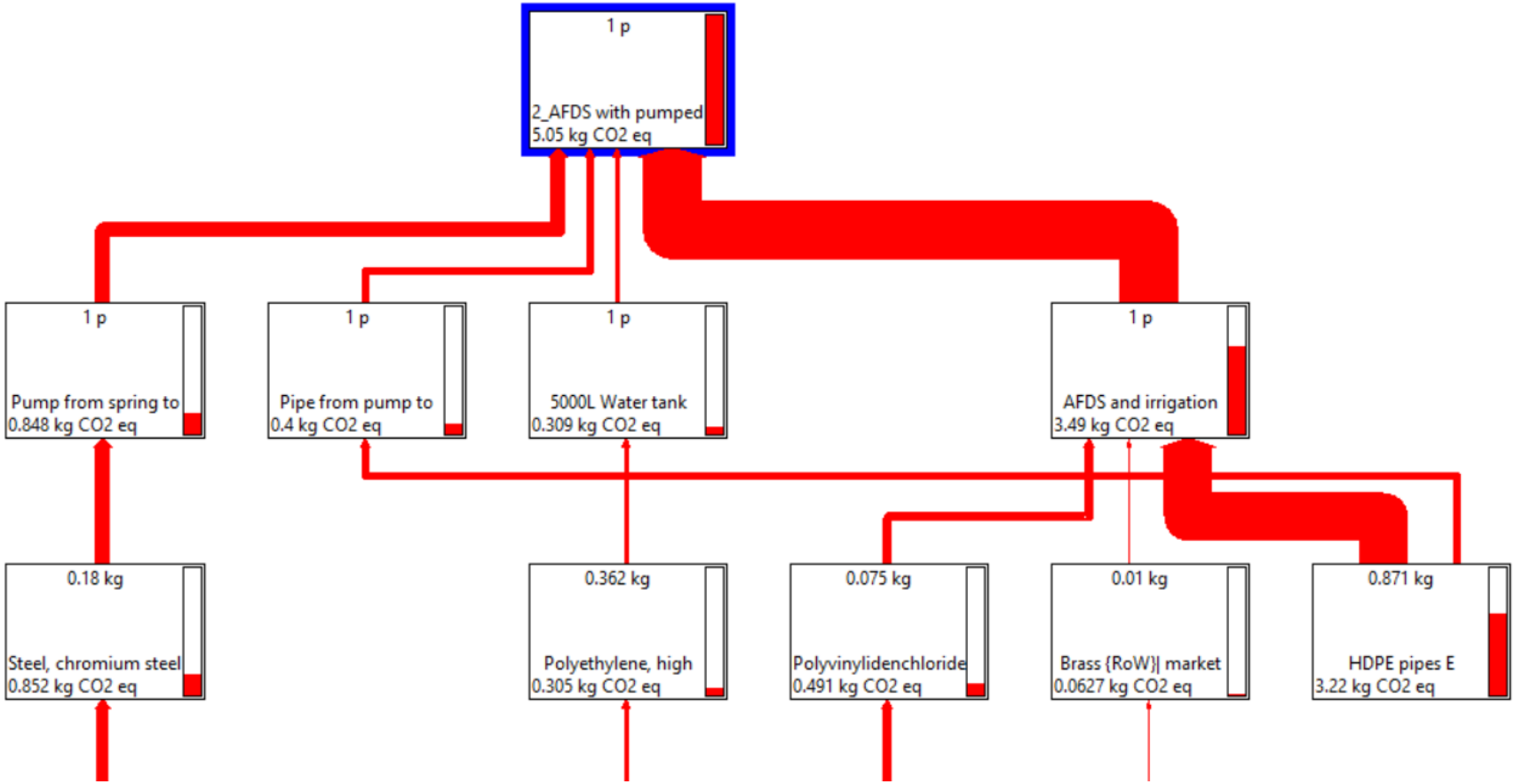
11.1.1 AFDS supplied with 3 fog collectors (500 surviving trees, 100%)



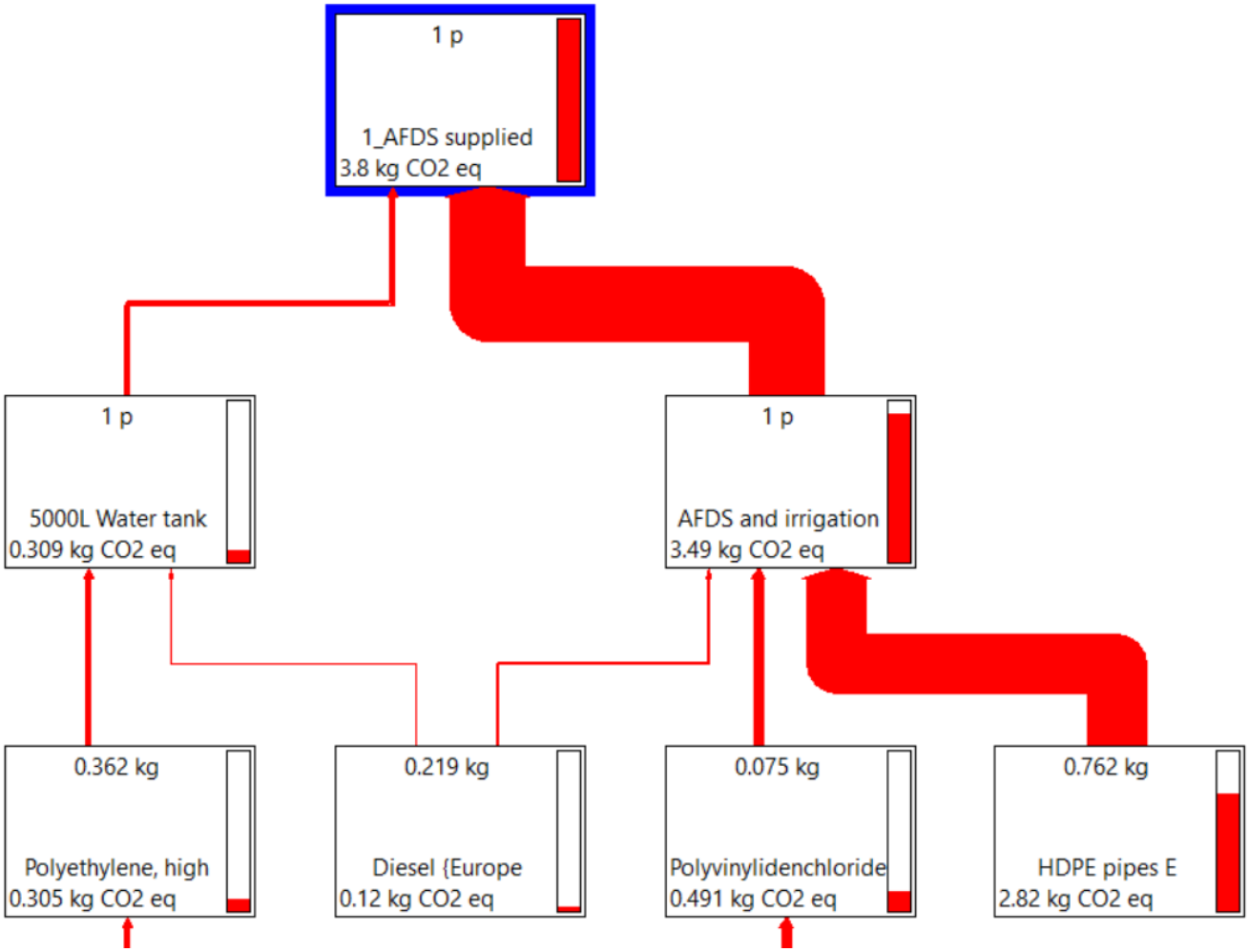
11.1.2 AFDS supplied with 3 fog collectors (400 surviving trees, 80%)



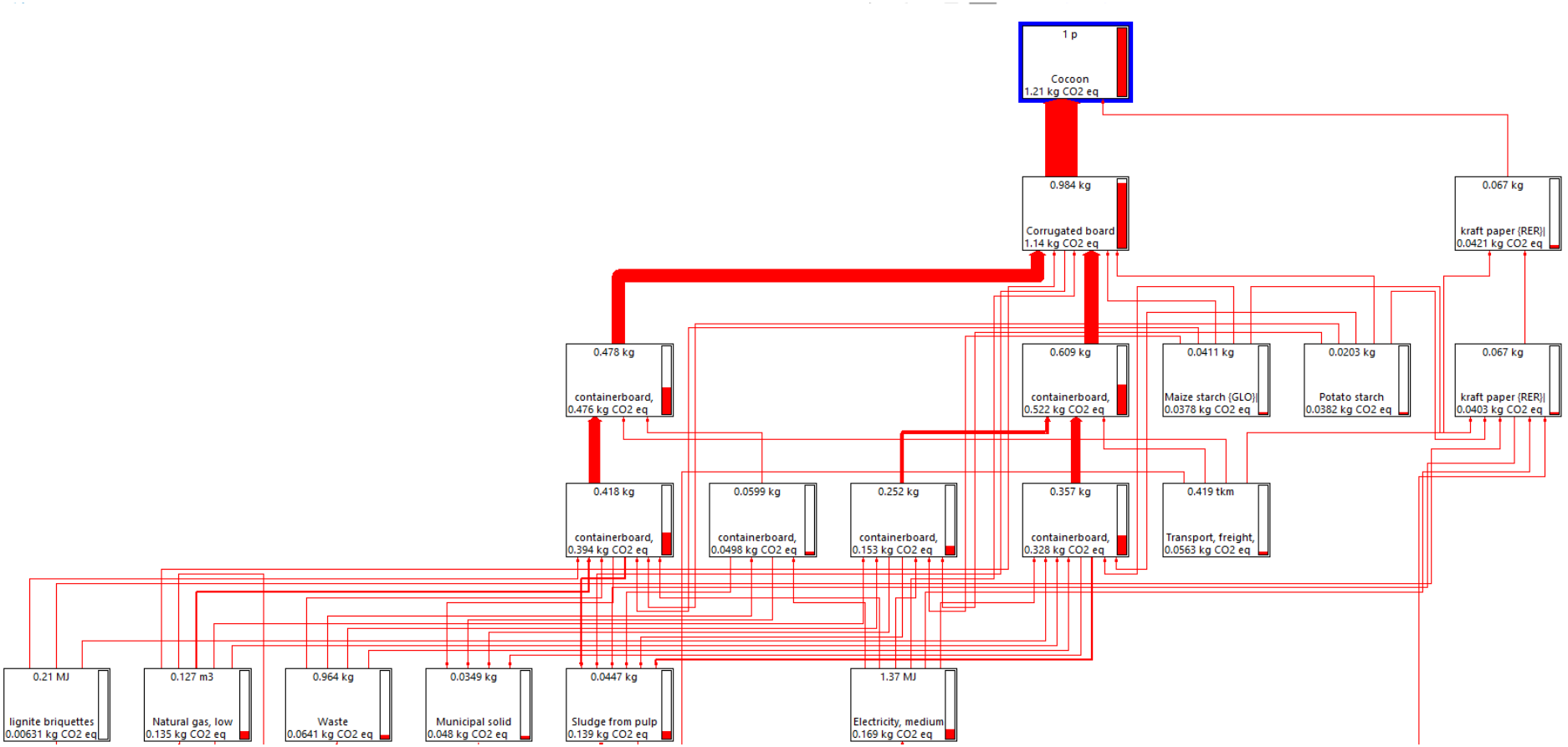
11.1.3 3 AFDS supplied with pumped water from spring (1,200 trees, 80%)



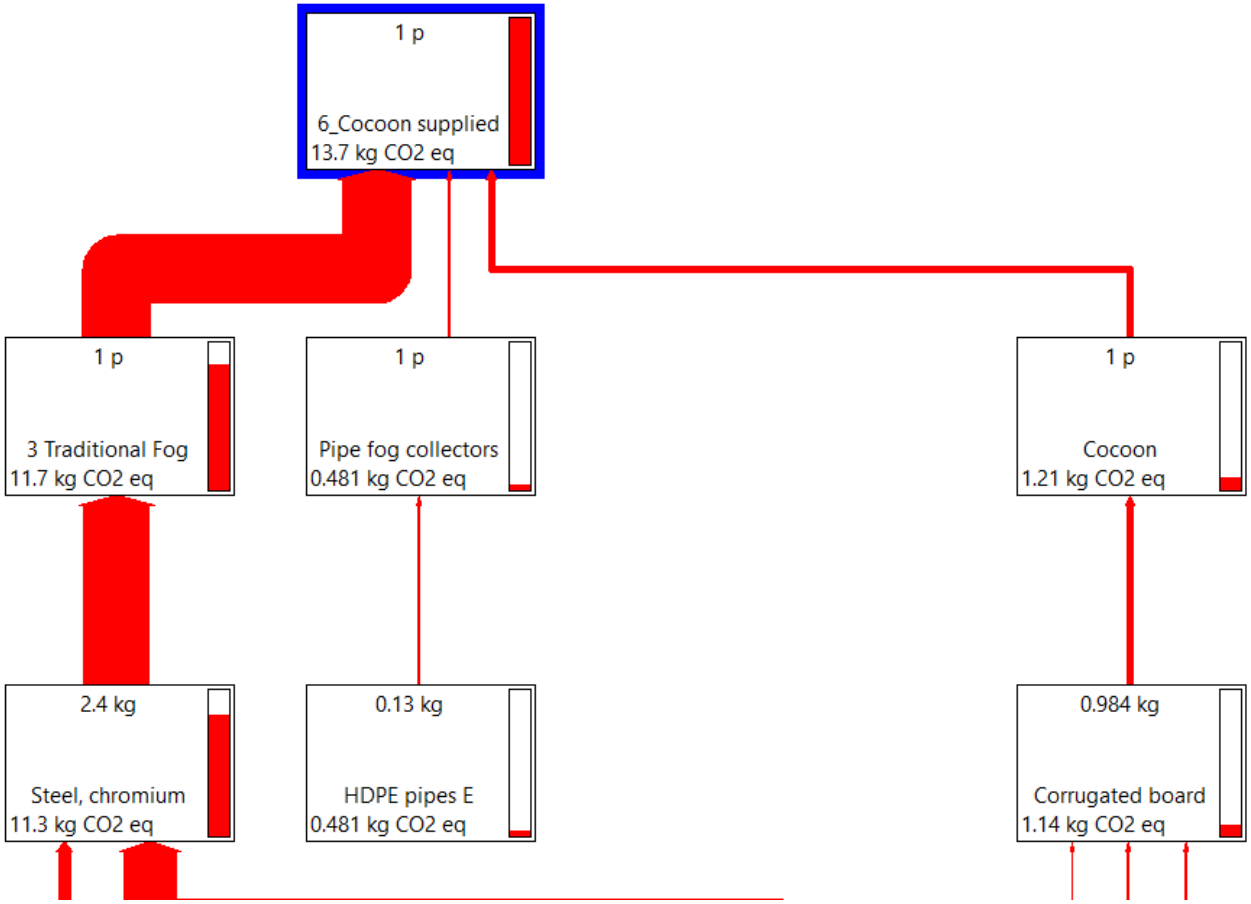
11.1.4 AFDS supplied with water tank truck (400 trees, 80%)



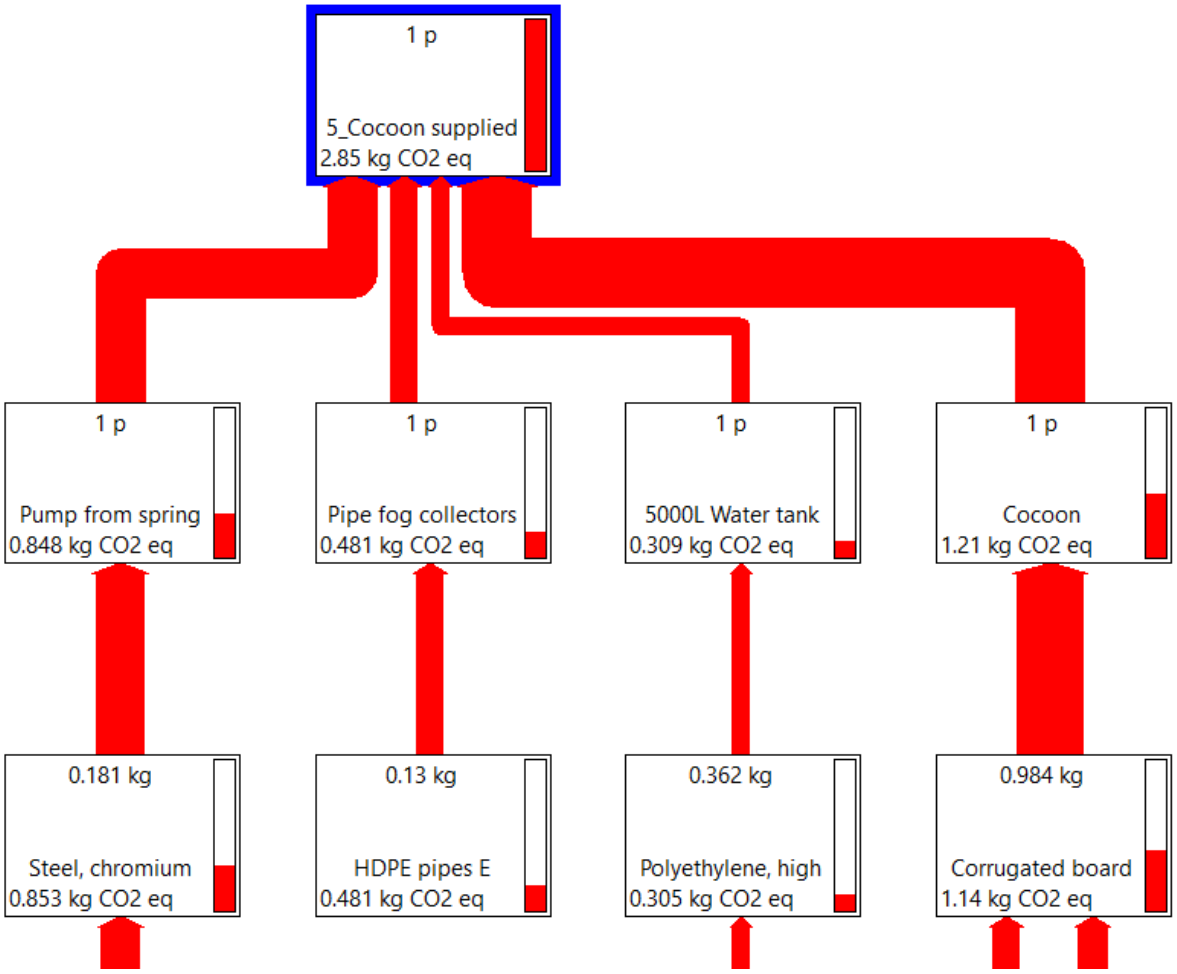
11.1.5 Cocoon emissions (LCA assessment)



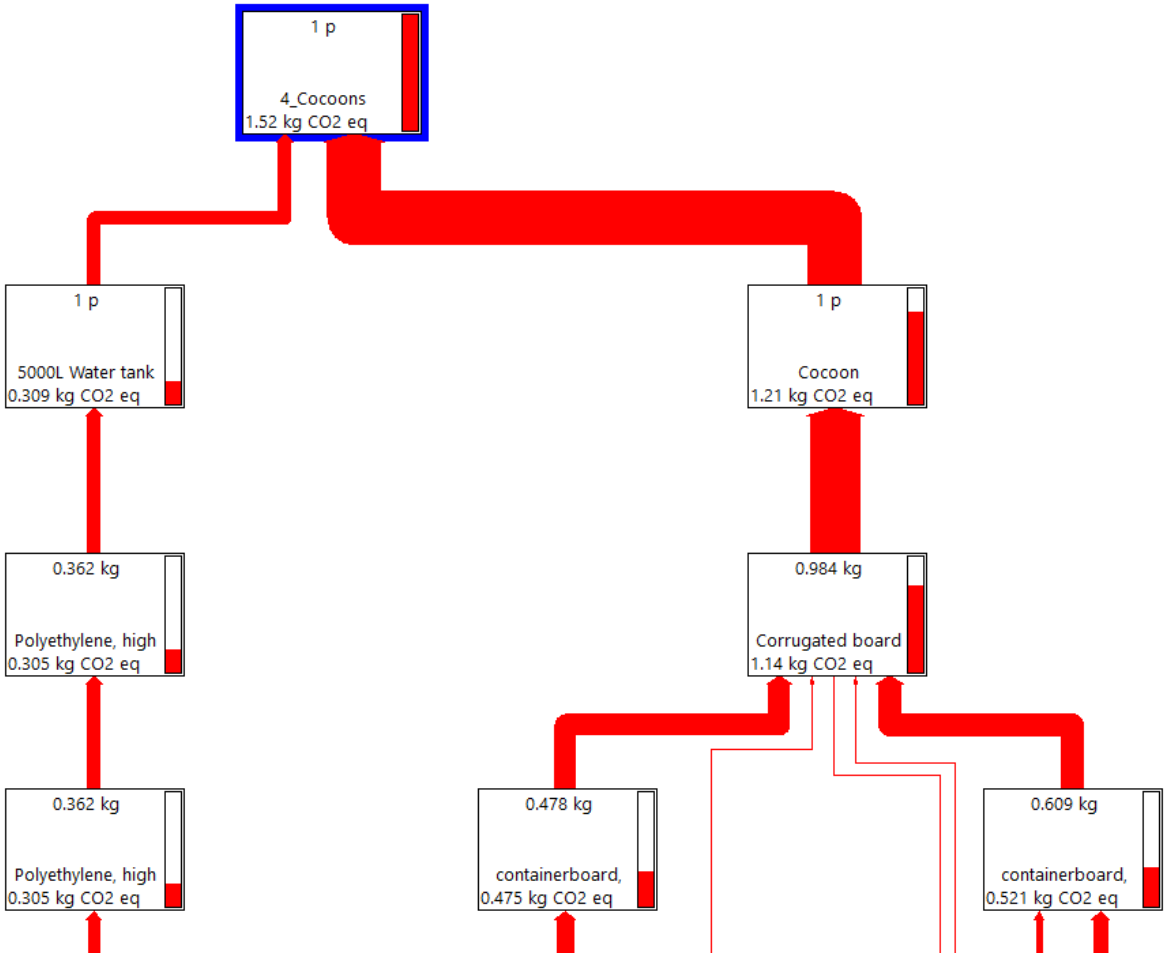
11.1.6 Cocoon supplied with tank and three fog collectors (400 trees, 80%)



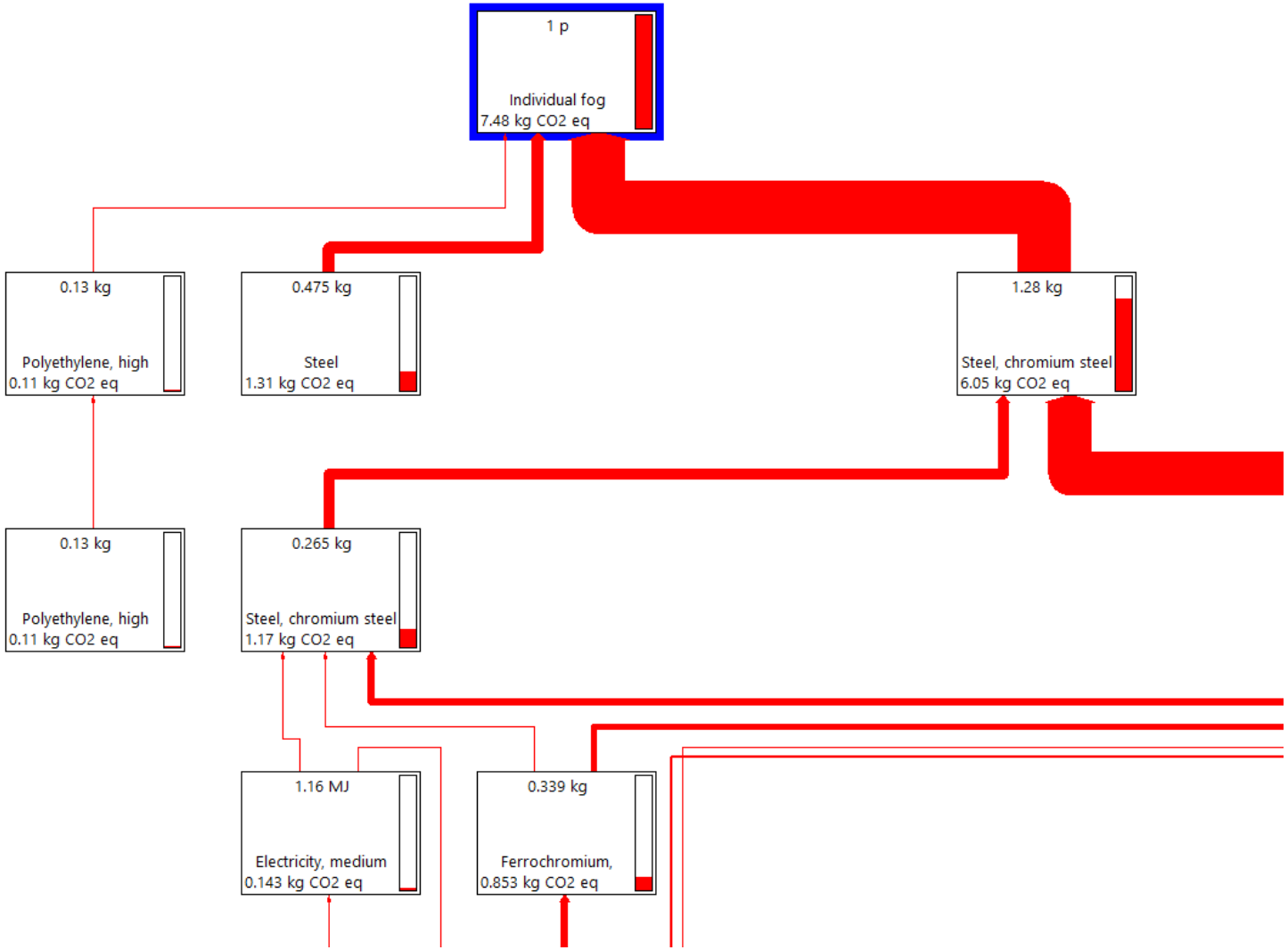
11.1.7 Cocoon supplied with pumped water form spring (400 trees, 80%)



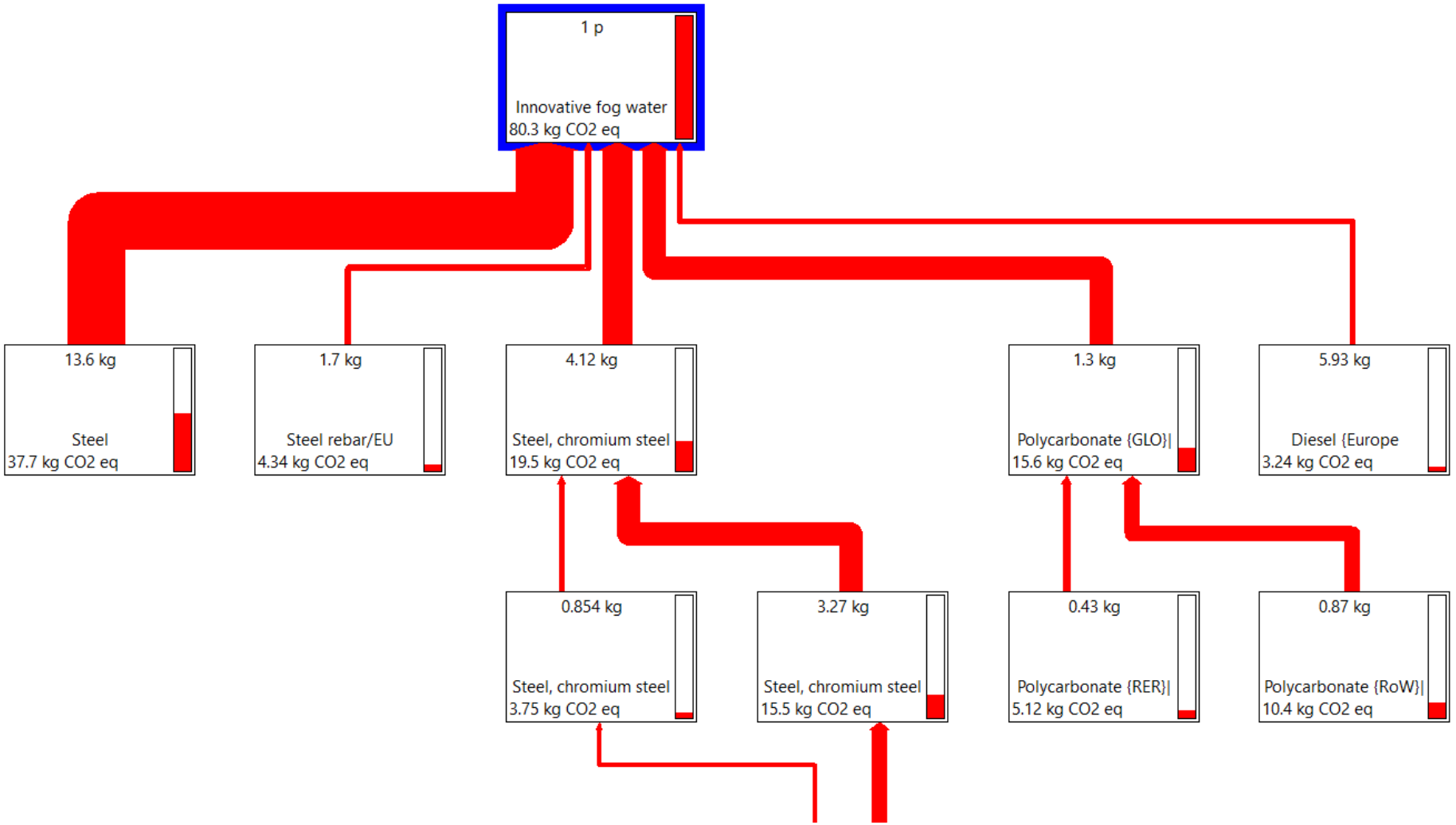
11.1.8 Cocoon supplied with water tank truck (400 trees, 80%)



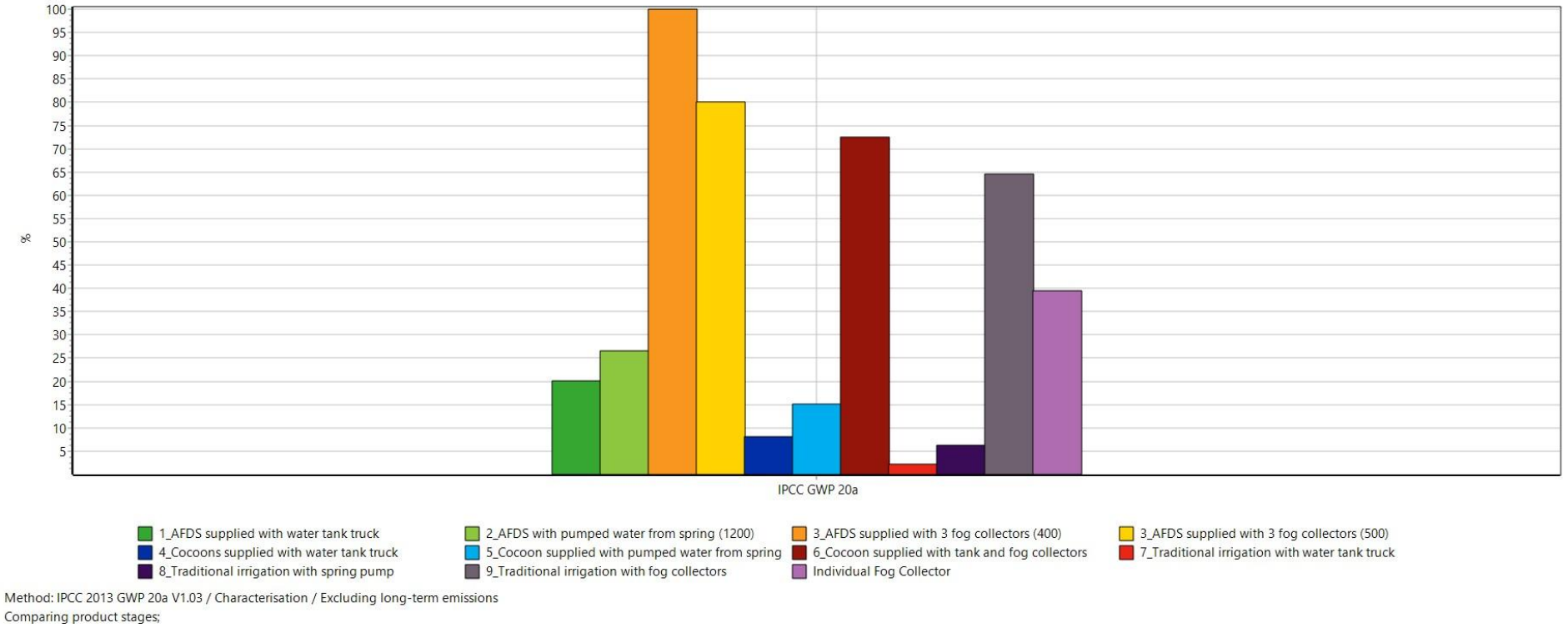
11.1.9 Individual fog water collector (IFWC)



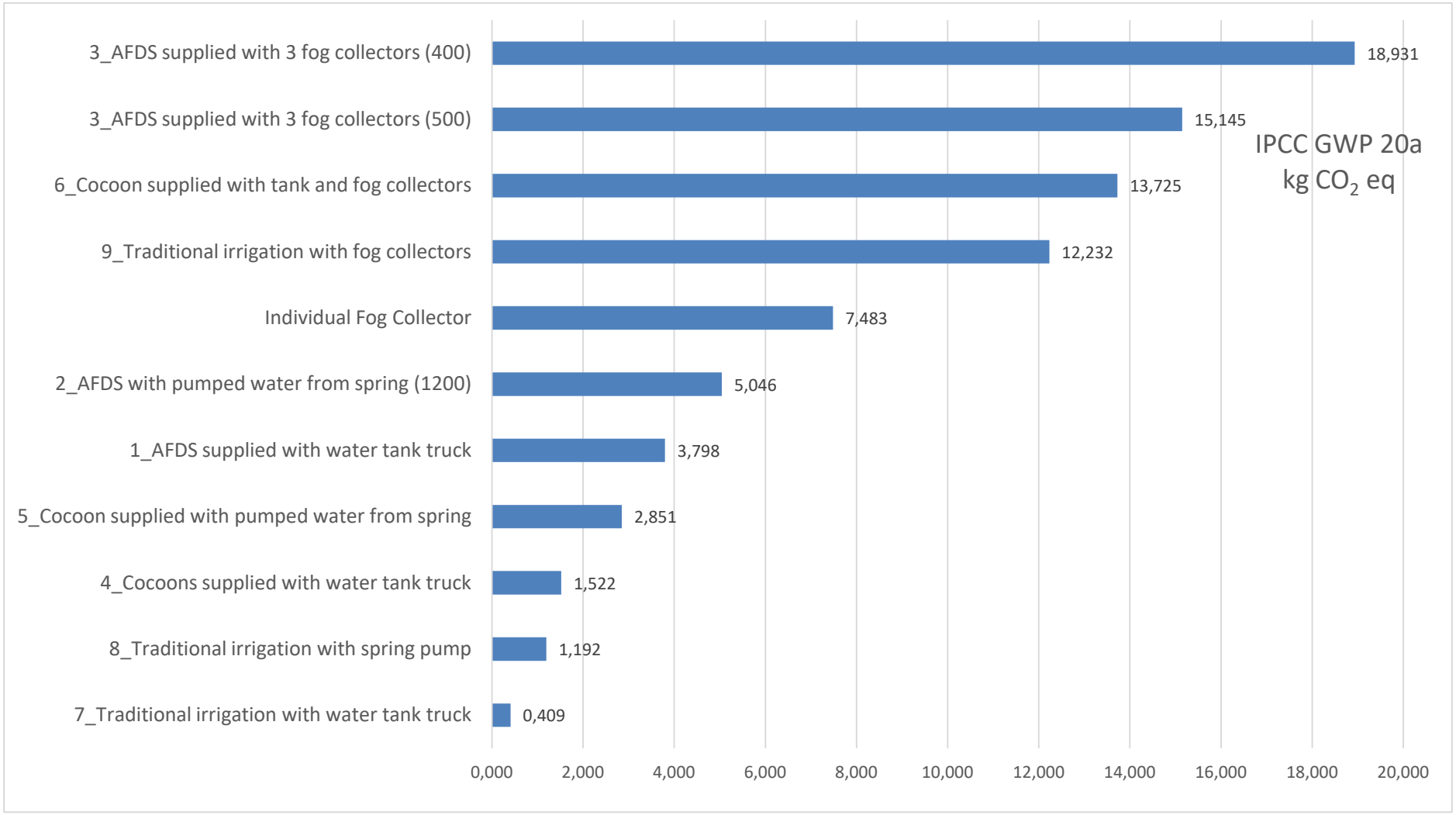
11.1.10 Innovative Fog Water Collector (i-FWC), total emissions.



11.1.11 Comparison in first Assembly Phase



Graph 1 Percentage comparison of emissions considering the initial installation of the necessary infrastructures for each reforestation system at La Finca El Pinillo, under different scenarios regarding the water source and the number of surviving trees in its first application. This analysis does not take into account the reuse of materials in future reforestation efforts or the manufacturing of necessary components when the water is sourced from outside the property.



Graph 2 Unitary emissions per surviving tree using IPCC 2013 GWP 20a V1.03 and Ecoinvent v3.7.1, considering initial infrastructure installation at La Finca El Pinillo under different water source and survival rate scenarios, without accounting for material reuse or water extraction/transport components.

From this initial analysis, it is observed that as more infrastructures are implemented in the reforestation area to enhance autonomy in water collection and storage, as well as to promote automated irrigation with minimal human intervention, the emissions associated with each surviving tree during its initial establishment increase. This trend becomes particularly evident when analysing the most extreme cases.

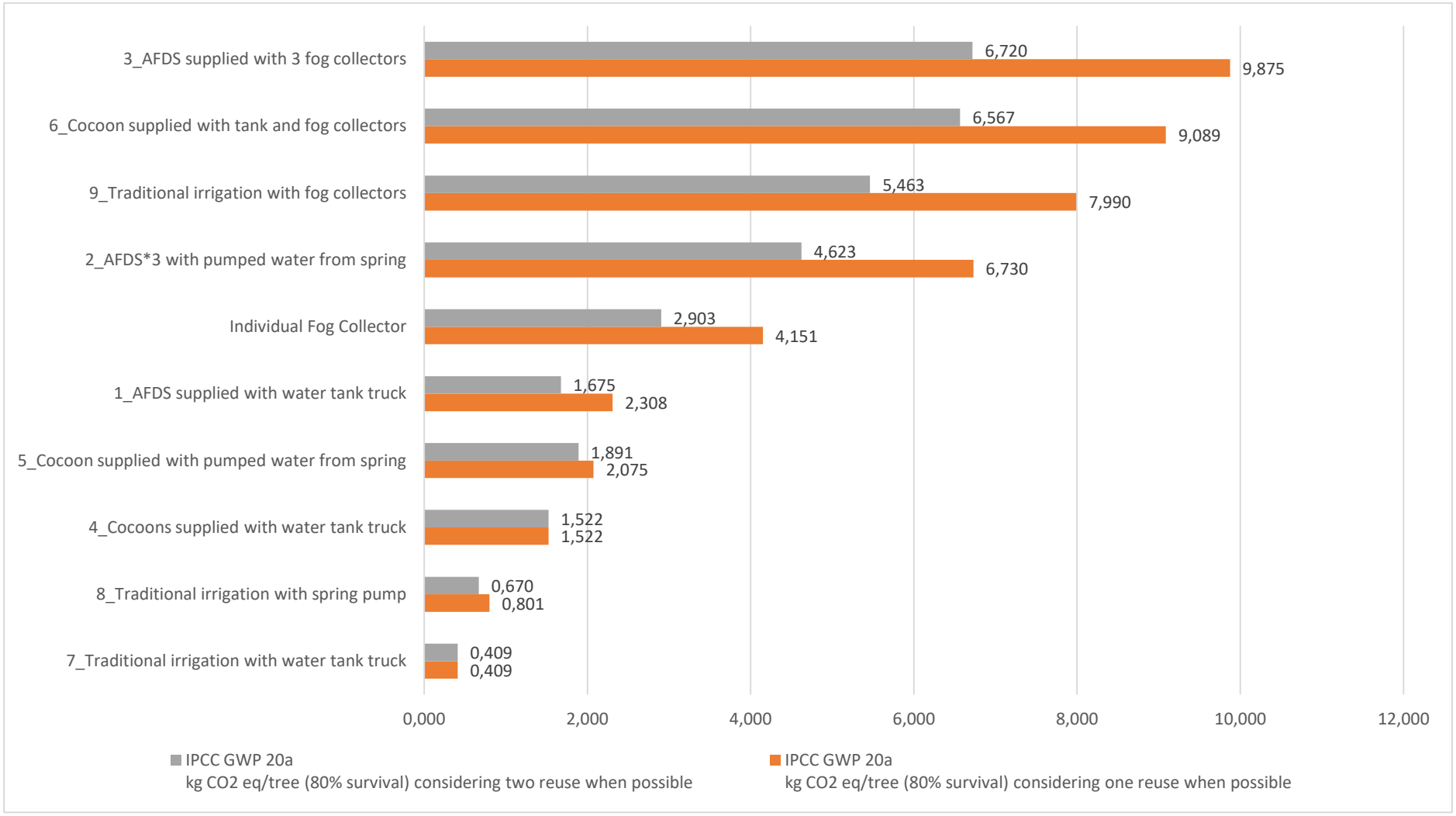
The reforestation system with the lowest emissions during its initial installation is the traditional system, as it only requires a 5,000-liter tank to store water delivered by a tanker truck and the personnel needed to dig planting holes and plant the trees. This analysis does not account for external emissions related to the construction of a 150-meter-deep water well or the manufacturing of the 6 m^3 tanker truck. Additionally, this system assumes that a single 5,000-liter tank is sufficient to irrigate 1,940 trees, as this corresponds to the volume transported by the tanker truck in each delivery. However, this reforestation system will generate the highest emissions during the operational phase, as will be discussed later.

At the other extreme is the system requiring the most infrastructure at the local site to achieve self-sufficiency in water collection and minimize human intervention during operation and maintenance. This is the case of the 5,000-liter AFDS supplied by three Traditional Fog Water Collectors (TFWC), each with an 8 m^2 exposure surface, and a drip irrigation network designed for 500 trees. This infrastructure requires fewer interventions (and therefore fewer emissions) during the operational phase, provided that meteorological conditions are favourable for fog water collection. As demonstrated in the LIFE NIEBLAS Project, TFWCs can be continuously reused for reforestation in the area unless extreme events cause their destruction. Moreover, once their function in an initial reforestation is complete, the 5,000-liter AFDS and the irrigation network can be recovered and relocated to another site for further reforestation, potentially reducing emissions per functional unit by nearly half.

In an intermediate position is the IFWC model, which has also demonstrated its capacity for material reuse.

Only the Cocoon cannot be reused, although the associated infrastructure for water collection and storage can be.

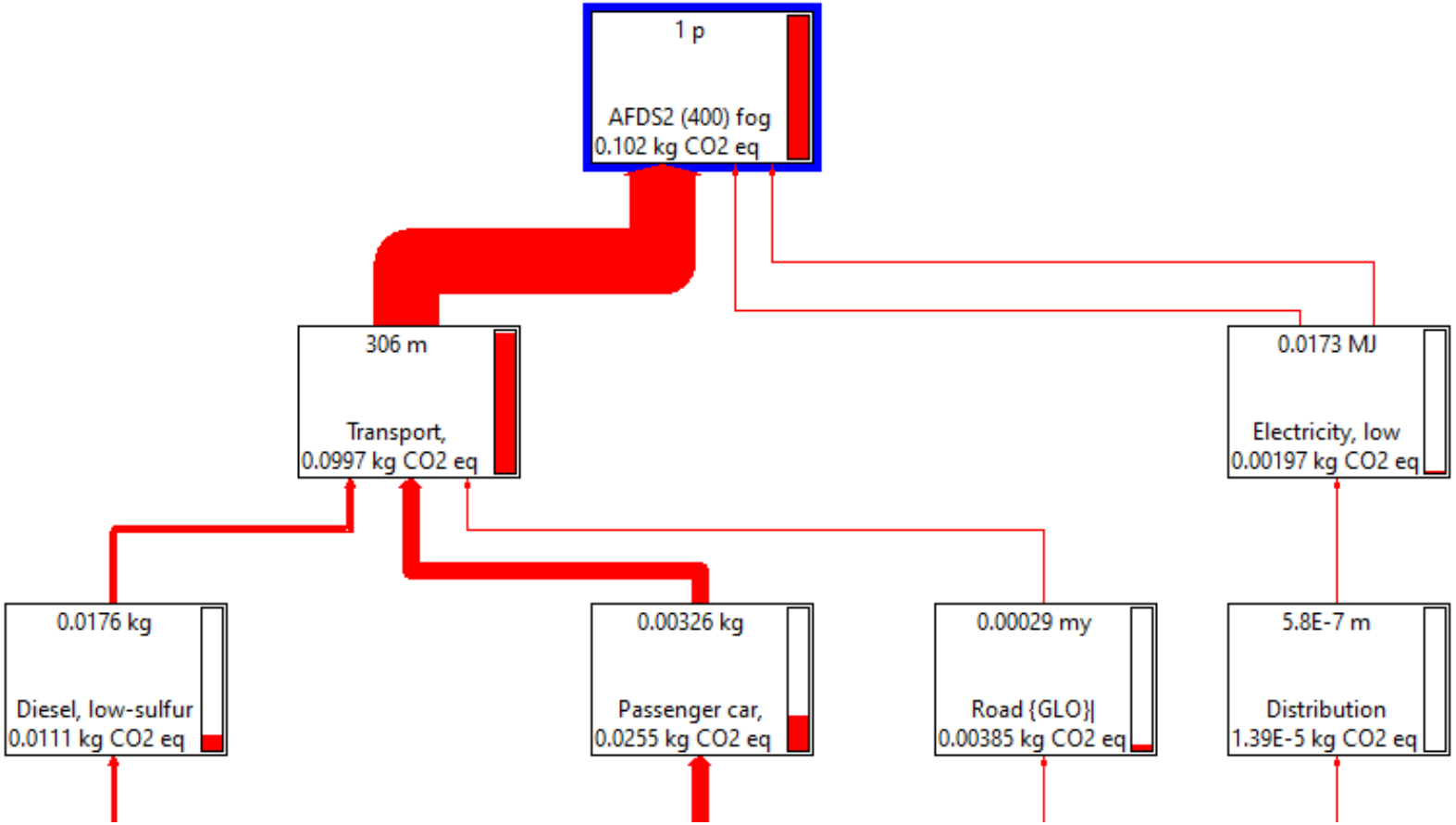
Unitary emissions under different material reuse scenarios are presented in Graph 3.



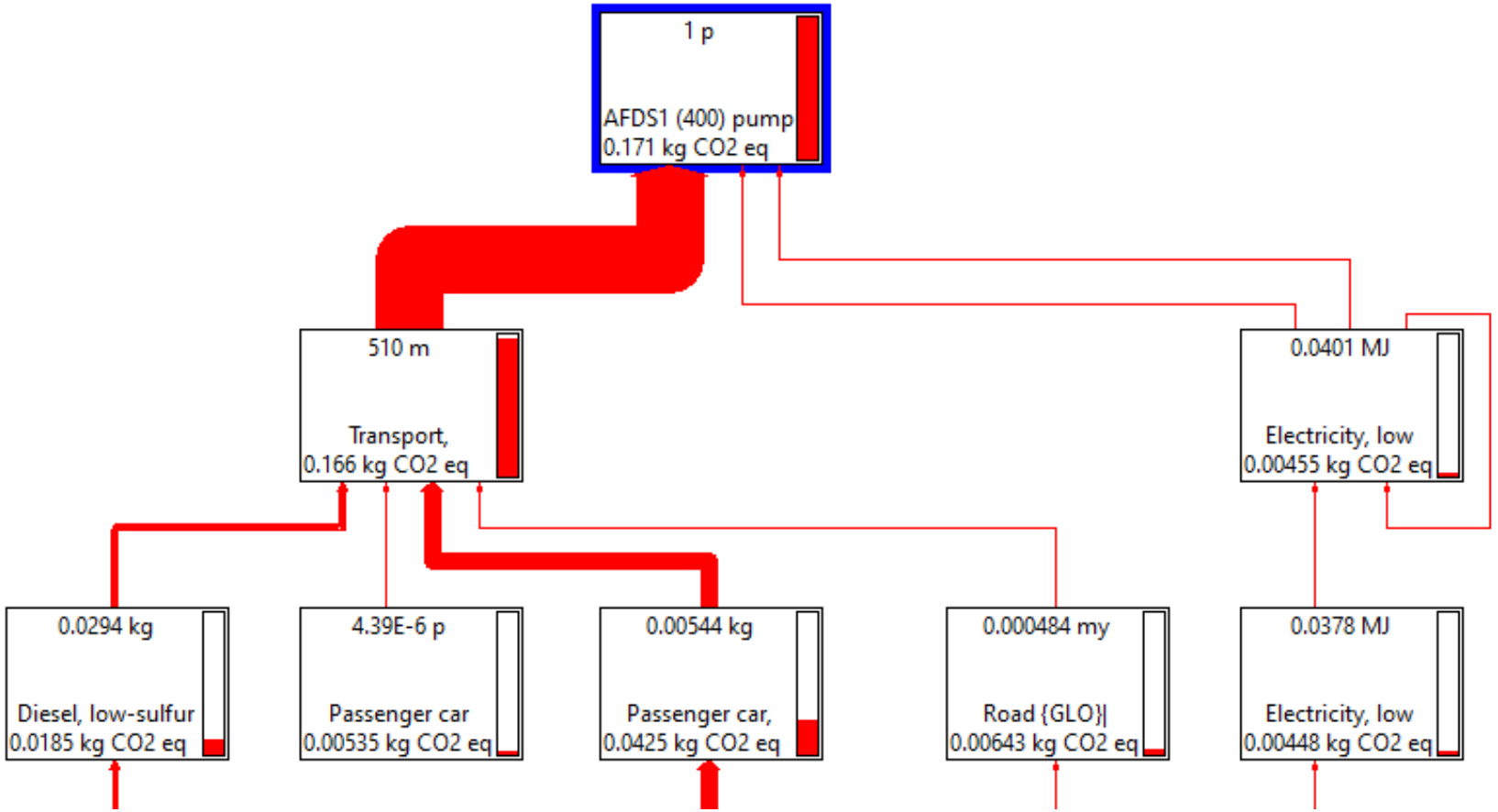
Graph 3 Unitary emissions per surviving tree using IPCC 2013 GWP 20a V1.03 and Ecoinvent v3.7.1, considering initial infrastructure installation at La Finca El Pinillo under different water source and survival rate and reusing initial materials scenarios, without accounting for material reuse or water extraction/transport components

11.2 Impact Assessment of the operation and maintenance phase (1 year).

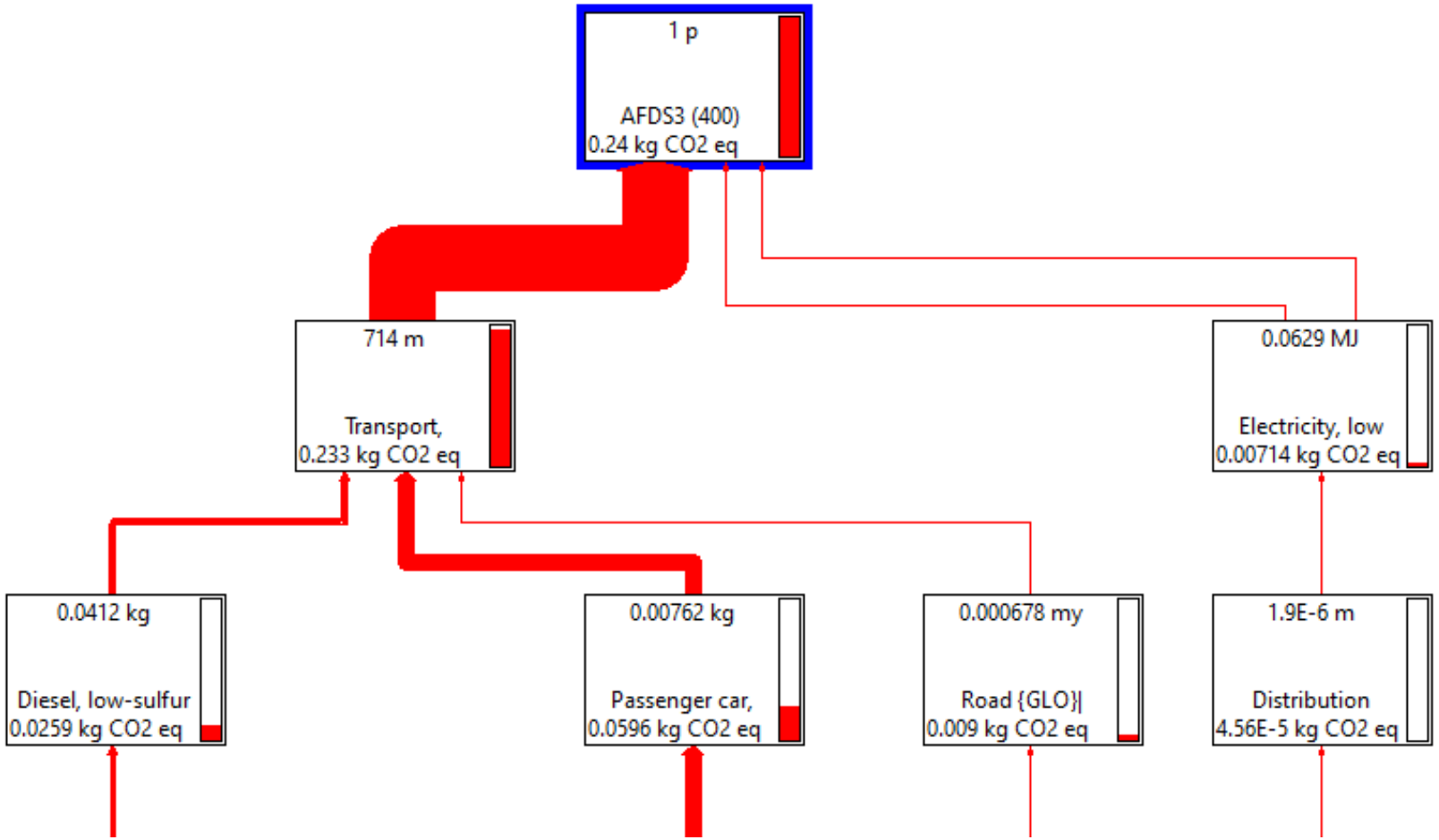
11.2.1 AFDS 2 supplied with 3 fog collectors with spring pump support in August.



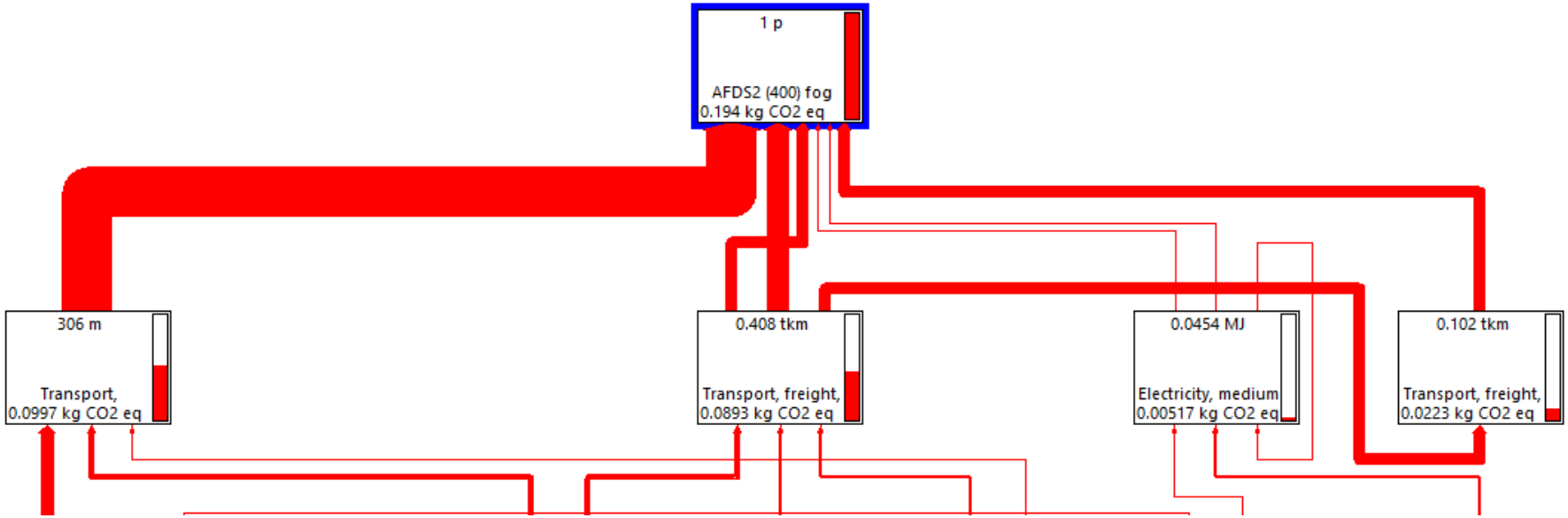
11.2.2 AFDS 1 supplied with pumped water from spring (July – Sep, irrigation regime)



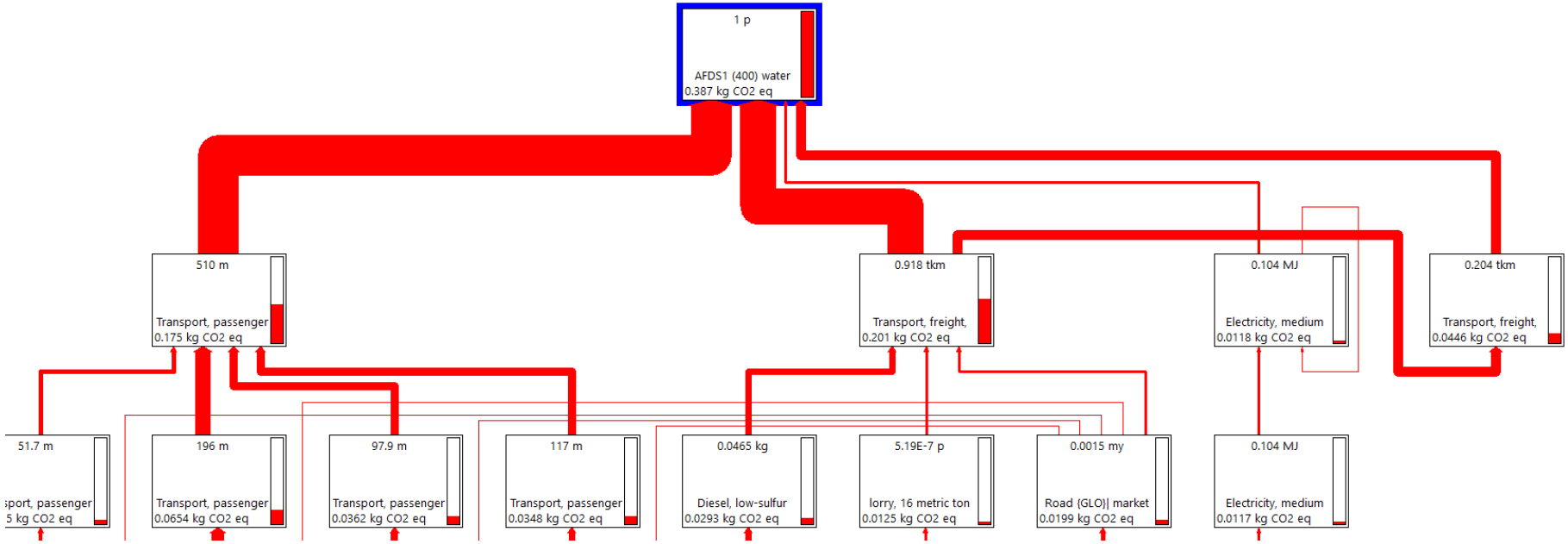
11.2.3 AFDS 3 supplied with pumped water from spring (May –Sep irrigation regime)



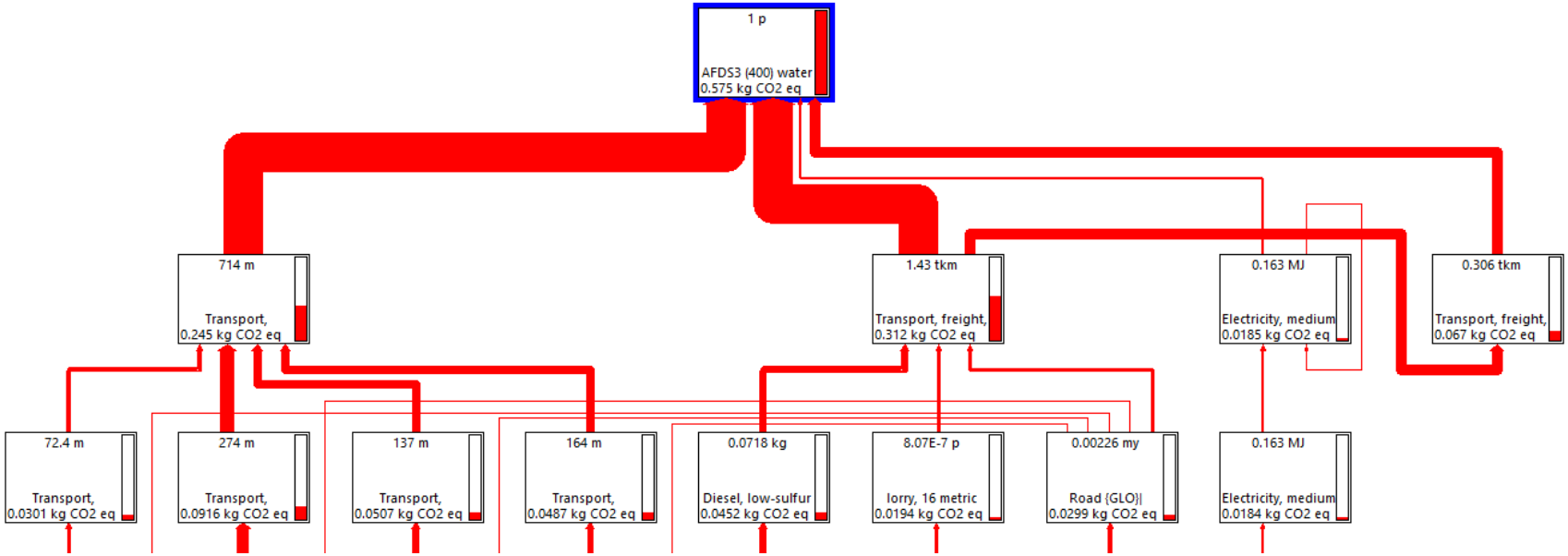
11.2.4 AFDS2 (400) fog collectors supply with water truck support In August.



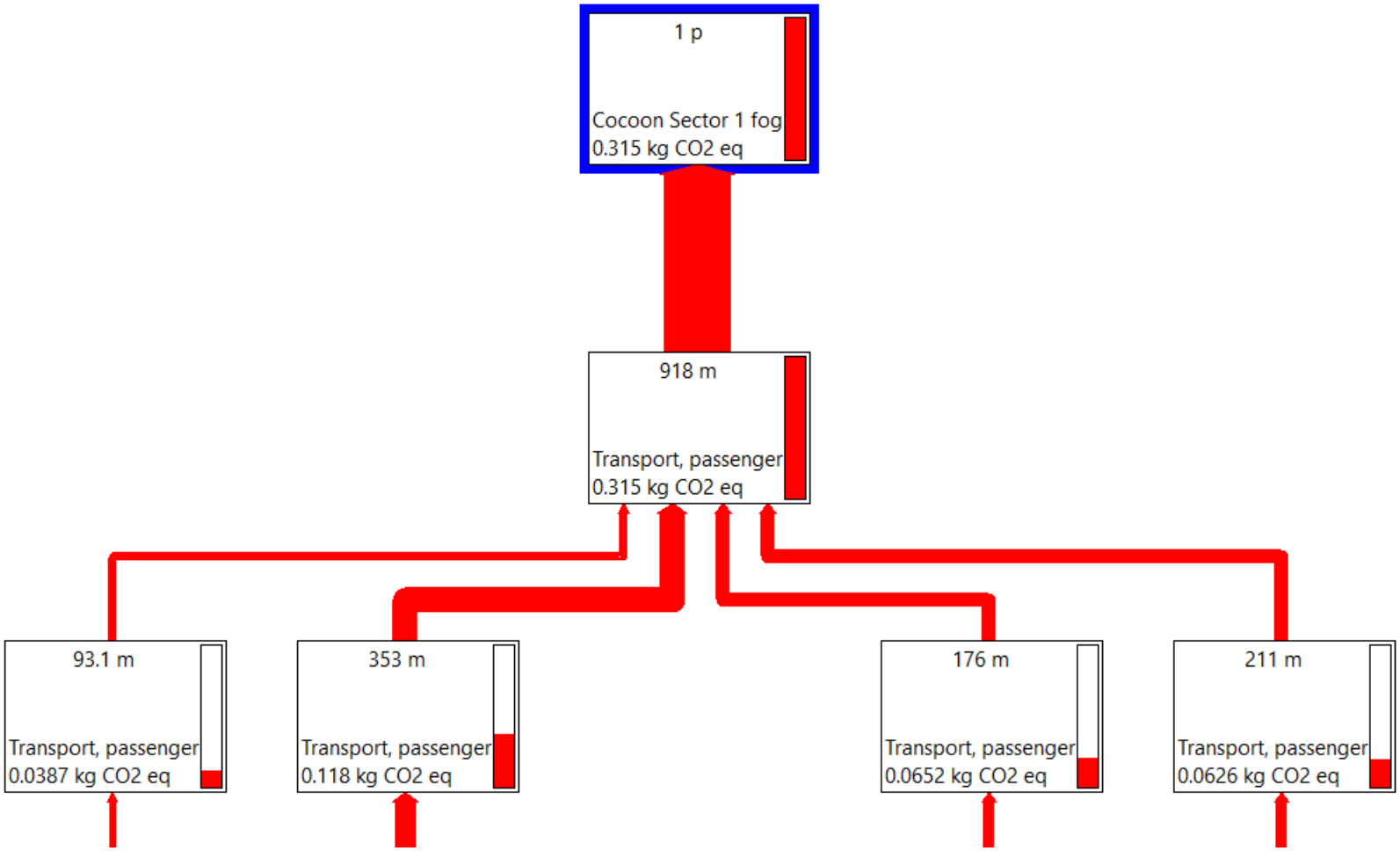
11.2.5 AFDS1 (400) water truck support (July – Sep, irrigation regime)



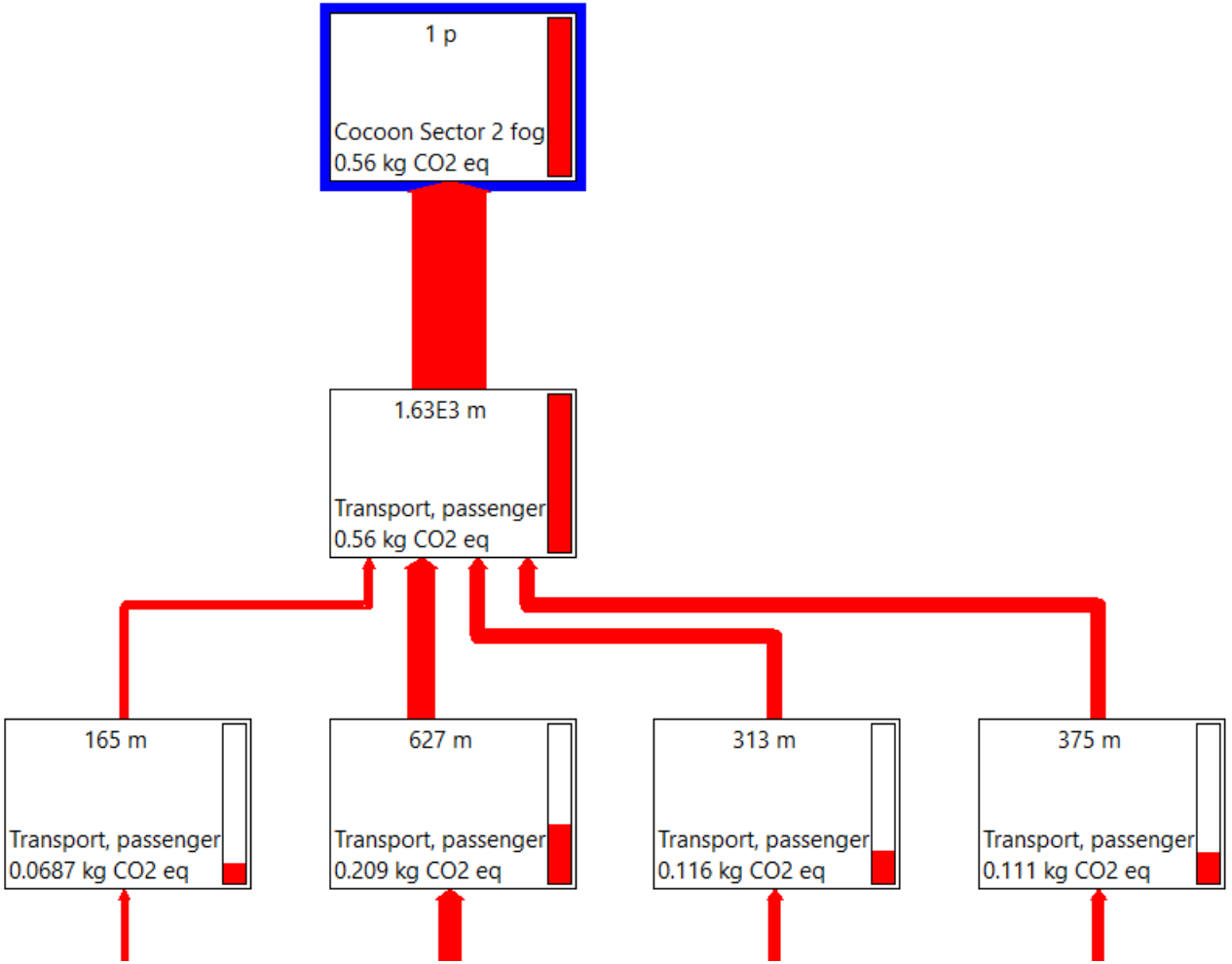
11.2.6 AFDS3 (400) water truck support (May – Sep, irrigation regime)



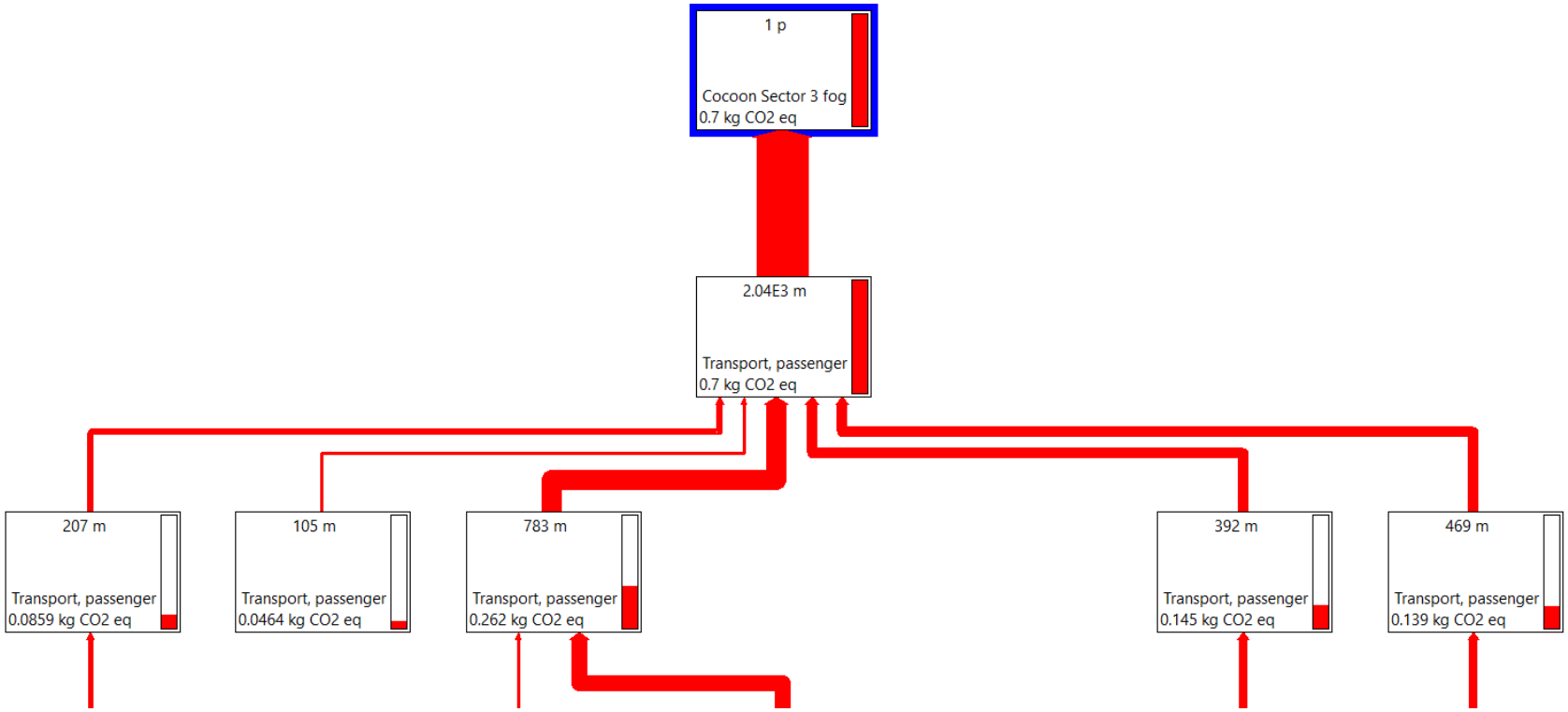
11.2.7 Cocoon Sector 1 fog collectors support



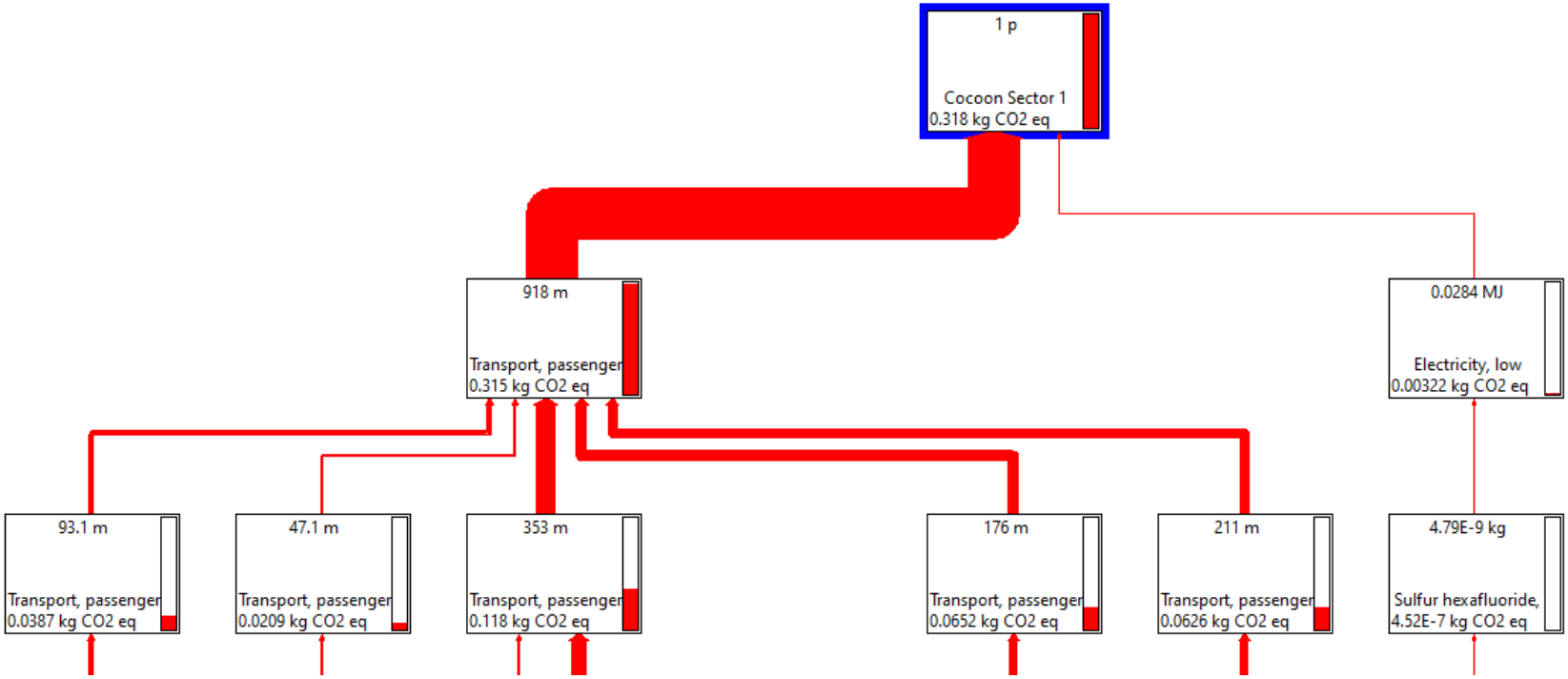
11.2.8 Cocoon Sector 2 fog support



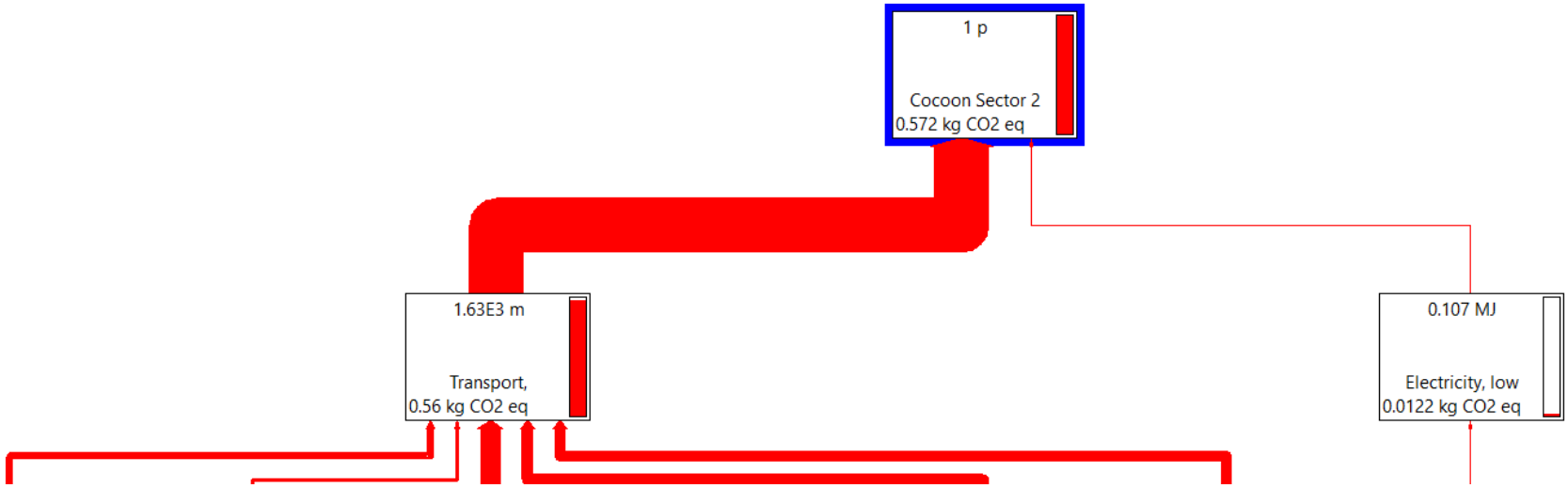
11.2.9 Cocoon Sector 3 fog support



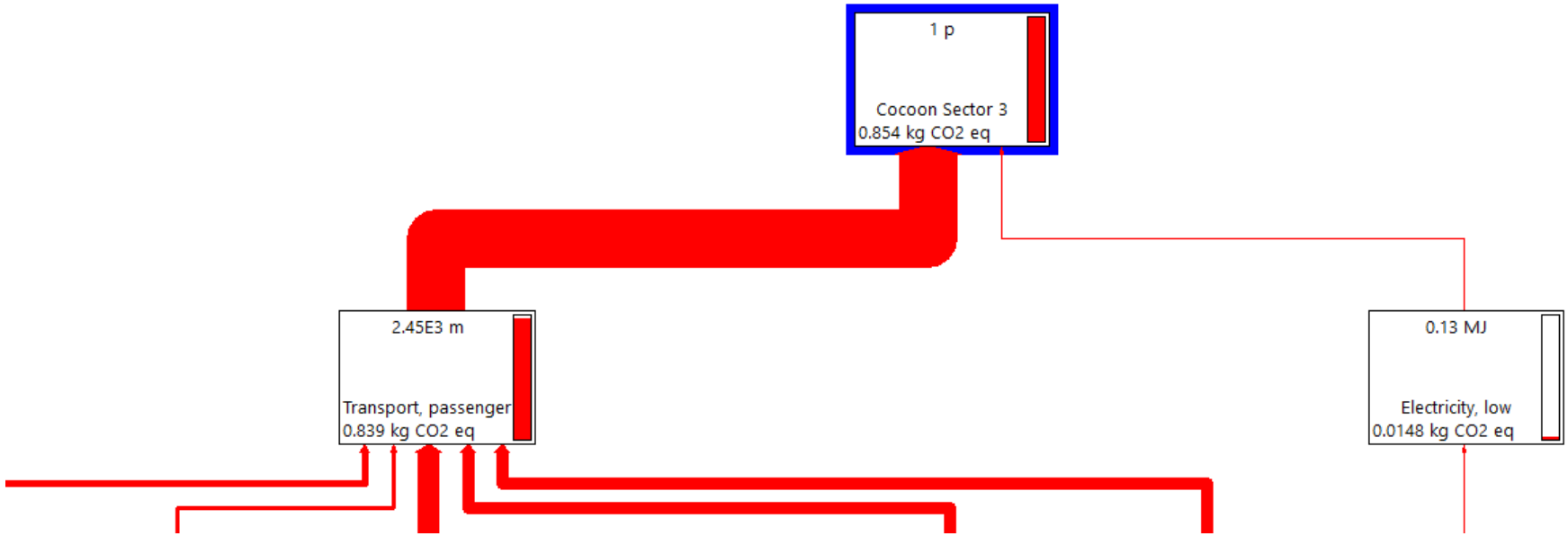
11.2.10 Cocoon Sector 1 pump support



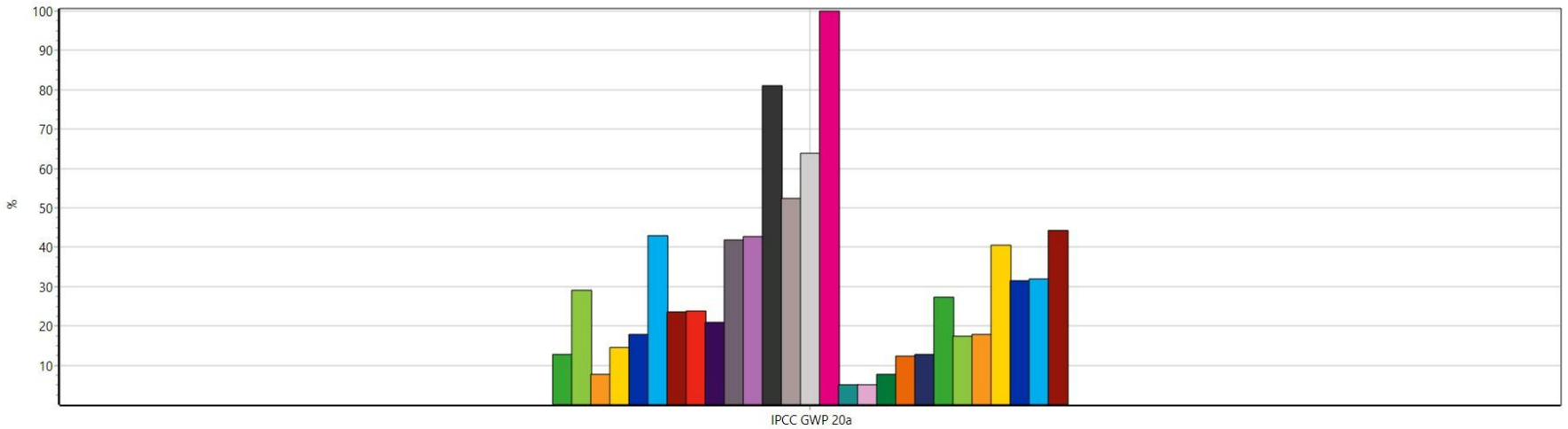
11.2.11 Cocoon Sector 2 pump support



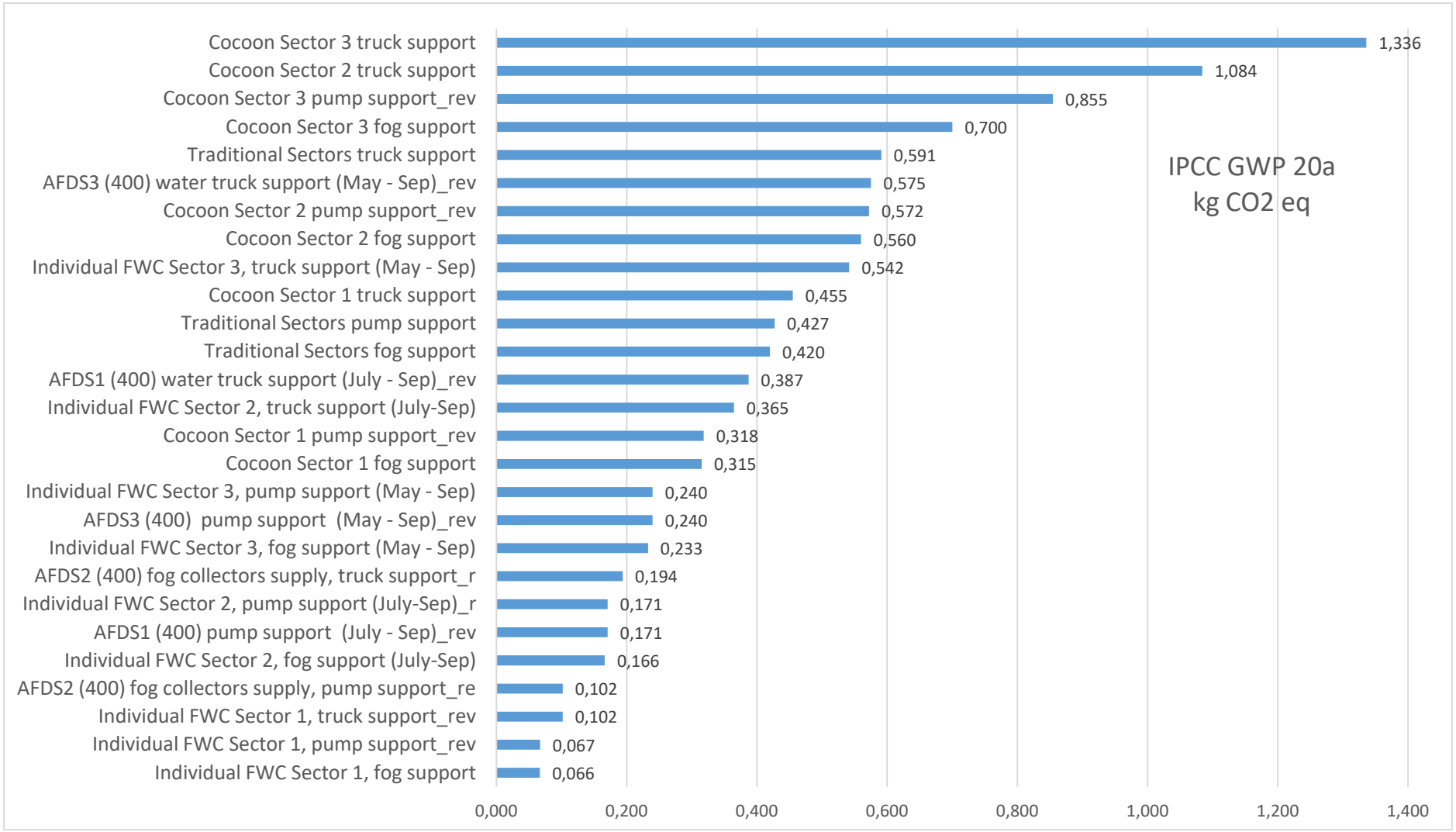
11.2.12 Cocoon Sector 3 pump support



11.2.13 Comparison between different systems and irrigation regimes



Graph 4 Percentage comparison of emissions considering one year of operation and maintenance at La Finca El Pinillo, under different irrigations regime and water source.



Graph 5 Unitary emissions per surviving tree considering one year of operation and maintenance at La Finca El Pinillo, under different irrigations regime and water source.

11.3 Relationships between initial assembly phase (without reusing materials) and operation phase (1 year).

Assembly phase

Impact category	IPCC GWP 20a kg CO2 eq
3_AFDS supplied with 3 fog collectors (400)	18.931
3_AFDS supplied with 3 fog collectors (500)	15.145
6_Cocoon supplied with tank and fog collectors	13.725
9_Traditional irrigation with fog collectors	12.232
Individual Fog Collector	7.483
2_AFDS with pumped water from spring (1200)	5.046
1_AFDS supplied with water tank truck	3.798
5_Cocoon supplied with pumped water from spring	2.851
4_Cocoons supplied with water tank truck	1.522
8_Traditional irrigation with spring pump	1.192
7_Traditional irrigation with water tank truck	0.409

Exploration and maintenance phase

Impact category	IPCC GWP 20a kg CO2 eq
Cocoon Sector 3 truck support	1.336
Cocoon Sector 2 truck support	1.084
Cocoon Sector 3 pump support_rev	0.855
Cocoon Sector 3 fog support	0.700
Traditional Sectors truck support	0.591
AFDS3 (400) water truck support (May - Sep)_rev	0.575
Cocoon Sector 2 pump support_rev	0.572
Cocoon Sector 2 fog support	0.560
Individual FWC Sector 3, truck support (May - Sep)	0.542
Cocoon Sector 1 truck support	0.455
Traditional Sectors pump support	0.427
Traditional Sectors fog support	0.420
AFDS1 (400) water truck support (July - Sep)_rev	0.387
Individual FWC Sector 2, truck support (July-Sep)	0.365
Cocoon Sector 1 pump support_rev	0.318
Cocoon Sector 1 fog support	0.315
AFDS3 (400) pump support (May - Sep)_rev	0.240
Individual FWC Sector 3, pump support (May - Sep)	0.240
Individual FWC Sector 3, fog support (May - Sep)	0.233
AFDS2 (400) fog collectors supply, truck support_r	0.194
AFDS1 (400) pump support (July - Sep)_rev	0.171
Individual FWC Sector 2, pump support (July-Sep)_r	0.171
Individual FWC Sector 2, fog support (July-Sep)	0.166
AFDS2 (400) fog collectors supply, pump support_re	0.102
Individual FWC Sector 1, truck support_rev	0.102
Individual FWC Sector 1, pump support_rev	0.067
Individual FWC Sector 1, fog support	0.066

Based on the previous tables and graphs, the conclusion is confirmed that systems with a higher initial investment in local water collection and automated irrigation generate the lowest emissions during the operational and maintenance phases. In this regard, the IFWC and AFDS systems stand out, particularly when supplied exclusively with fog or rainwater collected through TFWC units. However, in these cases, the survival of the reforestation will be highly dependent on meteorological conditions during the operational years.

Nevertheless, the LIFE NIEBLAS experience has demonstrated that even in particularly dry years (2023 and 2024), IFWC and AFDS systems associated with TFWCs have achieved survival rates exceeding 80%. Additionally, these systems have been shown to be reusable at least once, significantly reducing emissions per functional unit of initial implementation, as their operational emissions are very low.

12. Global contribution to climate objectives

One of the Indicators related to the "LIFE Key project level indicators Call 2019" is the reduction of CO_2 green house gas emissions per year.

There are two Indicators related to climate objectives and CO_2 emissions expressed in Table 25. The LCA analysis helps to compare different options of reforestation and take into account all the items, not only the ones proposed in the project.

Indicators	Estimated Impact (absolute values)
CO_2 emissions annual reduction comparison between the water captured with fog collectors respect to its obtention from water wells and its transport by road to the field	254.33 tons of CO_2
CO_2 emissions annual reduction comparison between the water captured with fog collectors respect to its transportation by road to the field	100 tons of CO_2

Table 25 LIFE NIEBLAS project indicators related to climate objectives and CO_2 emissions

For the first period of the project (April 2021 - February 2023) the water collected by fog water collectors were **86,500 litres**. With this frame we can calculate the CO_2 with different scenario.

As was explained in point Exploration and maintenance phase.carry out the analysis and it has been necessary to investigate and know different details of the activities carried out.

The necessary data would be:

- The consumption of the tank truck that supplies the tanks when the water is brought from the outside.
- The energy consumption required to pump water from a medium-deep well in the area for subsequent transport by tanker truck.

The conditions used were that the well is 150 or 300 meters deep (average in Gran Canaria) and the transportation is by water tank truck for approximately 20.4 kilometres.

The reference data used to assess the impact of the transport of water are as follows:

- Travel distance: 25km (Well in Arucas – Finca el Pinillo - Valleseco) = 50 km daily (round trip).
- Well water pumping, the following conditions are taken into consideration:

- Q=10l/s =32 m^3/h
- Well deep =150 – 300 meters
- Power pump = 26 kW
- In this scenario to pump each 1,000 litres is needed 0.78 – 1.56 kWh

Also, if it is considered we can take into account the visits to the area with the operators to receive the water tank truck. The reference processes used in the Ecoinvent database are expressed in the Table 20.

To asses this case the **SimaPro version 9.1.1** is used, with the **Ecoinvent v3.7.1** database. And the methodology used for the calculation of the carbon footprint has been the **IPCC 2013 GWP 20a V1.03**., which was developed by the Intergovernmental Panel on Climate Change. It contains the climate change factors of IPCC with a timeframe of 20 years. According with we create different scenario to calculate the CO_2 emissions saved: 150 and 300 meters deep of the well, transport from the well and transport from a water body.

Name	Status	Comment
Global estimated saved water by fog Feb23_300	None	

Assembly	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
	0		Undefined				

Processes	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
Transport, passenger car, EURO 4 {RER}| transport, passe	0	km	Undefined				Not considered
Transport, freight, lorry 7.5-16 metric ton, euro4 {RoW}|	(86.5*25) = 2.16E3	tkm					86,500 litres collected by fog water collectors (TFWC+i-FWC+V-FWC) till February 2023 and not transported to El Pinillo (25 kms)
Electricity, medium voltage {ES}| market for | Cut-off, U	1.56*86.5 = 135	kWh					86,500 collected by fog water collectors (TFWC+i-FWC+V-FWC) till February 2023 and not pumped from a well 300 meters deep
Transport, freight, lorry 7.5-16 metric ton, euro4 {RER}| r	(10*20.4) = 204	tkm					10 empty return journey

Table 26 Scenario used to calculate CO_2 emissions reduction comparison between water collected by fog water collectors (86.5 m3) in respect to obtaining water through wells (300 meters deep) and its transport by road to the field.

In the case described in Table 26 the results are as follows:

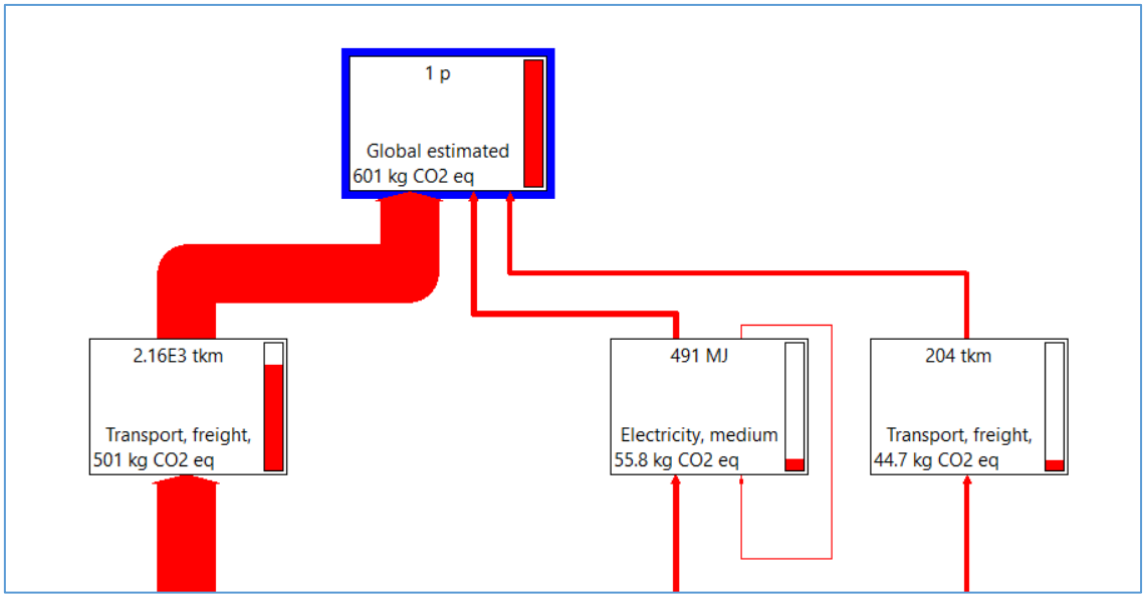


Figure 10 CO_2 emissions reduction comparison between water collected by fog water collectors (86.5 m3) in respect to obtaining water through wells (300 meters deep) and its transport by road to the field.

With these data the results till February 2023 the results (Table 27) are far from estimated.

Indicators	CO_2 emissions reduction from April 2021 till February 2023
CO_2 emissions reduction comparison between water collected by fog water collectors (86.5 m^3) in respect to obtaining water through wells and its transport by road to the field	601 kg of CO_2
CO_2 emissions annual reduction comparison between the water captured with fog collectors respect to its transportation by road to the field (without well pumping)	545.2 kg of CO_2

Table 27 LIFE NIEBLAS project indicators related to climate objectives and CO2 emissions with 86.5 m^3 fog water collected and using LCA method.

In fact, during this first period of the project more emissions have been saved, since all the water that has not been collected from mist has been pumped from the spring located in the area. To calculate this we evaluate the savings regarding using the spring water.

Name	Status	Comment					
Global savings for use spring water till Feb23	None						
Assembly	**Amount**	**Unit**	**Distribution**	**SD2 or 2SD**	**Min**	**Max**	**Comment**
	0		Undefined				
Processes	**Amount**	**Unit**	**Distribution**	**SD2 or 2SD**	**Min**	**Max**	**Comment**
Transport, passenger car, EURO 4 {RER}| transport, passe	0	km	Undefined				Not considered
Transport, freight, lorry 7.5-16 metric ton, euro4 {RoW}|	(303.5*25) = 7.59E3	tkm					303,500 litres collected by spring and pumped till February 2023 and not transported to El Pinillo (25 kms)
Electricity, medium voltage {ES}| market for | Cut-off, U	1.56*303.5 = 473	kWh					303,500 collected by spring and pumped till February 2023 and not pumped from a 300 meters deep well
Transport, freight, lorry 7.5-16 metric ton, euro4 {RER}| t	(38*20.4) = 775	tkm					38 empty return journey

Table 28 Scenario used to calculate CO_2 emissions reduction comparison between water collected by spring (303 m^3) in respect to obtaining water through wells (300 meters deep) and its transport by road to the field.

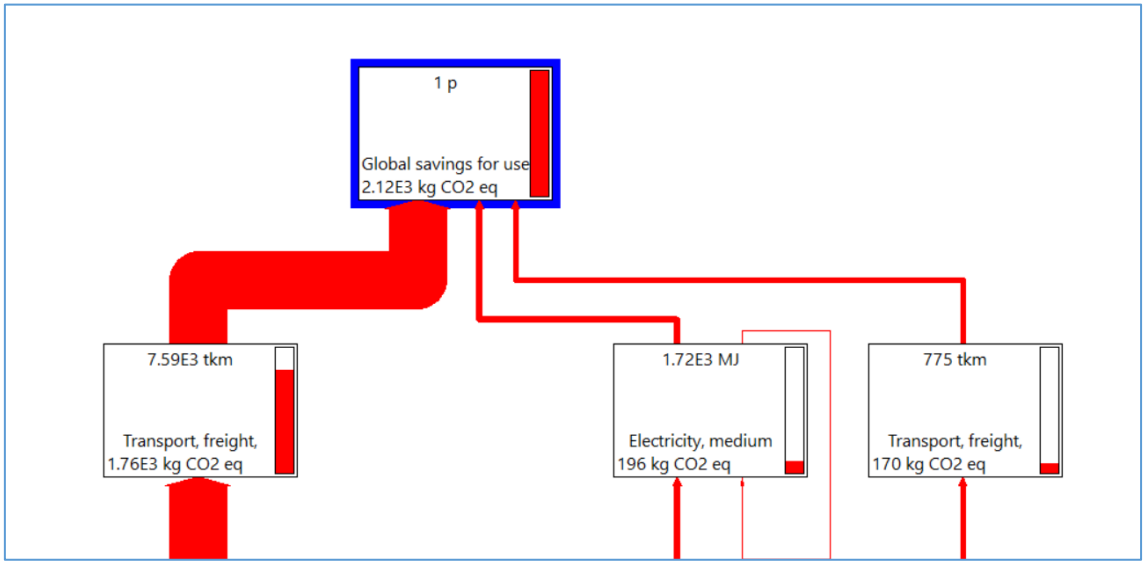


Figure 11 CO_2 emissions reduction comparison between water collected form the spring and pumped (303.5 m^3, 50 meters) in respect to obtaining water through wells (300 meters deep) and its transport by road to the field.

In Table 29 we can see the real savings in CO_2 emissions.

Indicators	CO_2 emissions reduction till February 2023
CO_2 emissions reduction comparison between	601 kg + 2,120 kg – 38.8 kg[9]=

[9] Emissions for pumping from the spring to the resevatoirs.

water collected by fog water collectors (86.5 m^3) and by local spring (303.5 m^3) respect to obtaining water through wells and its transport by road to the field	**2,682.8 kg of CO_2**
CO_2 emissions annual reduction comparison between the water captured with fog collectors and by local spring respect to its transportation by road to the field (without well pumping)	545.2 kg +1,760 kg – 38.8 kg = **2,266.4 kg of CO_2**

Table 29 LIFE NIEBLAS project indicators related to climate objectives and CO2 emissions with 86.5 m^3 fog water collected and 303.5 m^3 spring water, using LCA method.

We also can calculate the emissions reduction with more simple methodologies, for example, with emissions factors and calculating the fuel consumption of the water tank trucks and for production electricity in Gran Canaria.

Typically, under normal heavy truck operation, such a vehicle would achieve a fuel consumption of **30 liters/100km**. We can estimate 8 tons of water transported in each journey. The emission factor differentiated by type of fuel. From 2019 onwards, petrol and diesel fuels are referred to by letters E and B respectively, adding the proportion of biofuel they contain (RD 639/2016). For example (7% biodiesel): **B7 (kgCO_2/liter): 2.467**

To obtain the emission factor associated with electricity consumption we can consult the reports published by Red Eléctrica de España for Canary Islands (https://www.ree.es/es/generacion/no-renewable-detalle-emisions-CO2), as well as the percentage of renewable energy in the electricity mix without emissions. In Table 30 we can see the emissions for 2022 I Canary Islands.

Sources of generation with emissions	**Tons CO_2 equivalents (2022)**
Diesel engines	1.193.564
Gas turbine	292.321
Steam turbine	1.094.300
Combined cycle	2.154.006
tCO_2 eq./MWh	**0,55**

Table 30 CO_2 EMISSIONS AND EMISSION FACTOR (tCO_2 eq./MWh) | Electrical system: Canary Islands (2022).

That year the percentage for renewable energies was 20%. The final emissions factor applicable would be **0.44 kg CO_2 eq./kWh**.

In Table 31 we can see the savings in CO_2 emissions calculated with this method.

Indicators	**CO_2 emissions reduction till February 2023**
CO_2 emissions reduction comparison between water collected by fog water collectors (86.5 m^3) and by local spring (303.5 m^3) respect to obtaining water through wells and its transport by road to the field	Transport by road: 50 km/journey * (30 litres fuel/100 km)*(9 +38) journey * 2.467 kgCO_2/litre 333 kg of CO_2 (saved by fog water collectors) 1,406 kg of CO_2 (saved by local spring) Well pumping: 135 kWh (59.4 kg CO_2 eq saved by fog water collectors) 473 kWh – 91kWh = 382 kWh (168 kg CO_2 eq saved by local spring) 517 kWh*0.44 kg CO_2 eq./kWh 227.5 kg CO_2 eq

	Total emissions reduced: **1,966.5 kg CO_2 eq**
CO_2 emissions annual reduction comparison between the water captured with fog collectors and by local spring respect to its transportation by road to the field (without well pumping)	**1,739 kg of CO_2**

Table 31 LIFE NIEBLAS project indicators related to climate objectives and CO_2 emissions calculated with emission factor method.

The differences in the results from the two methods are not relevant and consistent, taking into account that the LCA method takes into account aspects that are not taken into account by the emission factor method.

With this data, we believe that the estimated value of emissions reduction per year, in the project sheet had some error of calculation. For example, to emit 254.33 tons of CO_2 we have pump form a well and transport by road more than 46.000 m^3 of water per year when the real necessities are around 400 m^3/year (100 times less).

In practice, during the project (April 2021 - December 2024) the water collected by all fog water collectors were **128,260 litres** and used form the spring were **584,423 litres**.

In Table 32 we can see the total savings in CO_2 emissions.

Indicators	CO_2 emissions reduction till December 2024
CO_2 emissions reduction comparison between water collected by fog water collectors (128.26 m^3) and by local spring (584.42 m^3) respect to obtaining water through wells and its transport by road to the field	**4,900 kg of CO_2**
CO_2 emissions annual reduction comparison between the water captured with fog collectors and by local spring respect to its transportation by road to the field (without well pumping)	**3,387.5 kg of CO_2**

Table 32 LIFE NIEBLAS project indicators related to climate objectives and CO_2 emissions using LCA method.

13. Conclusions of the study

After the analysis of the data, some conclusions of the study can be established.

- The use of metal materials (galvanized steel, iron bars, etc.) in the construction of the elements that constitute the fog collection and the irrigation systems represents a significant increase in the equivalent CO_2 emissions associated with the life cycle of the installations. → This can be improved by using alternative materials. For example, in the replication on Brava Island (Cape Verde), wooden stakes were used to support the IFWC.
- As systems incorporate more elements to ensure their autonomy from operation and maintenance, equivalent emissions are higher at the first assembly stage. → As the initial installations are used in new reforestations, the impact of these emissions per functional unit (surviving tree) decreases. Therefore, it is important to assess this aspect in the long term and maximize the reuse of initial materials.
- The system with the highest equivalent emissions per tree planted is the one that incorporates 3 FWCT, a 5,000 liter tank, an AFDS and a drip irrigation network for 500 trees (15 kg CO_2 equivalent/tree). In this case, 77.4% of the emissions are due to fog

collectors, 18.4% to AFDS and irrigation network, and 2.5% to interconnection pipelines between the fog water collection area and the reservoir for AFDS. This deposit accounts for 1.6% of emissions. On the contrary, this same system in the operation and maintenance phase is the one with the least associated emissions. Considering a survival rate of 80%, emissions would be 0.1 kg of equiv/surviving tree CO_2, taking into account that an emergency irrigation is carried out in August (in this case with water pumped from the spring). → Clearly, the TFWCs will be used in the long term to produce water and continue promoting reforestation. Likewise, it has been demonstrated that the AFDS and the irrigation network can be dismantled and reused in new areas. Therefore, these systems must be designed with a long-term vision, distributing the emissions from the initial installation over the entire lifespan of the equipment rather than only considering their first use for reforestation. In this regard, a promising application of this configuration is the development of permanent irrigation systems in remote areas, as they will help reduce emissions in the long run.

- The system that incorporates less emissions in the assembly phase is the traditional irrigation system that will later be irrigated in the exploitation phase by transporting water tanks from the outside (0.4 kg CO_2 equv/tree). It requires the installation of minimal infrastructure in the field, basically water storage tank and hoses. On the contrary, it would be one of the systems that would generate more emissions in the exploitation phase, depending on the irrigation system, with about 0.6 kg of equiv/tree CO_2. → In practice, this shows that the traditional system can generate up to six times more emissions during the operational phase compared to systems that require more initial infrastructure. As mentioned, the final decision on which model to follow depends on the long-term reuse of the initial installations.
- The system with the highest emissions associated in the operation and maintenance phase is the Cocoon system in sector 3 with Cocoon fillers from May to September, and with water transport from the outside 1.3 kg of equiv/tree CO_2. This is because it is the system that requires the most water transported and more visits by operators to carry out irrigation.
- The system with the least emissions in the maintenance phase is associated with the IFWC and use of fog water as a support irrigation. → This system has also achieved the highest survival rates; however, it is highly dependent on the specific meteorological conditions of the site. The most significant conclusion is that, regardless of the use of other irrigation methods or supplementary water sources, this system should be implemented in all cases. Care must be taken to remove the mosquito screen mesh and stakes after a reasonable period, once the reforestation has been successfully established.
- More than 96 % of the emissions associated with traditional FWC correspond to the metal elements of which they are composed. In the case of IFWC, it accounts for 98% and 76% in the i-FWC. Any innovation involving replacing metallic materials with others will significantly reduce the installation's carbon footprint[10].

[10] It is worth highlighting the adaptation made by the NGO BiFlores in Cape Verde, on the island of Brava, which has replaced corrugated iron bars with wooden stakes, significantly reducing the carbon footprint of this system at the local level.

14. Annex: Ecoinvent v3.7.1 database references

14.1 Diesel {Europe without Switzerland}| market for | Cut-off, U

Inventory for the distribution of petroleum product to the final consumer (household, car, power plant, etc.) including all necessary transports.

[This dataset was already contained in the ecoinvent database version 2. It was not individually updated during the transfer to ecoinvent version 3. Life Cycle Impact Assessment results may still have changed, as they are affected by changes in the supply chain, i.e. in other datasets. This dataset was generated following the ecoinvent quality guidelines for version 2. It may have been subject to central changes described in the ecoinvent version 3 change report (http://www.ecoinvent.org/database/ecoinvent-version-3/reports-of-changes/), and the results of the central updates were reviewed extensively. The changes added e.g. consistent water flows and other information throughout the database. The documentation of this dataset can be found in the ecoinvent reports of version 2, which are still available via the ecoinvent website. The change report linked above covers all central changes that were made during the conversion process.]

Production volume: 117973393408 kg

Included activities start:

Included activities end: Transportation of product from the refinery to the end user. Operation of storage tanks and petrol stations. Emissions from evaporation and treatment of effluents. Excluding emissions from car-washing at petrol stations.

Energy values: 0

Geography: The inventory is modelled for Europe without Switzerland

Technology level: 0

Technology: Distribution of petroleum products.

Start date: 01/01/1989

End date: 31/12/2020

Is data valid for entire period: True

Time period: Most information for the year 2000. Split up of NMVOC emissions published 1989.

Macro-economic scenario name: Business-as-Usual

Version: 92.3.0.0

Created: 7/28/2010 6:23:32 PM

Last edited: 3/14/2013 3:15:40 PM

Source: 423bf17b-7f05-4f38-b5b1-05318934b0a3_291fc06d-1b3e-4077-aabb-346b588ed24b.spold

UUID: 423bf17b-7f05-4f38-b5b1-05318934b0a3

14.2 Transport, passenger car, médium size, diésel, EURO 4

This dataset represents the service of transport in a passenger car for a journey length of 1vkm and is valid for Europe. Fuel consumption and emissions are for average vehicle use and not representative of a specific driving cycle. The dataset is parametrized with respect to vehicle size, fuel consumption and vehicle lifetime.

Production volume: 39659884544 km

Included activities start: From combustion of fuel in the engine. The dataset takes as input the infrastructure of the car and road network, the materials and efforts needed for maintenance of these and the fuel consumed in the vehicle for the journey.

Included activities end: The activity ends with the transport over 1vkm and the emissions of exhaust and non-exhaust emissions into air, water and soil.

The dataset includes the construction, operation, maintenance and disposal of the vehicle and road infrastructure. Operation of the vehicle includes all the direct emissions produced by fuel combustion and evaporation as well as from tyre, brake and road wear.

The dataset doesn't specifically model cold start emissions. These are assumed to be included in the data for average driving which was used.

Energy values: 0

Geography: The inventory is modelled for Europe

Technology level: 3

Technology: Transport in a passenger car with internal combustion engine, fueled by petrol. The size is large, with engine size above 2.0 litres and weight of approximately 2000 kg. ;Technology classifications are based on those used widely within the works of the European Environment Agency, particularly in the Emissions Inventory Guidebook. The Tremove model - which is also used to generate fuel consumption and emission factors for the datasets presented here - follows this classification system.

Start date: 01/01/2012

End date: 31/12/2020

Is data valid for entire period: True

Time period:

Macro-economic scenario name: Business-as-Usual

Version: 4.3.0.0

Created: 3/26/2019 5:22:36 PM

Last edited: 3/26/2019 5:22:36 PM

Source: a5569d0a-1d99-4dd1-b0ac-5e77462aeaeb_58f087c9-c348-4c55-bdc4-9805b5a0239a.spold

UUID: a5569d0a-1d99-4dd1-b0ac-5e77462aeaeb

Reference: European Commission - Mobility and transport. (n.d.). Euro 5 and Euro 6 standards: reduction of pollutant emissions from light. Retrieved May 31, 2012, from http://ec.europa.eu/transport/index_en.htm: http://ec.europa.eu/transport/urban/vehicles/doc/legislation_guide_other.pdf

Datasets for three different passenger car categories are available in ecoinvent in view of size: small, medium and large.

The category “small” includes passenger cars with engine size up to 1.4 litres. The average weight of this category is estimated to be 1200 kg.

The category “medium” includes passenger cars with engine size between 1.4 and 2.0 litres. The average weight of this category is estimated to be 1600 kg.

The category “large” includes passenger cars with engine size larger than 2.0 litres. The average weight of this category is estimated to be 2000 kg.

The passenger car size influences the amount of both exhaust and non-exhaust emissions. The exhaust emissions caused by the burning of fuel are divided into two groups: fuel dependent emissions (dependent on fuel type and quantity) and Euro class dependent emissions which reflect the emission standards which the vehicle complies with. Three classes of Euro engine type are considered: Euro 3, Euro 4 and Euro 5. The higher the class (e.g. Euro 5), the lower the emissions and viceversa. The Euro engine regulation is set by the European Commission “in order to limit as much as possible the negative impact of road vehicles on the environment and health” (European Commission 2012). This dataset considers a large petrol passenger car of Euro 5 class. Also included within the direct exchanges to the environment are the fuel evaporation emissions from the fuel tank, relevant to petrol vehicles only.

None

Non-exhaust emissions are those resulting from tyre, brake and road wear. These emissions are considered as by-products.

None

14.3 Electricity, low voltage {ES}| market for | Cut-off, U

This dataset describes the electricity available on the low voltage level in {{location}} for year {{year}}. This is done by showing the transmission of 1kWh electricity at low voltage.

The shares of electricity technologies on this market are valid for the year 2017. They have been calculated by the data provider and don't necessarily correspond with the production volumes entered in the undefined datasets of the different electricity producers. The shares have been calculated based on statistics from 2017: IEA World Energy Statistics and Balances. OECD iLibrary, eISSN: 1683-4240, DOI: 10.1787/enestats-data-en and ENTSO-E: Physical Energy & Power Flows, https://www.entsoe.eu/data/power-stats/physical-flows/. Grid losses are based on data from 2017 (also IEA World Energy Statistics and Balances). Further information can be found in a report available on ecoQuery, section 'Files'.

location: Spain

Production volume: 138484645888 kWh

Included activities start: This activity starts from 1kWh of electricity fed into the low voltage transmission network.

Included activities end: This activity ends with the transport of 1 kWh of low voltage electricity in the transmission network over aerial lines and cables.

This dataset includes:

- electricity inputs produced in this country and from imports and transformed to low voltage

- the transmission network

- direct emissions to air (SF6 from the insulation gas in the high voltage level switchgear are allocated to the electricity demand on medium voltage).

- electricity losses during transmission

This dataset doesn't include

- electricity losses during transformation from high to medium voltage or medium to low, as these are included in the dataset for transformation

- leakage of insulation oil from cables and electro technical equipment (transformers, switchgear, circuit breakers) because this only happens in case of accidental release

- SF6 emissions during production and deconstruction of the switchgear, as these are accounted for in the transmission network dataset.

Energy values: 0

Geography: The inventory is modelled for Spain

Technology level: 3

Technology: Average technology used to transmit and distribute electricity. Includes underground and overhead lines, as well as air-, vacuum- and SF6-insulated high-to-medium voltage switching stations. Electricity production according to related technology datasets.

Start date: 01/01/2014

End date: 31/12/2020

Is data valid for entire period: True

Time period: The composition of this market is valid for the year 2014.

Macro-economic scenario name: Business-as-Usual

Version: 1.3.0.0

Created: 1/25/2021 5:17:49 PM

Last edited: 7/27/2015 10:49:34 AM

Source: 11ca08e1-515c-4119-b5b1-040e918da854_d69294d7-8d64-4915-a896-9996a014c410.spold

UUID: 11ca08e1-515c-4119-b5b1-040e918da854

year: 2014

14.4 Electricity, medium voltage {ES}| market for | Cut-off, U

This dataset describes the electricity available on the medium voltage level in {{location}} for year {{year}}. This is done by showing the transmission of 1kWh electricity at medium voltage.

Production volume: 210568888320 kWh

Included activities start: This activity starts from 1kWh of electricity fed into the medium voltage transmission network.

Included activities end: This activity ends with the transport of 1 kWh of medium voltage electricity in the transmission network over aerial lines and cables.

This dataset includes:

- electricity inputs produced in this country and from imports and transformed to medium voltage

- the transmission network

- direct emissions to air (SF6 from the insulation gas in the high voltage level switchgear are allocated to the electricity demand on medium voltage).

- electricity losses during transmission

This dataset doesn't include

- electricity losses during transformation from high to medium voltage or medium to low, as these are included in the dataset for transformation

- leakage of insulation oil from cables and electro technical equipment (transformers, switchgear, circuit breakers) because this only happens in case of accidental release

- SF6 emissions during production and deconstruction of the switchgear, as these are accounted for in the transmission network dataset.

Energy values: 0

Geography: The inventory is modelled for Spain

Technology level: 3

Technology: - Medium voltage level between 1 kV and 24 kV (medium to small scale industry, service sector;and public buildings); - High voltage level above 24 kV (large scale industry);Definition of the voltage levels: ;Average technology used to transmit and distribute

electricity. Includes underground and overhead lines, as well as air-, vacuum- and SF6-insulated high-to-medium voltage switching stations. Electricity production according to related technology datasets. ; - Low voltage level below 1 kV (Households)

Start date: 01/01/2014

End date: 31/12/2020

Is data valid for entire period: True

Time period: The composition of this market is valid for the year 2014.

Macro-economic scenario name: Business-as-Usual

Version: 1.3.0.0

Created: 1/25/2021 5:17:49 PM

Last edited: 8/6/2015 12:19:17 PM

Source: 1d1651f5-1eac-4ccf-bf2d-e710f00420b9_759b89bd-3aa6-42ad-b767-5bb9ef5d331d.spold

UUID: 1d1651f5-1eac-4ccf-bf2d-e710f00420b9

The shares of electricity technologies on this market are valid for the year 2017. They have been calculated by the data provider and don't necessarily correspond with the production volumes entered in the undefined datasets of the different electricity producers. The shares have been calculated based on statistics from 2017: IEA World Energy Statistics and Balances. OECD iLibrary, eISSN: 1683-4240, DOI: 10.1787/enestats-data-en and ENTSO-E: Physical Energy & Power Flows, https://www.entsoe.eu/data/power-stats/physical-flows/. Grid losses are based on data from 2017 (also IEA World Energy Statistics and Balances). Further information can be found in a report available on ecoQuery, section 'Files'.

location: Spain

year: 2014

14.5 Transport, freight, lorry 7.5-16 metric ton, EURO4 {RER}| transport, freight, lorry 7.5-16 metric ton, EURO4 | Cut-off, U

This dataset represents the service of 1tkm freight transport in a lorry of the size class 7.5-16 metric tons gross vehicle weight (GVW) and Euro IV emissions class. The transport datasets refer to the entire transport life cycle i.e. to the construction, operation, maintenance and end of life of vehicle and road infrastructures. Fuel consumption and emissions are for average European journeys and load factors and not representative of a specific transport scenario. The average load factors are taken from the Tremove model v2.7b (2009) and EcoTransIT (2011) report. These are as follows:

Production volume: 15299999744 tkm

Included activities start: From combustion of fuel in the engine. The dataset takes as input the infrastructure of the lorry and road network, the materials and efforts needed for maintenance of these and the fuel consumed in the vehicle for the journey.

Included activities end: The activity ends with the transport service of 1tkm and the emissions of exhaust and non-exhaust emissions into air, water and soil.

Energy values: 0

Geography: The inventory is modelled for Europe

Technology level: 3

Technology: Diesel and diesel engine. Lorry transport is further differentiated with respect to vehicle weight and emission technology standard (EURO-standard). ;Technology classifications are based on those used widely within the works of the European Environment Agency, particularly in the Emissions Inventory Guidebook.

Start date: 01/01/2009

End date: 31/12/2020

Is data valid for entire period: True

Time period:

Macro-economic scenario name: Business-as-Usual

Version: 5.3.0.0

Created: 3/7/2019 3:48:19 PM

Last edited: 3/7/2019 3:48:19 PM

Source: 2354eae5-d496-4af6-a876-d22fc6a74630_639dba7b-1762-4e9a-a95c-f30380e65d53.spold

UUID: 2354eae5-d496-4af6-a876-d22fc6a74630

For road infrastructure the expenditures and environmental interventions due to construction of roads have been allocated based on the gross tonne kilometer performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometer performance. The same assumption on vehicle lifetime performance has been transferred from the ecoinvent v2 datasets of 540 000 km/vehicle. The production, maintenance and disposal of the vehicle are as reported in the ecoinvent (2007) report on transport services.

Main data sources:

De Ceuster, G., et al. (2009) TREMOVE: Final Report. Model code v2.7b, 2009. European Commission, Brussels.

Keller, M. et al. (2010) Handbook emission factors for road transport v3.1, HBEFA. INFRAS, Berne, CH.

Knörr, W. et al. (2011) Ecological Transport Information Tool for Worldwide Transports (EcoTransIT): Methodology and data update. Berlin, Hannover, Heidelberg, DE.

Ntziachristos, L., et al. (2013) EMEP/EEA air pollutant emissions inventory guidebook 2009: Exhaust emissions from road transport. European Environment Agency, Copenhagen, DK.

Spielmann, M., et al. (2007) Transport Services. ecoinvent report No. 14., Swiss Centre for Life Cycle Inventories, Dübendorf, CH.

Lorry size class	Average load factor	GVW
3.5-7.5t	0.98t	4.98t

7.5-16t	3.29t	9.29t
16-32t	5.79t	15.79t
>32t	15.96t	29.96t

The lorry size and load factor determines the GVW and therefore also the fuel consumption and amount of both exhaust and non-exhaust emissions. Non-exhaust emissions are those resulting from tyre, brake and road wear.

Fuel consumption and exhaust emissions are taken from v3.1 of the HBEFA model, using the data for Germany and without applying model weighting. There are a higher number of size categories used in HBEFA than in ecoinvent and so the data are grouped in order to fit the lorry size classes used in ecoinvent. The selective catalytic reduction (SCR) technology is around 3 times more common than that of exhaust gas recovery (EGR) as an emissions reduction measure and so the emission factors given in the dataset are weighted to reflect this. The data for the HBEFA categories SCR* and VI* were disregarded. The exhaust emissions caused by the burning of fuel are either fuel dependent (fuel type and quantity) or Euro class dependent. The latter reflect the emission regulations to which the vehicle complies. Regulated emissions are CO, NOx, particulate matter (PM) and total hydrocarbons (HC). Data from the Emissions Inventory Guidebook (EMEP/EEA, 2013) were used for specific exhaust emissions not covered by the HBEFA model.

Non-exhaust emissions are accounted for as weight dependent by-products and exist as seperate datasets.

Method: IPCC 2013 GWP 20a V1.03

IPCC 2013 is the successor of the IPCC 2007 method, which was developed by the Intergovernmental Panel on Climate Change.

It contains the climate change factors of IPCC with a timeframe of 20 years.

Contact info: http://www.ipcc.ch/contact/contact.htm

IPCC characterisation factors for the direct (except CH4) global warming potential of air emissions. They are:

- not including indirect formation of dinitrogen monoxide from nitrogen emissions.

- not accounting for radiative forcing due to emissions of NOx, 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.

Normalization and weighting are not a part of this method.

Climate Change 2013. The Physical Science Basis. Working Group I contribution to the Fifth Assessment Report of the IPCC.

http://www.climatechange2013.org

Intergovernmental Panel on Climate Change (IPCC)

http://www.ipcc.ch/

Some remarks about the implementation by PRé Consultants

- The factor for biogenic methane was calculated by subtracting 2.75 kg of CO2 per kg of methane from the methane factors. The correction factor of 2.75 is the molar mass of CO2 divided by the molar mass of CH4.

- The factors for fossil methane in the IPCC report were not used. The factors for methane in IPCC also apply to fossil methane.

- 101 substances are new in IPCC 2013, but 8 of them were not added in SimaPro, because the substance name is unclear.

For further information see the database manual.

Other adaptations (October 2016, version 1.03):

- 7 new substances added: HG-02, HG-03; Ether, i-nonafluorobutane ethyl-, HFE569sf2 (i-HFE-7200); Ether, n-nonafluorobutane ethyl-, HFE569sf2 (n-HFE-7200); 1-Propanol, i-3,3,3-trifluoro-2,2-bis(trifluoromethyl)-, i-HFE-7100 and 1-Propanol, n-3,3,3-trifluoro-2,2-bis(trifluoromethyl)-, n-HFE-7100 and Carbon dioxide, to soil or biomass stock. The last one is included due to change in the way land tenure is modelled in Ecoinvent.

- The factor for Decane, 1,1,3,3,4,4,6,6,7,7,9,9,10,10,12,12-hexadecafluoro-2,5,8,11-tetraoxado- changed from 8270 to 9050 (there was a mistake in the previous version).

Other adaptations (March 2016, version 1.02):

- The characterization factors for 106 substances were aligned with the IPCC report. Previously, they were based on Hodnebrog et al. (2013)**.

- For substances, which in the IPCC report have a factor "<1", characterization factors from Hodnebrog et al. (2013) are applied.

- 5 substances from the IPCC report are not included in this implementation.

n-HFE-7100, i-HFE-7100, n-HFE-7200 and i-HFE-7200 - because including the mixtures of those isomers (HFE-449s1 (HFE-7100) and HFE-569sf2 (HFE-7200)) is considered sufficient.

HG-02 - because no corresponding substance is available in SimaPro.

- Added new substance: Decane, 1,1,...,15,15-eicosafluoro-2,5,8,11,14-Pentaoxapenta- This name is abbreviated, the full name is: Decane, 1,1,3,3,4,4,6,6,7,7,9,9,10,10,12,12,13,13,15,15-eicosafluoro-2,5,8,11,14-Pentaoxapenta-

- For "Methane", "Methane, biogenic" and "Methane, fossil" the factors from previous adaptation remain the same.

- Introduced changes have a minor impact on the results.

**Hodnebrog, Ø., M. Etminan, J. S. Fuglestvedt, G. Marston, G. Myhre, C. J. Nielsen, K. P. Shine, and T. J. Wallington (2013), Global warming potentials and radiative efficiencies of halocarbons and related compounds: A comprehensive review. Rev. Geophys., 51, 300-378, doi:10.1002/rog.20013. Spreadsheet: http://folk.uio.no/oivinho/halocarbonmetrics/

Other adaptations (June 2015, version 1.01):

- Corrected the characterization factors, according to Munoz and Schmidt (2016)*:

Methane, biogenic to 82.65 kg CO2eq/kg CH4 (84 + 1.4 for correction of methane degradation to carbon dioxide - 2.75 for correction of not characterized carbon dioxide uptake)

Methane, fossil and Methane to 85.4 kg CO2eq/kg CH4 (84 + 1.4 for correction of methane degradation to carbon dioxide)

- Added the characterization factor for Methane, land transformation (equal to the factor for Methane).

*Munoz, I. and Schmidt, J.H., 2016. Methane oxidation, biogenic carbon, and the IPCC's emission metrics. Proposal for a consistent greenhouse-gas accounting. The International Journal of Life Cycle Assessment, 21:1069-1075.

15. Authors:

Gilberto Manuel Martel Rodríguez - gmartel@itccanarias.org

Saul Oliva Cabrera - solicab@gesplan.es