BRITE GREENHOUSE

CO_2 FOOTPRINT STUDY

Table of Contents

1.0 CO_2 Footprint Study

In 2020, Tsantali Vineyards & Wineries and Brite Solar Nanomaterials Company initiated an innovative project in the field of sustainable agriculture. Specifically, an alternative greenhouse for vine cultivation was constructed and began operations in the facilities of Tsantali S.A. at Agios Pavlos, Chalkidiki, Greece. The main feature of this project is the installation of specially designed photovoltaic solar glass panels on the roof of the greenhouse, which not only provides a total degree of energy autonomy for the operation of the greenhouse but also contributes to setting the appropriate climatic conditions for the initiation of a second crop season within the same year. Additionally, the remaining energy is channelled and used for other purposes in the surrounding facilities of Tsantali S.A., providing in this way respectable environmental and economic savings. This sustainable feature makes this particular greenhouse one of the first in this category in Greece. Additionally, it allows the production of Tsantali's main raw material (wine grape) in a profitable and zero-emission fashion, by increasing the efficiency of agricultural operations and providing energy neutrality throughout the production line.

Carbon Footprint (kg CO_2e)	Carbon Footprint per kg of product (kg CO_2e/kg grape)	Carbon Footprint per greenhouse area (kg CO_2e/m^2 greenhouse)
-15779.66	**-15.78**	**-12.84**

Table 1: The carbon footprint of wine grape production in the greenhouse at a first glance

In full agreement with the policy of the two companies involved for the protection of the natural environment and the reduction of their impact on climate change, a carbon footprint study was carried out for calculating the greenhouse's carbon emissions that took place during the production of wine grapes in 2020. By employing the method of Life Cycle Analysis, which is the most appropriate method for measuring the environmental impacts along the supply chain and production lines of products and processes, the emissions of greenhouse gases that take place during the production of Tsantali wine grapes were quantified and measured.

More specifically, a total of 1000 kg of wine grapes were produced during one crop season. Also, at the beginning of the third semester of 2020, the Brite Solar photovoltaic installation began operations and provided a total of 24756 kWh of electricity during the same crop period. In order to calculate the carbon footprint of the production of these quantities of grapes and electricity, the total sum of production inputs was considered, including the infrastructure inputs for the construction of the greenhouse and manufacturing of the photovoltaic installation, in line with the instructions of the respective ISO standards which provide the standard techniques and methods for the realization of such studies.

The findings of the carbon footprint study are especially encouraging since the total carbon footprint for the production of the abovementioned quantity of greenhouse wine grapes was measured at an impressive -15780 kg CO_2e, which represents a negative emission and a very positive result, not only in comparison with respective global studies but also in the broader context. This emission quantity corresponds to -15.78 kg CO_2e/ kg wine grape or -12.84 kg CO_2e/ greenhouse m^2.

The two companies are completely committed to transparency of operations when it comes to environmental protection, between other matters. As a result, the GHG emissions that result from all operations are measured and presented in this report, even though they are completely offset by the production of solar electricity from the photovoltaic panel. In this context, the respective operational and productive processes of wine grape production and their contribution to the total carbon footprint were analyzed.

Additionally, carbon emissions that result from the infrastructure inputs were also measured and equally distributed along the functional life cycle of the greenhouse, the solar installation, and their respective building materials life cycles. It should be noted that the carbon emissions of the infrastructure category, along with the emissions that originate in the pellet combustion for heating purposes constitute almost 1164.87 kg CO_2e or 67.17% of the total carbon footprint of the production of wine grapes which equals 1733.92 kg CO_2e before considering the emission offsets provided by the Brite Solar system. The carbon emissions after the inclusion of the Brite Solar emission offsets are presented in Figure 1:

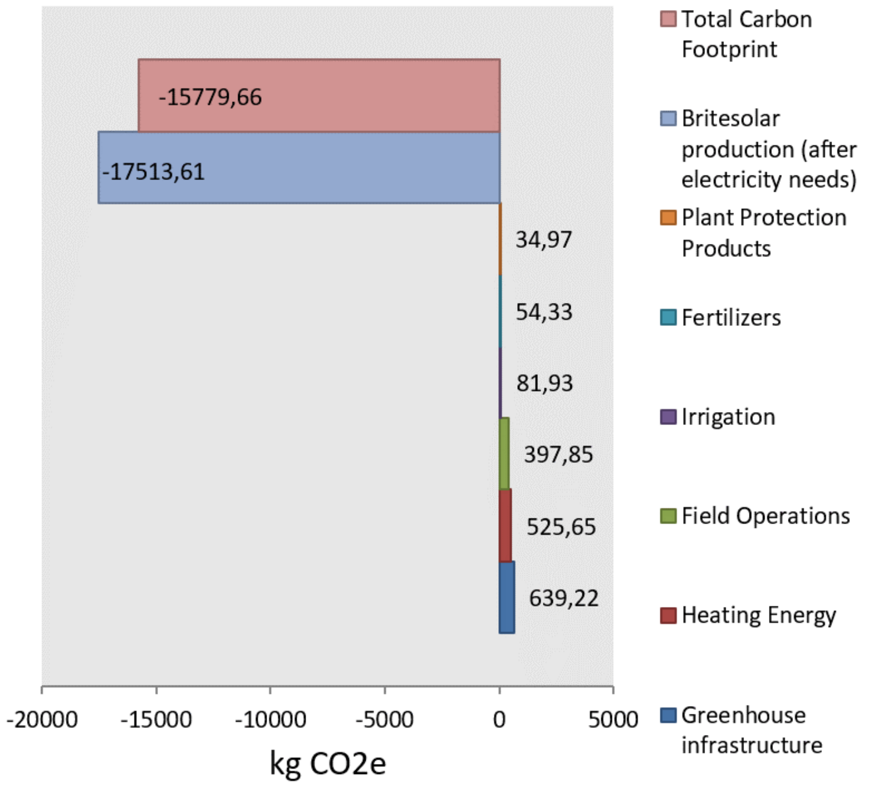

Figure 1: The carbon footprint of each major input category and total at a glance

As illustrated in Figure 1, the production of solar electricity from Brite Solar installation provides a total compensation of carbon emissions, by replacing fully the consumption of conventional grid electricity for covering the needs of the greenhouse operations, which were measured to be 6480 KWh for the timeframe of this study and saving in this way at least 6209 CO_2e on behalf of the greenhouse electricity needs. Additionally, since the electricity surplus is channelled in other purposes and facilities of Tsantali S.A., additional indirect savings of -17513.61 kg CO_2e come up as result, launching the total carbon savings to an eye-opening -23723.3 kg CO_2e.

The classification of carbon emissions in the three categories of GHG Protocol (Scope 1, 2 and 3) provide a clear picture regarding the origin and destination of the reported emissions. The GHG Protocol dictates the distribution of carbon emissions in these three categories, each one of which indicates a specific origin of the emissions spatially and in terms of the supply chain of the final product. In a brief manner, Scope 1 emissions include the emissions resulting from fuel use directly by the companies or from company-controlled resources, Scope 2 emissions include the emissions resulting indirectly by power purchase, while Scope 3 emissions include the rest of indirect emissions and belong in a wide spectrum of purposes and processes (Figure 2).

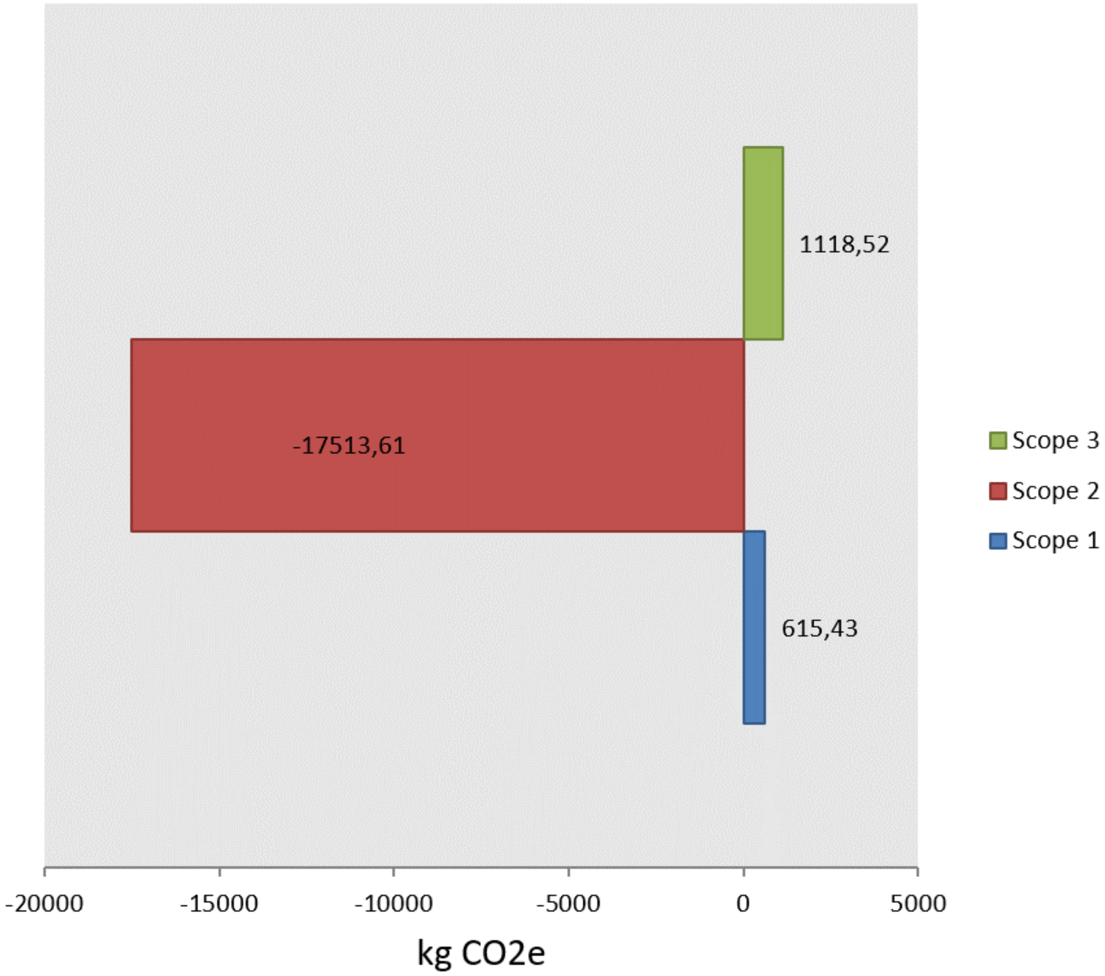

Figure 2: The carbon footprint of the three scope emission categories at a glance

As presented in Figure 2 and mentioned earlier, Scope 2 emissions are completely offset and on the negative spectrum, as the dominant electricity needs of the greenhouse mainly for ventilation (5400 KWh) and heating purposes (1080 KWh) are covered by the electricity provided by the Brite Solar PV installation. At the same time, the electricity surplus is transferred and exploited in other company facilities and replaces the consumption of the same amount of grid electricity from the Greek public power company, which still largely depends on conventional sources for this purpose. These circumstances create indirect carbon emission savings which reach the amount of -17513.61 kg CO_2e for the Scope 2 category. Therefore, all of the carbon emissions that take place during the production phase of grapes in the greenhouse belong in Scope 1 and Scope 3 emission categories.

More specifically, Scope 1 direct emissions constitute an amount of 615.43 kg CO_2e, and Scope 3 emissions equal to 1118.52 kg CO_2e. More information on the exact source of the emissions of each category is included in Section 4.

1.1 Introduction

Tsantali Vineyards & Wineries and Brite Solar Nanomaterials' company, as two of the most recognized and respected business entities of their respective fields, joined forces for the implementation of a pioneer project in the field of sustainable agriculture. This project includes the construction and operation of an alternative greenhouse reinforced with a specially designed photovoltaic installation in the vicinity of Agios Pavlos, Chalkidiki which hosts part of the facilities of Tsantali S.A. This special feature not only allows the production of green energy from solar sources but also contributes to the setting of appropriate climatic conditions for the initiation of a second crop season within the same year in the interior of the greenhouse. The combination of increased crop yields and efficiency of operations under fully sustainable and zero-carbon conditions create an innovative agricultural technique.

The main goal of this report is capturing the extent of carbon emissions that result from the necessary inputs and processes for the production of wine grape within the greenhouse premises. In order to carry out a valid measurement, the method of Life Cycle Analysis was employed. This method represents the most popular, trustworthy, and scientifically valid technique for the quantification and measurement of the environmental impacts of products and processes. As will be presented later in this report, this type of study is a holistic method that considers the total inputs and processes across the supply chain of products, starting from the mining phase of raw materials and ending at the final product.

For carrying out this study, a significant amount of real-life data was sourced from the databases of Tsantali S.A. and Brite Solar. Also, a large volume of scientific literature and ISO 14040 standards were employed, for the realization of an accurate and scientifically valid carbon footprint calculation.

This study results in a quantitative display of the carbon footprint of greenhouse grape production in Tsantali S.A. facilities. As mentioned earlier, the negative carbon emissions of -15.78 tons CO_2e

during the production of 1 ton of wine grapes illustrates the fully sustainable profile of this project, while the potential for further improvement is very real and promising.

In order to highlight the improvement potential, this report presents a series of possible improving scenarios which will potentially improve the already low carbon footprint of operations. Additionally, all carbon emissions were classified and presented according to the GHG protocol, in order to ensure the transparency of calculations and facilitate the tracing of “weak” spots carbon-wise in which the two involved companies could intervene for implementing improvement strategies.

The rest of this report starts with an analytic presentation of the employed methodology and techniques (Section 2-Methodology) and continues with the results of the carbon footprint study (Section 3-Carbon Footprint), the presentation of the environmental indicators (Section 4-Environmental Indicators) and the analysis of the improvement scenarios (Section 5-Proposed Policies and Scenarios). At the end of the report, two Appendix Sections are included: Appendix I includes the relative scientific literature, while Appendix II includes a complete list of the sourced data for the realization of this study.

1.2 Methodology

The carbon footprint calculation of wine grape production in the greenhouse facilities of Tsantali S.A. and Brite Solar was carried out by employing the Life Cycle Analysis method. Specifically, the standard research processes which must be followed for this purpose are defined by ISO standards 14040 and 14067, which in turn define a series of standard procedures, scientific protocols and environmental indicators that must be employed for the study to result in scientifically valid measurements. In this sense, ISO standards 14041, 14042 and 14043 were also considered, as they define the procedures for the collection of reliable data, the standard impact assessment methods and the necessary steps for the scientific valid interpretation of results.

A detailed presentation of the employed steps follows, starting from the goal and scope definition (Step I), and continuing with the definition of the system boundaries (Step II), the data collection procedure (Step III) and the impact assessment indicators for the calculation of the grape production carbon footprint (Step IV).

Step I: Goal and Scope Definition

The ISO 14040 standard defines the goal and scope definition of the analysis as the first step of such studies. The two involved companies were asked to define the purpose and the desired application of the study at this point. Firstly, a group of similar scientific and commercial studies were analyzed for mapping the usual purposes that lay behind such studies, in order to extract useful examples that facilitate the realization of this step. As was expected, a majority of life cycle analysis studies (Appendix I) focuses on tracing the most environmentally intensive operational and production processes (purpose of study) that result in final products, in order to intervene and improve their footprint (desired application).

At this step, it was also noticed that a common purpose behind similar life cycle analysis studies is the comparative analysis of different operational and production scenarios in an environmental impact context. These studies frequently take place in order to indicate the optimal improvement strategies for companies and industries that are committed to shifting to more environmentally friendly operational procedures.

Additionally, for the scope definition of this LCA (Life Cycle Assessment), the two companies in cooperation with the LCA researchers defined the exact procedure that would be placed under the microscope, along with its functional unit. This LCA study focuses on carbon emissions during the production of 1 kg of wine grape in the greenhouse facilities (functional unit). As it will be shown later in this report, the impact results are presented both per functional unit (Carbon Emissions per kg of wine grape) and per total amount of product (Carbon Emissions per 1000 kg of wine grape).

The goal and scope definition step is very important for the realization of an LCA study, as it lays the foundation for the successful implementation of the following LCA steps. After the implementation of the abovementioned actions, the involved companies defined the goal and scope of this LCA study, which is the calculation of the carbon footprint that takes place during the production of 1000 kg of wine grapes in the greenhouse facilities of Agios Pavlos, Chalkidiki, in order to trace environmentally weak-spots across the supply chain and apply improving strategies when possible. It should be highlighted that wine grapes are the main raw material for the production of Tsantali S.A. winery products.

As mentioned earlier, the results of this LCA study are displayed both per kg of product and per total amount of product. The employed carbon emission measurement unit is the quantity of CO_2 equals (kg CO_2e) that are emitted during the production of 1 kg of product (kg CO_2e/ 1 kg wine grape) or during the production of the total amount of grape produced during the timeframe of this study (kg CO_2e/ 1000 kg wine grape). An analytic presentation of this measurement unit is included in Step IV.

Step II: System Boundaries

At this second step of the LCA study, the system boundaries were defined. This procedure clarifies the relevant operational and production procedures that must be taken into consideration during the carbon footprint measurements. Three dominant types of system boundaries are defined in the employed ISO standards and the majority of the reviewed scientific studies. These types are presented in a greenhouse wine grape production context:

I. *Cradle-to-gate, C2G*: In this approach, the LCA study includes all operational and production processes, starting from the extraction of raw materials and ending at the greenhouse external gate. It includes all intermediate processes between these two points. Additionally, the relevant product of the study is the wine grape; the physical limitations of the study are the exit gate of the greenhouse and the functional unit is the amount of produced wine grapes.

II. *Cradle-to-bottle, C2B*: In this second approach, the LCA study includes all operational and production processes, starting from the extraction of raw materials and ending at the winery external gate. It includes all intermediate processes between these two points, including the greenhouse cultivation phase. Additionally, the relevant product of the study is the bottle of the product; the physical limitations of the study are the exit gate of the winery and the functional unit is the amount of produced product bottles.

III. *Cradle-to-grave, C2Gr*: In this last approach, all processes from the two abovementioned approaches are included, with the addition of the management of waste across the total production line and supply chain of raw materials. In this case, the functional unit of the LCA study could be both of production nature (grape or bottle) and waste nature (amounts of waste).

In Figure 3, the total group of operational and production processes and inputs/outputs that take place during the production of wine grapes and product bottles is illustrated. Dashed lines present the system boundaries of each one of the abovementioned boundary cases. Tsantali S.A and Brite Solar informed the researchers that the wine grape is the desired functional unit of this study. Therefore, only the processes and inputs/outputs that are enclosed by the red dashed line are relevant for this LCA study.

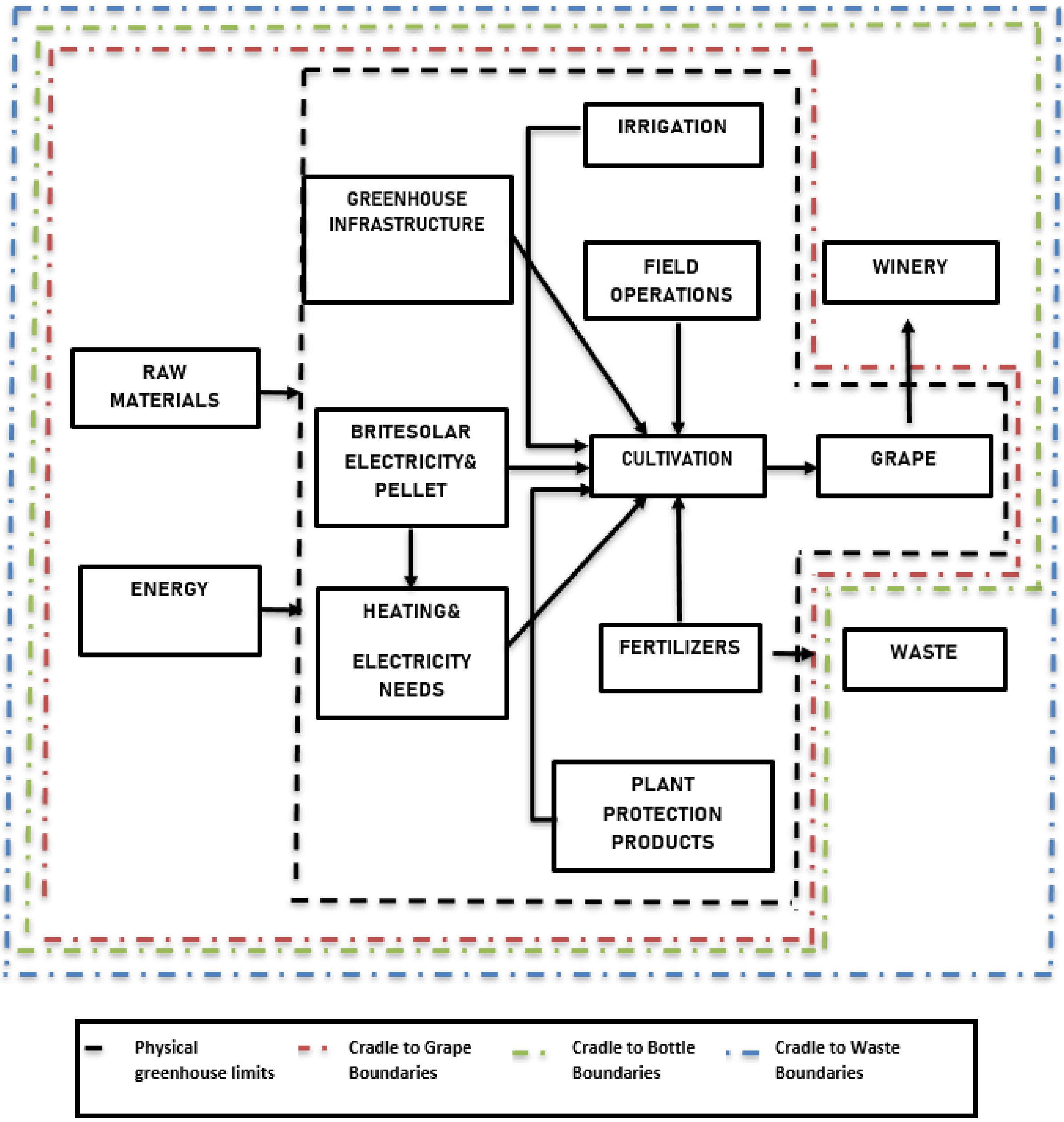

Figure 3: Typical flow of inputs/processes in Tsantali S.A. and system boundaries

Step III: Data collection procedure

In this respective step, the procedures for the collection of valid quantitative data were planned. In order to ensure the successful gathering of information, continuous cooperation between the involved companies and the research team was necessary. Researchers informed Tsantali Wineries and Brite Solar regarding the specific kind and volume of the necessary information, which was mainly concerned with raw material, energy and resources inputs during the timeframe of this respective LCA study, including the infrastructure inputs for the construction of greenhouse facilities and the manufacturing of the photovoltaic installation.

Regarding the carbon emissions from the latter infrastructure inputs, they were appropriately adjusted to reflect the functional lifespan of their respective materials, according to global standards. The functional lifespan of these materials was traced and imported from the findings of valid scientific and institutional publications. Picture 1 illustrates the main inputs for which quantitative data were sourced. It should be highlighted that for some recyclable materials a second life-time from reuse strategies was hypothesized.

What is more, additional important information besides input data, such as the area of the greenhouse, its geographical location and irrigation type and sources were requested and obtained. Finally, a significant amount of data regarding the installation and operation of the Brite Solar photovoltaic panel was requested.

Step IV: Life Cycle Impact Assessment – Environmental Indicators

There is a variety of computational methods for the analysis of the carbon footprint and the overall environmental impacts of products and processes as a whole. Choosing the appropriate method of impact analysis is highly dependent on the included environmental indicators of each method. It is obvious that for the instance of carbon footprint Life Cycle studies, indicators that calculate the amounts of CO_2 equivalent gases are necessary, as highlighted in ISO 14067 standard and scientific literature. Three main indicators reflect the emitted amounts of CO_2 equivalent gases and used in the majority of similar studies:

a) GWP-20a (Global Warming Potential 20 annum)

b) GWP-100a (Global Warming Potential 100 annum)
c) GWP-500a (Global Warming Potential 500 annum)

In more detail, these three indicators represent the amount of GHG that is emitted and remain in the atmosphere after 20, 100 and 500 years from the moment of emission, respectively. These indicators take into consideration the greenhouse potential (GWP) of each gas. For example, it is believed that 1 kg of methane (CH_4) has the same greenhouse potential as 25 kg of CO_2.

As a result, the life cycle impact assessment (LCIA) of choice must necessarily include at least one of the abovementioned GWP indicators. Additionally, since the lifespan of materials were manually traced and imported, all LCIA that includes a feature of automated detection of lifespans of materials were excluded. Finally, appropriate allocation and normalization methods of input data were taken into consideration.

1.3 Carbon Footprint

For the interpretation of the results of the carbon footprint measurement, the GWP-100a is employed. This indicator represents the amount of CO_2 equivalent gases that remain in the atmosphere 100 years after the moment of emission.

Total carbon emissions and carbon emissions per unit of product and greenhouse area

In 2020, the production of 1000 kg of wine grapes in the greenhouse (1228.8 m^2) not only emitted zero GHG but also prevented indirectly the emission of 15.78 tons of CO_2e. This quantity equals to -15.78 kg CO_2e/ kg wine grape or -12.84 kg CO_2e/ m^2 greenhouse (Table 2).

Total carbon emissions (kg $C0_2$e)	Carbon emissions per unit of product (kg $C0_2$e/ kg grape)	Carbon emissions per unit of greenhouse area (kg $C0_2$e/ m^2 greenhouse)
-15779.66	**-15.78**	**-12.84**

Table 2: Summary results of the carbon footprint of greenhouse grape production

Individual carbon emissions of inputs and processes

In order to calculate the total carbon footprint of the production of greenhouse grapes, all inputs and operational/production processes were classified into the following six major input categories:

i. Greenhouse infrastructure
ii. Heating needs
iii. Electricity needs & Brite Solar electricity production
iv. Field Operations
v. Fertilizers & Plant Protection Products
vi. Irrigation

A brief synopsis of the respective carbon footprints of the six major input categories is presented in Table 3:

	Input Category	Carbon Footprint (kg CO_2e)	Percentage, pro-offset (%)	Percentage, after-offset (%)
1.	Greenhouse infrastructure	639.22	+36.86	-4.05
2.	Heating Needs	525.65	+30.32	-3.33
3.	Brite Solar Electricity Production (after greenhouse needs)	-17513.61	-	+110.99
4.	Field Operations	397.85	+22.94	-2.52
5.	Fertilizers & Plant Protection Products	89.28	+5.15	-0.56
6.	Irrigation	81.93	+4.73	-0.52
	Total	**-15779.68**	**+100**	**+100**

Table 3: Carbon footprints of the six major input categories

Table 3 presents the general results of the measurements, for each one of the six main input categories. The contribution of each category to the total carbon footprint is also included and demonstrated in two cases:

i. Before the carbon emission offsets provided by the electricity production of Brite Solar PV system (pro-offset)
ii. After the carbon emission offsets provided by the electricity production of Brite Solar PV system (after-offset)

The reason behind this distinction of the two cases lies in the fact that despite the negative total carbon footprint of the production of grape, carbon emissions still happen on-site. More specifically, the various inputs and their production processes along the supply chain produce and emit CO_2, independently of the fact that they are compensated in different spatial and temporal points of the supply chain. Therefore, it is interesting to study these two cases separately and as a whole.

The majority of the total carbon emissions from the production of greenhouse grapes before the emission offset provided by Brite Solar results from the consumption of energy during the construction of greenhouse facilities and for heating purposes. Emissions of these two inputs take up to 67.17% of the pro-offset total carbon footprint. Field operations contribute to a respectable 23% of the total pro-offset emissions, and the other input categories result to the rest 9.89% off the total pro-offset carbon footprint. Regarding the right-most column of Table 3, it should be highlighted that some percentage values are negative to indicate quantitatively positive carbon emissions in a negative after-offset total. The contribution of each input category is presented in Figure 4:

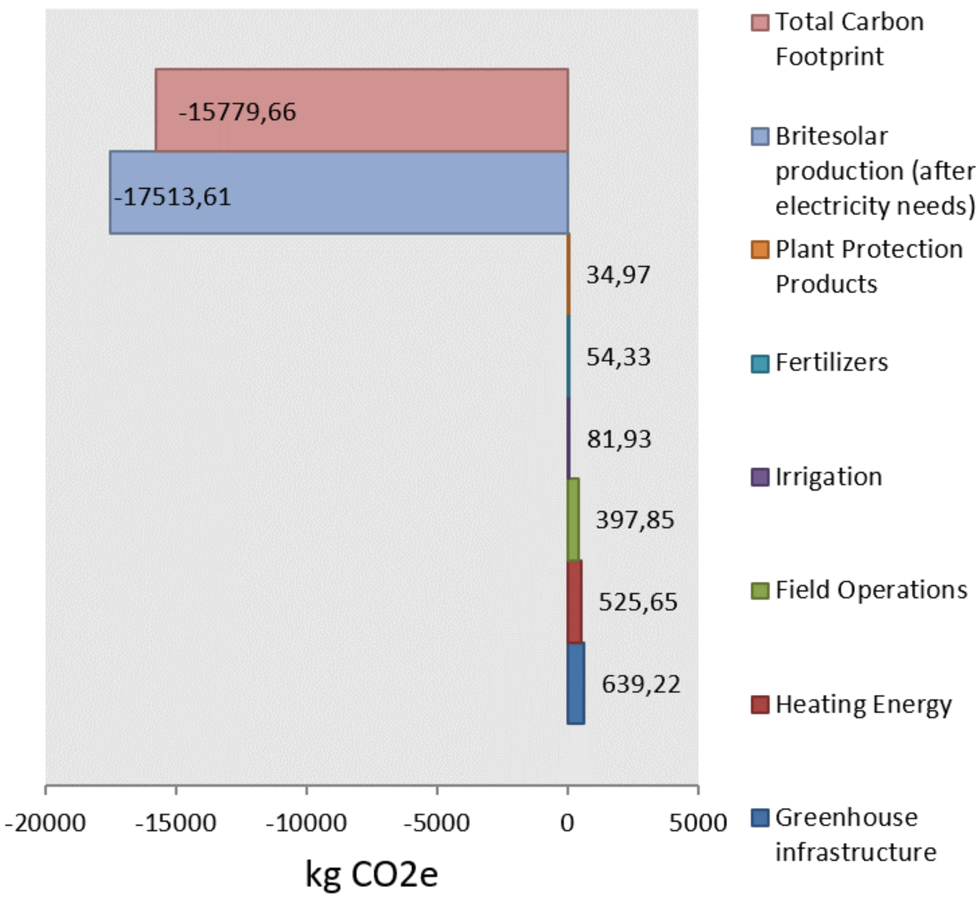

Figure 4: The carbon footprint of each major input category and total

It is also important to highlight that if the electricity needs were to be covered by grid electricity, this category would by far be the most "problematic" since conventional grid power generation for greenhouse uses would result in 6210 kg CO_2e. This fact is analyzed in more depth in the upcoming analysis of each input category.

Greenhouse Infrastructure

This input category includes the carbon emissions that originate from the total sum of operational/ production processes and raw materials that result in the construction of the greenhouse facilities, with the exception of the infrastructure emissions of the manufacturing of the photovoltaic installation which are included later in the electricity category. Initially, the measurement of the carbon emissions of these inputs begins from the extraction of the necessary building materials and include all intermediate phases, from their industrial processing and transportation to the final installation at the greenhouse location. The emissions of the infrastructure inputs that result from the manufacturing of the system of mechanical ventilation, heating and their respective control units are also included in this category.

Additionally, as mentioned earlier, the infrastructure emissions were adjusted to reflect the functional lifespan of their respective materials and the total entity of the greenhouse, according to global standards. Regarding the reuse hypotheses of recyclable materials, it should be noted that recycling actions were assumed after the use of these materials in the greenhouse either for the same or different purposes. Lastly, the land occupation and transformation emissions were not considered, as no reliable data was available for valid measurements in this regard. The carbon emissions of this respective input category are displayed in Table 4:

Input Type	GHG Emissions (kg $C0_2e$)	Percentage, Input Category (%)
Aluminum	289.70	45.34
Glass	110.50	17.29
Steel	82.10	12.84
Heating System	103.50	16.19
Other	53.42	8.36
Total	**639.22**	**100**

Table 4: The carbon footprint of various input types of greenhouse infrastructure

Table 4 shows that the construction of the 1228.8 m^2 greenhouse results in the emission of 639.22 kg $C0_2e$. The infrastructure input types with the most important contribution in the total carbon emissions of this input category belong in the construction of aluminium, glass and steel parts, which together form 75.5% of the emissions of this input category. A remarkable contribution to the total emissions of this input category originates from the manufacturing of the heating system, which results in 103.50 kg $C0_2e$ (16.19% of greenhouse infrastructure emissions). Regarding other emissions of this category, all intermediate transportation emissions and the construction of concrete foundations and blocks were included. The latter input does not make a significant contribution to the footprint of this category since it is characterized by a very long functional lifespan. The contribution of each input type in the total footprint of the greenhouse infrastructure category is illustrated in Figure 5:

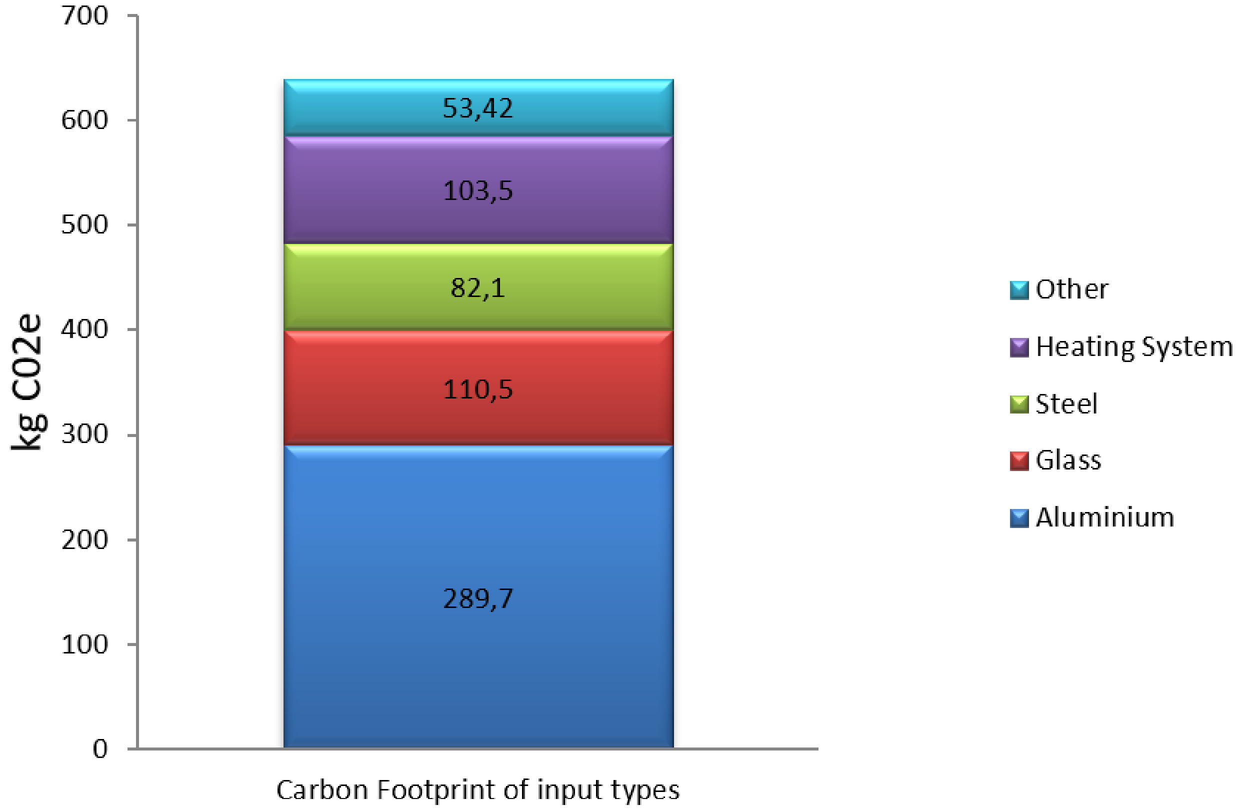

Figure 5: Contribution of input types to the total carbon footprint of greenhouse infrastructure

Heating Needs

As shown in Table 3, the heating input category makes a significant portion of the pro-offset emissions reaching 30.32% or 525.65 kg CO_2e. Nevertheless, the use of pellet provides significant carbon emission saves in comparison with other conventional heating fuels, such as diesel. This fact, in conjunction with the mild climatic conditions that characterize Greece, leads to relatively small heating requirements for setting the ideal temperatures for the desired plant growth. Additionally, it should be noted that the use of fan heaters is included in the electricity category since their primary source of energy is electrical power. Also, the infrastructure inputs for the manufacturing phase of the heating system have been included in the previous category. The carbon footprint results of this input category are presented in Table 5 and Figure 6.

Heating Needs	GHG Emissions (kg $C0_2e$)	Percentage, Input Category (%)
Heating (Pellet)	525.65	100
Total	525.65	100

Table 5: The carbon footprint of various input types of heating needs

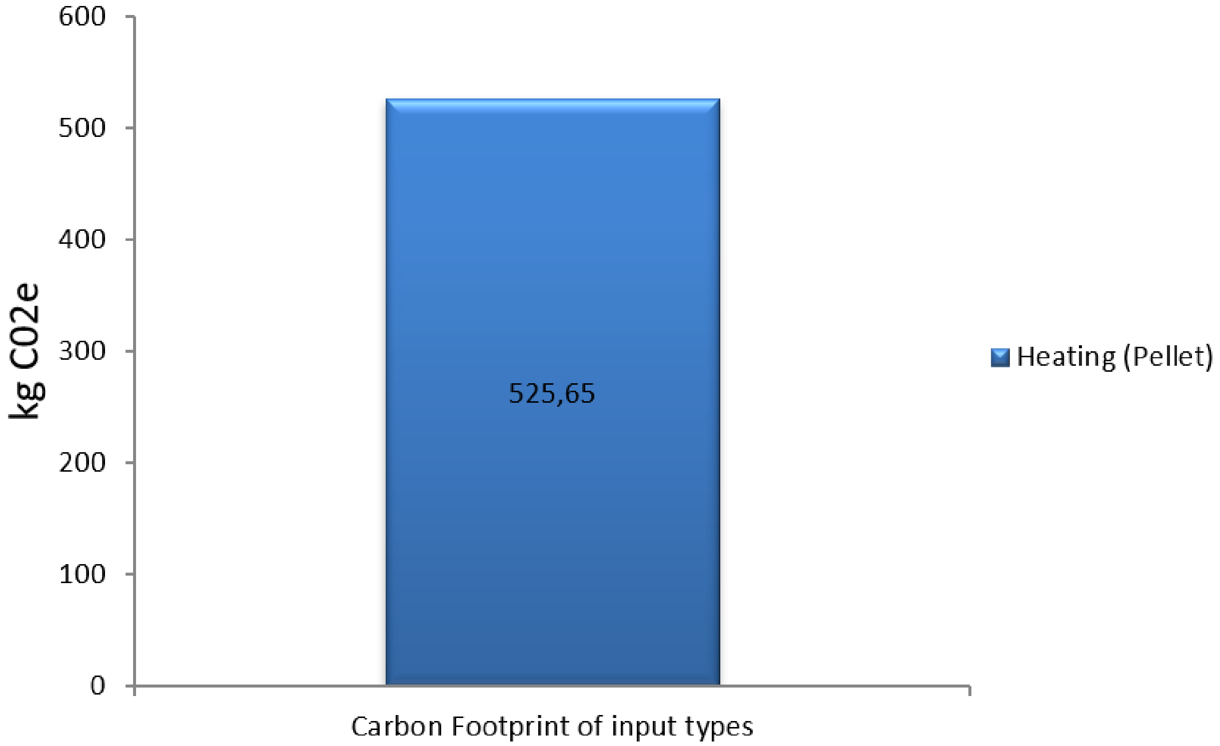

Figure 6: Contribution of input types to the total carbon footprint of heating needs

Electricity Needs & Brite Solar electricity production

This input category requires special attention due to the specificities of its nature. As mentioned earlier, the primary and only source of electricity during the greenhouse production of grapes is the PV Brite Solar installation. The powerful and specially designed Brite Solar roof installation has been estimated to produce almost 50 MWh of electricity per year. For calculating the carbon footprint of this input category, two main variables had to be quantified and measured:

i. The total electricity needs during the greenhouse production of grapes
ii. The total electricity needs during the timeframe of the production of grapes

These two quantities were extensively studied and calculated. Regarding the first variable, Tsantali S.A. and Brite Solar informed the researchers of this study that the two majority purposes of electricity required for the production of 1 ton of grapes concerned the mechanical ventilation and fan heater needs and was equal to 6480 KWh of electrical energy. The mechanical ventilation system was estimated to consume 5400 KWh during this time period and the fan heater respectively consumed an amount of 1080 KWh for heating purposes. Therefore, the electricity needs of the greenhouse production were estimated to 6480 KWh.

The second variable concerned the total PV installation of electricity production. This quantity of electricity, as stated earlier in this report, totally covers the electricity needs for the operation of the greenhouse, while any potential electricity surpluses were channelled for use in other parts of the facilities of Tsantali S.A., such as the winery and other structures. By employing the European Union instrument of Photovoltaic Geographical Information System (PVGIS), the electricity production for the same timeframe of the production of one ton of greenhouse grape has been estimated to be 24756 KWh. It is obvious that this amount of energy not only fully covers the greenhouse needs but also supplies with electricity a large spectrum of external processes, concerning the physical limits of the greenhouse.

According to the LCA calculations, if the electricity needs of the greenhouse production were to be covered by Greek grid electricity, this will lead to an astonishing 6210 kg CO_2e of additional emissions at the best-case scenario. From this amount, the 5175 kg of CO_2 equivalents results from the supply of the mechanical ventilation system, while the rest of 1035 would originate from the power that feeds the fan heater. Not only these potential emissions are offset by the Brite Solar PV system, leading to zero carbon emissions, but additional emissions are saved from the external replacement of grid electricity, leading to an impressive total of -23723 kg CO_2 of carbon savings. The total situation is presented in detail in Table 6 and illustrated in Figure 7:

Input Type	GHG Emissions (kg $C0_2e$)	Percentage, Input Category (%)
Ventilation Electricity	5174.74	-29.54
Fan Heater Electricity	1034.95	-5.91
PV Brite Solar Electricity (Greenhouse + Surplus)	-23723.3	+135.45
Total	**-17513.61**	**+100**

Table 6: The carbon footprint of various input types of electricity needs & Brite Solar electricity production

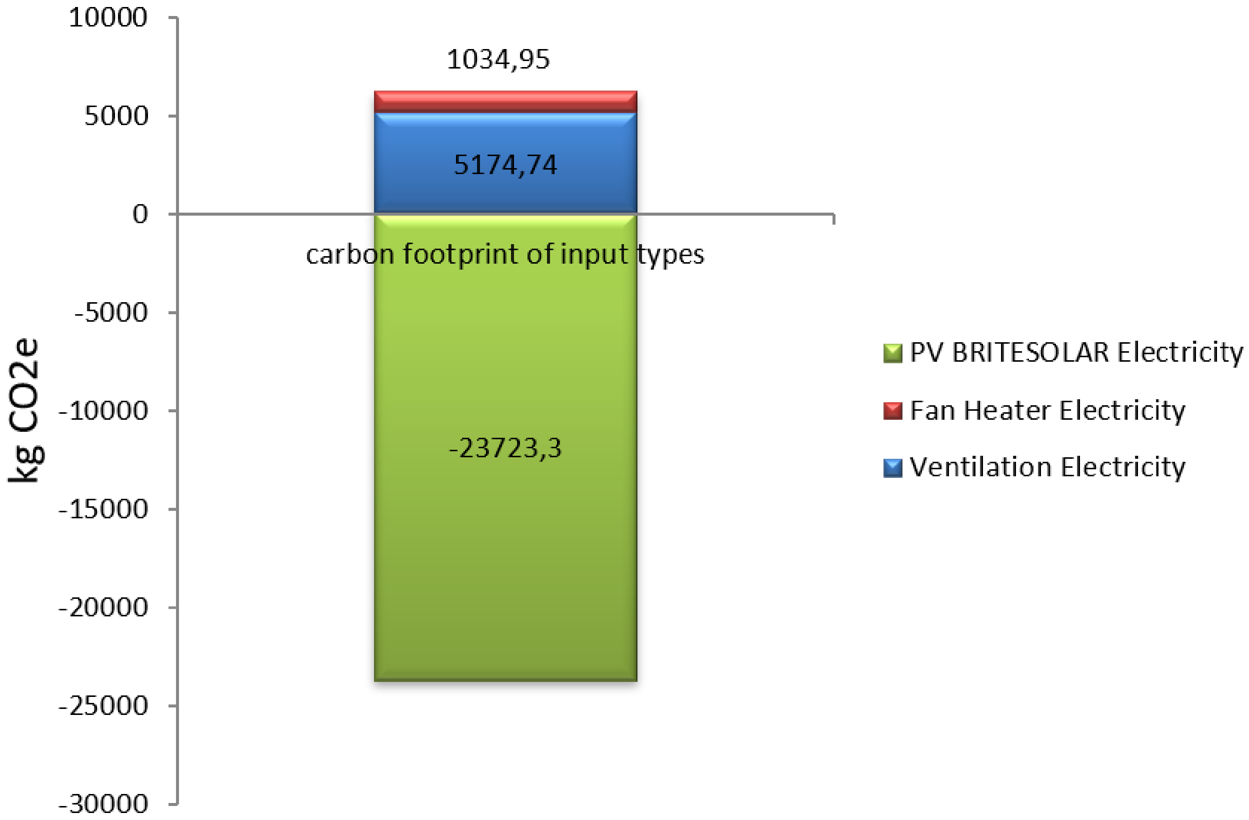

Figure 7: Contribution of input types to the total carbon footprint of electricity needs & Brite Solar PV production

Field Operations

Field operations include production and operational processes for nursing and harvesting of the plants. Various types of machinery, their fuel use as well as the emissions that result in the appliance of different types of products are included in the carbon footprint of this category.

Input Type	GHG Emissions (kg $C0_2e$)	Percentage, Input Category (%)
Agricultural Machinery	276.58	69.52
Pruning	94.73	23.81
Harvesting	16.40	4.22
Fuel	6.61	1.66
Other	3.51	0.87
Total	**397.85**	**100**

Table 7: The carbon footprint of various input types of field operations

The total carbon footprint of field operations was measured to 397.85 kg CO_2e. The production phase of agricultural emissions which were adjusted to reflect the functional lifetime of products is responsible for almost 70% of the total carbon footprint, while other inputs contribute the remaining 30% of the carbon footprint of this category. Table 7 (above) and Figure 8 present the carbon footprint results of this input category.

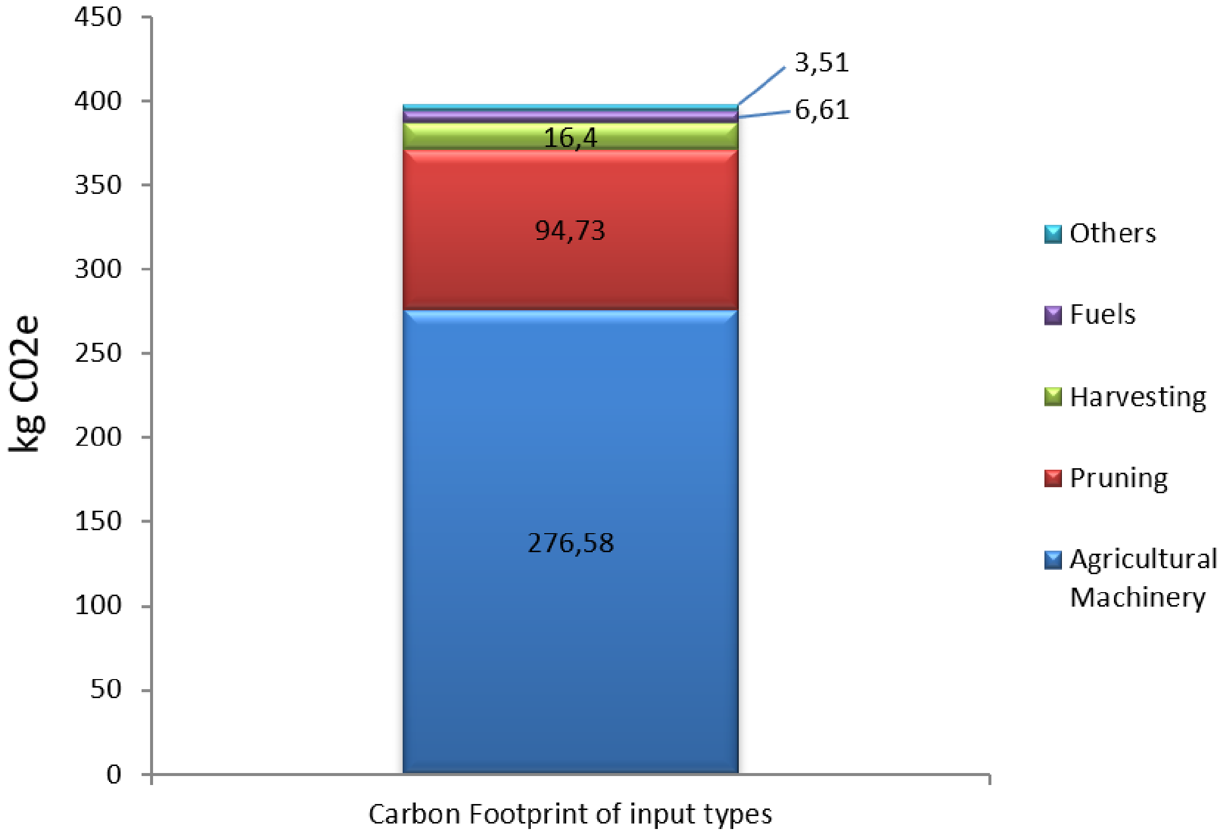

Figure 8: Contribution of input types to the total carbon footprint of field operations

Irrigation, Fertilizers & Plant Protection Products (PPP)

The last two input categories are merged in this analysis section, due to their relatively small footprint and their similar importance in a plant growth context. These merged categories include the production emissions and the emissions of the operation of the irrigation system, as well as the respective emissions of the production and transportation on the greenhouse site of the various fertilizers and PPP that are necessary for the growth and protection of plants. The estimation of the emissions of each input type is presented in Table 8:

Input Type	GHG Emissions (kg $C0_2e$)	Percentage, Input Category (%)
Irrigation system and energy	81.93	100
Fertilizers, P	1.61	2.97
Fertilizers, S	19.57	36.06
Fertilizers, N	33.09	60.97
Fertilizers, Total	54.27	100
Fungicides	32.16	94.78
Insecticides & Pesticides	1.77	5.22
PPP, Total	33.93	100
Packaging, Total	1.1	100
Total	**397.85**	**100**

Table 8: The carbon footprint of various input types of irrigation, fertilizers, and PPP

The larger amount of the carbon emissions of this category is attributed to the manufacturing and operation of the irrigation system, which has been estimated to supply the greenhouse with 250 m^3 of water at the timeframe of this study. Additionally, most of the emissions of the fertilizers and PPP products result from the use of nitric ammonium fertilizers and fungicides which facilitate the growth of the plants and their protection from pathogen fungus. It is highlighted that the transportation emissions for each type of product are included in each respective type of input, but as will be illustrated in Section 4, they have a very low contribution to the total carbon footprint since they are mainly supplied locally. Figure 9 presents visually the contribution of each type of input in the total carbon footprint of this input category.

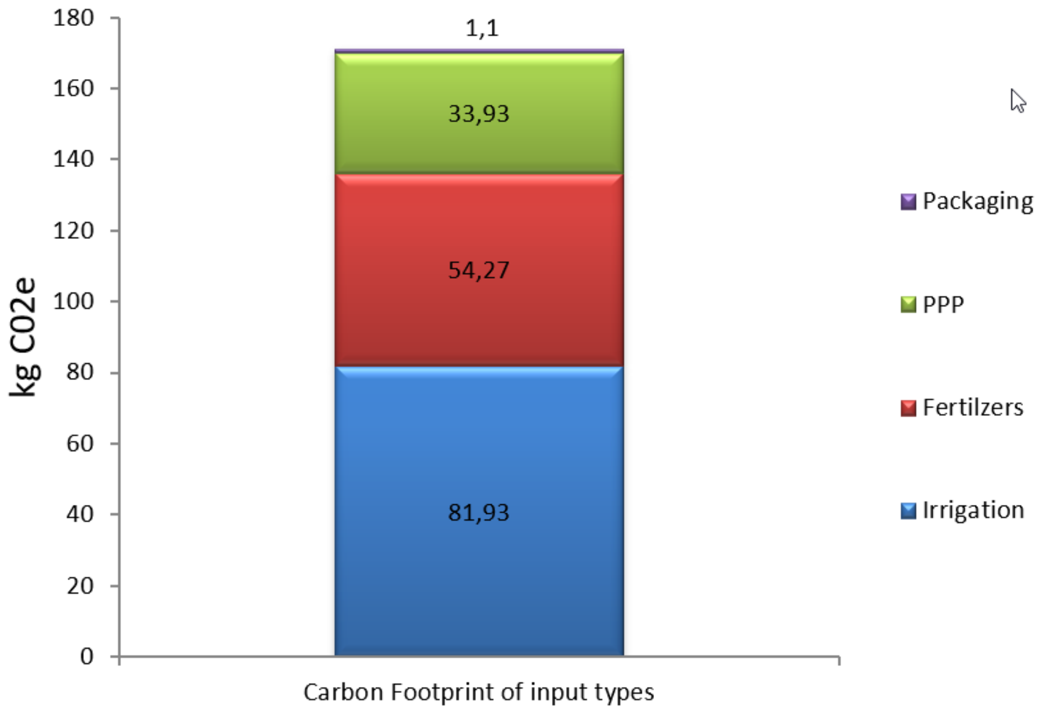

Figure 9: Contribution of input types to the total carbon footprint of irrigation, fertilizers & PPP

1.4 Environmental Indicators

By employing the standard Scope 1, 2 and 3 emission indexes of GHG Protocol, the emissions of the greenhouse production of wine grapes were classified into the respective categories and calculated. The results are presented in Table 9, 10 and 11. As previously noted, Scope 1 emissions include the carbon emissions that originate directly in fuel use from company-owned resources. Usually, fuel use in heating, machinery and company-owned vehicles are the dominant input types of Scope 1 category. In the instance of this carbon footprint report and the selected system boundaries, pellet use for heating and combustion of diesel for various functions constitute the origin of Scope 1 Emissions.

In the Scope 2 category, the emissions that result indirectly from the production of purchased power are included. As already presented in detail in previous sections, the emissions of this type not only are non-existent, since the electricity needs of the greenhouse production are fully satisfied by Brite Solar PV production, but additional saves are achieved through the valorization of the electricity surplus in other operations that take place within the Tsantali S.A. premises. Finally, Scope 3 category carbon emissions include all indirect carbon emissions that do not fulfil the requirements of inclusion in any of the previous two scopes. They mainly include the adjusted carbon emissions that take place at the construction phase of the greenhouse facilities, the production and transportation of fertilizers and PPP, agricultural machinery, as well as all transportation and logistics emissions that take place across the supply chain of wine grapes.

Scope	Input Category	Input Type	GHG Emissions (kg CO_2e)	GHG Emissions per kg of product (kg CO_2e/kg grape)	GHG Emissions per greenhouse area,1228,8 m^2 (kg CO_2e/m^2)
Scope 1	Heating Needs	Pellet	525.65	0.526	0.428
	Others	Diesel	89.78	0.090	0.073
	Total Scope 1 emissions		615.43	0.15	0.5

Table 9: Scope 1 Emissions

As shown in Table 9, 526 out of the total 615.43 kg CO_2e emissions originate in the combustion of pellet for heat production. The remaining 89.78 kg of CO_2e concern the use of diesel fuels in other agricultural operations.

Regarding the Scope 2 Emissions (Table 10), it is already mentioned that not only they are non-existent, but large indirect savings occur. The electricity needs of 6480 KWh and the resulting emissions of 6210 kg CO_2e are fully compensated and the electricity surplus feeds with electricity the surrounding premises, reaching an overall carbon saving amount of -17514 kg CO_2e.

Scope	Input Category	Input Type	GHG Emissions (kg CO_2e)	GHG Emissions per kg of product (kg CO_2e/kg grape)	GHG Emissions per greenhouse area,1228,8 m^2 (kg CO_2e/m^2)
Scope 2	Electricity Needs	Ventilation	+5174.74	+5.4	+4.39
		Fan Heater	+1034.95	+1.08	+0.879
	Brite Solar PV Production	Energy Production	-23723.3	-23.723	-19.31
	Total Scope 2 Emissions		-17513.61	-17.51	-14.25

Table 10: Scope 2 Emissions

Finally, Scope 3 category represents a variety of carbon emission origins since they include all of the emissions that did not meet the criteria for being included in Scope 1 and 2 categories. As presented in Table 10, a large portion of Scope 3 emissions can be attributed to the construction of the greenhouse infrastructure and its respective parts and materials. Additionally, the low emissions resulting from transportations (56.06 kg CO_2e) are an impressive feature of this analysis, because most of the raw materials are supplied locally. Also, the comparatively low use of fertilizers and PPP products, limit the emissions that occur during the production and application face of these products. A summary of Scope 3 emissions can be seen in Table 11:

Scope	Input Category	Input Type	GHG Emissions (kg CO_2e)	GHG Emissions per kg of product (kg CO_2e/kg grape)	GHG Emissions per greenhouse area,1228,8 m^2 (kg CO_2e/m^2)
Scope 3	Other	Transportation & Logistics	56.06	5.6E-2	4.6E-2
		Other	62.22	0.62	5E-2
	Fertilizers	Fertilizers P	1.32	1.32E-3	1,07E-3
		Fertilizers N	31.4	3.1E-2	2.6E-2
		Fertilizers S	18.5	1.9E-2	1.5E-2
	PPP	Fungicides	31.45	3.1E-2	2.6E-2
		Insecticides &Pesticides	1.57	1.57E-3	1.28E-3
	Greenhouse Infrastructure	Aluminum	289.70	0.29	0.236
		Glass	110.50	0.11	0.09
		Steel	82.10	8.2E-2	6.7E-2
		Heating System	103.50	0,104	8.4E-2
		Other	53.42	5.34E-2	4.1E-2
	Field Operations	Agricultural Machinery	276.78	0.277	0.225
	Total Scope 3 Emissions		1118.52	1.12	0.91

Table 11: Scope 3 Emissions

The net carbon footprint of the greenhouse production of grape is negative, indicating savings of GHG emissions. Carbon emissions do take place, although, despite being compensated by the PV Brite Solar installation. By taking a look at the pro-offset situation, one can see that most of the emissions take place indirectly in the Scope 3 category, which contributes to 64.5% (1118.52 kg CO_2e) of the total pro-offset carbon emissions. The remaining 35.5% (615.43 kg CO_2e) belongs to Scope 1 direct emissions of the greenhouse grape production. The following figures illustrate the contribution of each scope category for both pro-offset (Figure 10) and after-offset cases (Figure 11):

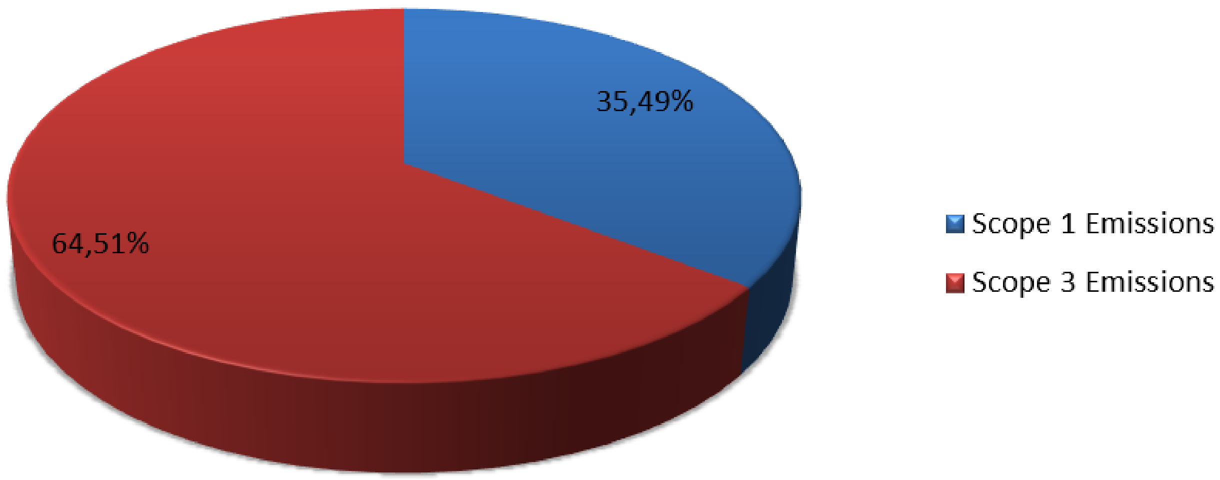

Figure 10: Contribution of inputs per scope before the offset of emissions by Brite Solar PV installation

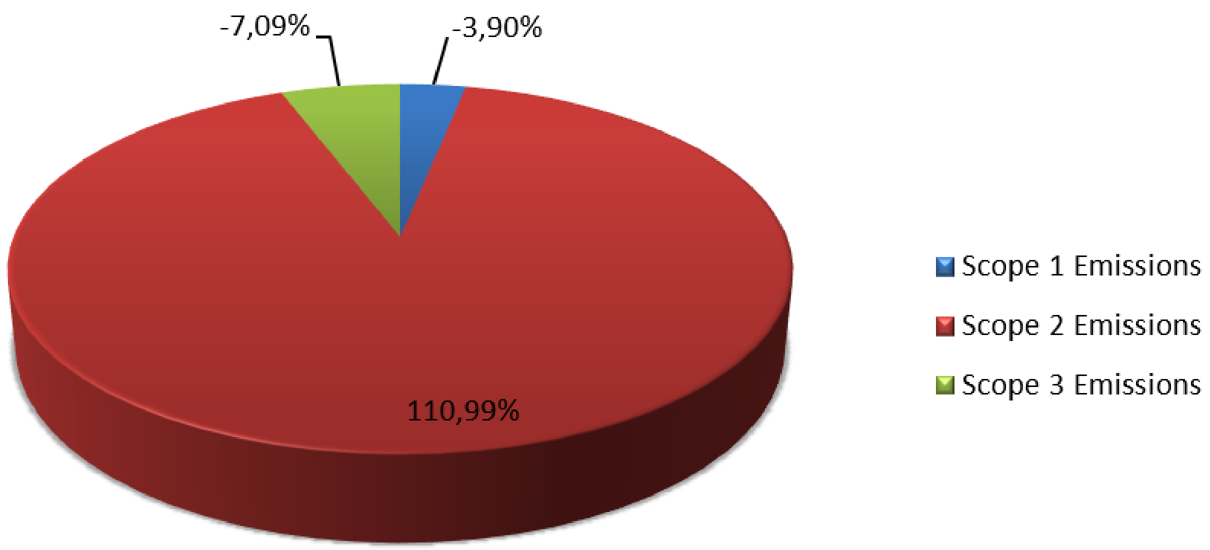

Figure 11: Contribution of inputs per scope after the offset of emissions by Brite Solar PV installation

1.5 Proposed Policies and Improving Scenarios

In this section, researchers present two different scenarios in order to discover potential improving policies that would facilitate the further reduction of the carbon footprint of the greenhouse grape production. For each scenario, a small number of assumptions that slightly differentiate certain processes and inputs in comparison with the baseline scenario (Scenario A) are made, in order to examine their influence on the overall carbon footprint of grape production. The two hypothetical scenarios (Scenarios B and C) and the baseline scenario (Scenario A) are the following:

1. Scenario A: Baseline Scenario- Real-life conditions
2. Scenario B: Combined Ventilation (natural/mechanical 50%-50%)
3. Scenario C: Increase of 50% of crop yield per crop and consequent input increases

This analysis aims at highlighting how simple changes can have a positive impact on the carbon footprint of grape production. Despite having already achieved a negative carbon emissions impact, Tsantali S.A. and Brite Solar are completely committed to potential further improvements. Therefore, this section is dedicated to facilitating this constant struggle for improvement and environmental protection. A detailed analysis of each scenario is presented below:

Scenario A: Baseline Scenario

This Scenario represents the contemporary conditions in the greenhouse production of grape. The production of 1000 kg of product in the 1229 m^2 leads to the carbon savings of nearly 15.77 tons of CO_2e. The respective emissions of different input categories and types, or in this particular case the savings of carbon emissions, remain as presented earlier in this report.

Scenario B: Combined Ventilation (natural/mechanical 50%-50%)

In Scenario B, the only differentiation in comparison with baseline scenario A is the adjustment of the infrastructure to allow the flow of natural air in the greenhouse facilities. It is assumed that this policy reduces 50% the use of the mechanical ventilation system, while this move results in a

100% increase in heating needs due to more intense loss of heat. All other inputs remain the same as in baseline Scenario A.

Scenario C: Increase of 50% of crop yield per crop and consequent input increases

The basic assumption of Scenario C is an increase of 50% in crop yield per crop in comparison with the baseline scenario, translating to an increase of 500 kg of grapes. In this scenario, the resulting quantity per crop is 1500 kg of wine grapes, while consequent increases in all inputs take place to support this yield improvement. It has been assumed that all inputs increase by 50% concerning Scenario A, with the exception of heating and electricity needs which increase by 25% and greenhouse infrastructure which remain the same with baseline scenario A. In this scenario, as in Scenario B, the production of electricity by the Brite Solar PV installation remains as it is in real-life conditions.

In Table 12, the assumptions of each scenario are presented mathematically in detail, by employing variables that represent the respective input quantities for each Scenario (A for Baseline Scenario A, B for Scenario B and Scenario C).

	Scenario A	Scenario B	Scenario C
Crop Yield	1000 kg	1000 kg	1500 kg
Input Categories	Input Quantities		
1.Greenhouse Infrastructure	A_1	$B_1=A_1$	$C_1=A_1$
2. Heating Needs	A_2	$B_2= 2A_2$	$C_2=1.25A_2$
3.Electricity Needs (Ventilation)	A_3	$B_3=0.5A_3$	$C_3=1.25A_3$
4.Electricity Needs (other)	A_4	$B_4=A_4$	$C_4=1.25A_4$
4.Brite Solar PV electricity production	A_5	$B_5=A_5$	$C_5=1.5A_5$
5. Field Operations	A_6	$B_6=A_6$	$C_6=1.5A_6$
6.Irrigation, Fertilizers, and PPP	A_7	$B_7=A_7$	$C_7=1.5A_7$

Table 12: Assumptions for each scenario

Comparative Analysis of Scenarios

The two scenarios were built in the LCA tool, in order to examine the differences that occur in comparison to the baseline Scenario A. The results of this process are presented in detail in the following Figures:

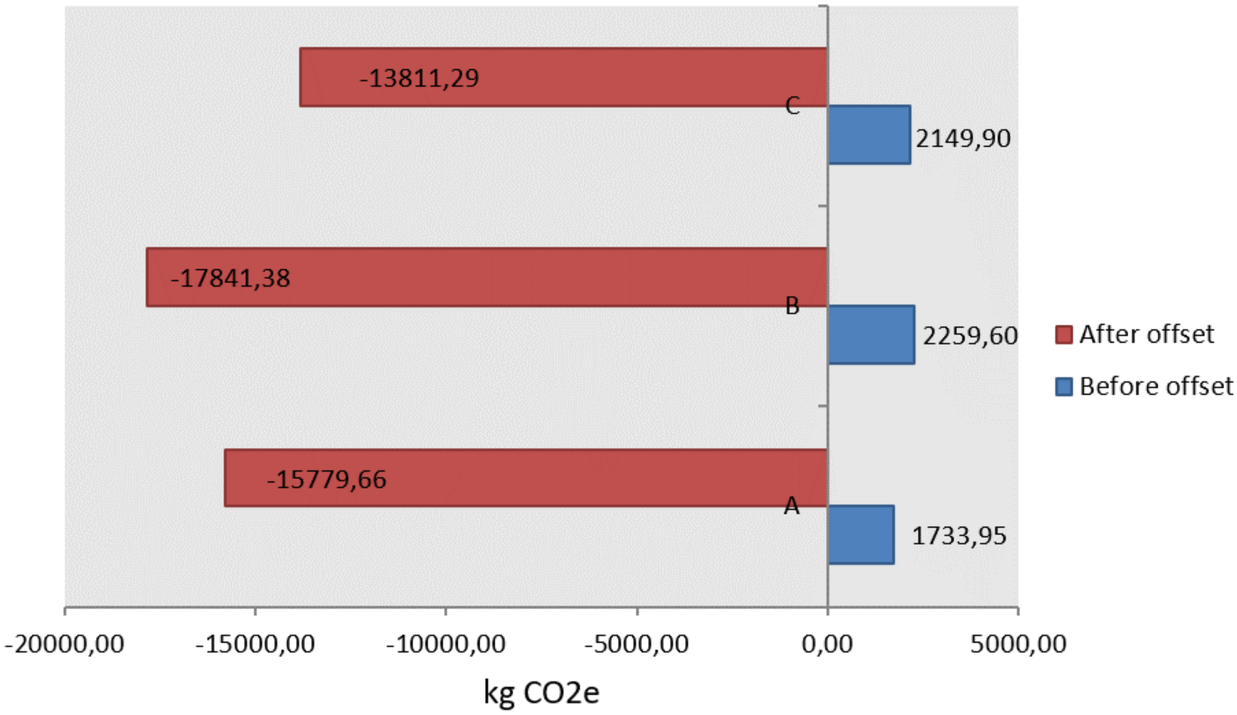

Figure 12: Pro- and after-offset total carbon footprints for each scenario

In Figure 12, the resulting total carbon emissions for each scenario are presented. In Scenario B, the doubling of heat consumption leads to a higher pro-offset carbon footprint in comparison with baseline scenario A, but the simultaneous reduction of electricity needs for ventilation allowed a greater amount of carbon emissions to be saved in total after-offset. Additionally, in Scenario C we see an increase of the pro- offset carbon footprint concerning baseline scenario, and at the same timeless emission savings. Therefore, in this perspective, the most promising policy scenario is the combined ventilation strategy.

However, the examination of carbon emissions that result per kilogram of produced grape for each scenario gives a slightly different picture (Figure 13). An interesting element in this perspective is that in Scenario C, despite the increase of the total carbon footprint pro- and after-offset, a considerable reduction of the emissions per kg of grape takes places in the pro-offset case. This is due to an increase in the efficiency of inputs in comparison with scenario A and indicates that real emissions are emitted with more environmentally efficient ratios in the atmosphere. This scenario is evidence that if companies decide to increase their crop yield for a variety of reasons, there are ways to implement intensive production strategies without considerably increasing the impact of the product on climate change. However, when emission compensation by the PV system takes place, this difference is no longer noticeable.

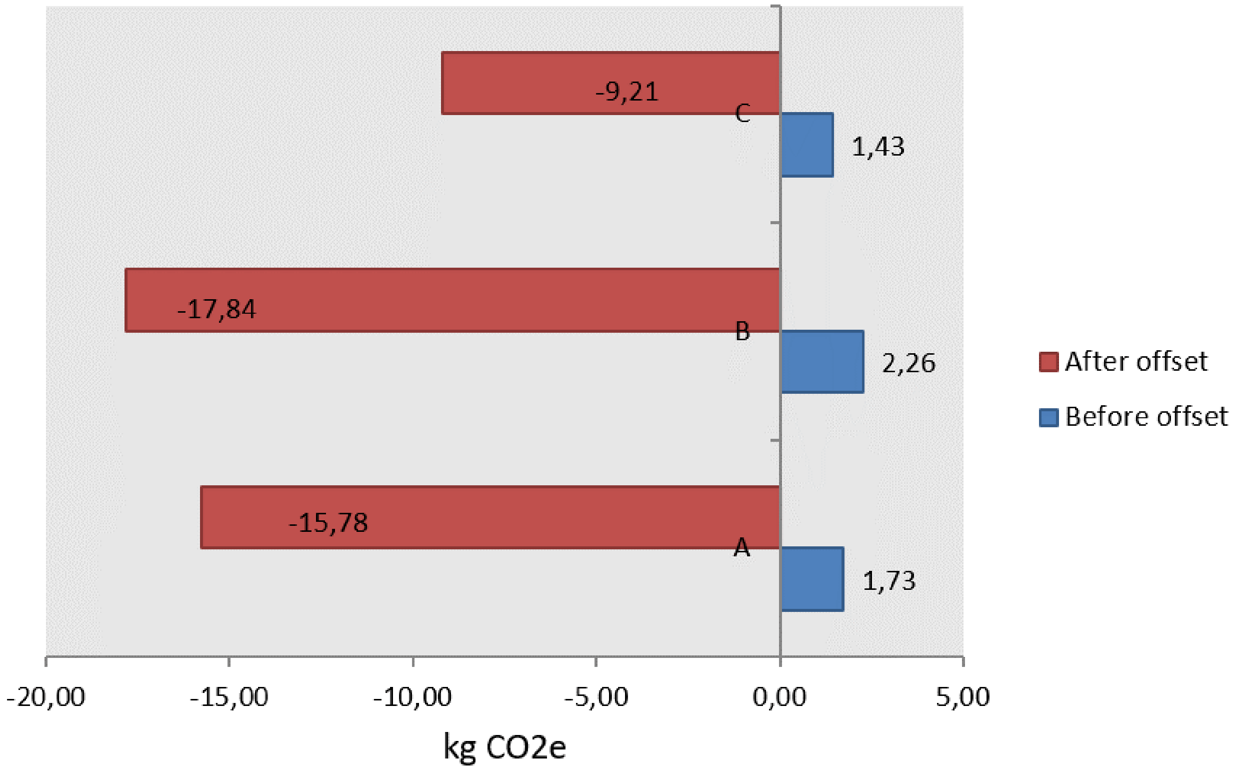

Figure 13: Pro- and after-offset total carbon footprints per kg of grape for each scenario

The business world is a dynamic place, where changes occur by the second. Adapting to the ever-changing business conditions certainly affects their means of operation and their environmental performance. The creation and demonstration of these scenarios prove that companies are always able to estimate their environmental outcomes under any circumstances and strive for better environmental performances, especially in the case of carbon emissions. This is achieved by constructing potential scenarios, calculating their performance, and choosing the best option with environmental, societal, and economic benefits in mind.

It should be noted that in the creation of the abovementioned scenarios such as the realistic feasibility, the specific conditions that characterize the operational environment, were not considered. On the other hand, this Section was completely dedicated to inspiring the involved companies into striving for greater improvements and demonstrate how simple changes make significant positive differences.

Appendix I- Relative Literature

Authors	Title	Year	Country /Area	Product/ Cultivation environment
Ntinas et al.	Carbon footprint and cumulative energy demand of greenhouse and open-field tomato cultivation systems under Southern and Central European climatic conditions	2016	Greece, Germany	Tomato cultivation/ Greenhouse &Open Field
Torrellas et al.	LCA of a tomato crop in a multi-tunnel greenhouse in Almeria	2012	Spain	Tomato cultivation/ Greenhouse
Bartzas et al.	Life cycle assessment of open field and greenhouse cultivation of lettuce and barley	2015	Spain, Italy	Lettuce & Barley cultivation/ Greenhouse &Open Field
Khoshnevisan et al.	Environmental impact assessment of tomato and cucumber cultivation in greenhouses using life cycle assessment and adaptive neuro-fuzzy inference system	2013	Iran	Tomato & Cucumber cultivation / Greenhouse
Cellura et al.	Life Cycle Assessment (LCA) of protected crops: an Italian case study	2011	Italy	Various products/ Greenhouse

Martinez-Blanco et al.	Assessment of tomato Mediterranean production in open-field and standard multi-tunnel greenhouse, with compost or mineral fertilizers, from an agricultural and environmental standpoint	2010	Mediterranean Sea	Tomato cultivation/ Greenhouse &Open Field
Steenwerth et al.	Life cycle greenhouse gas, energy, and water assessment of wine grape production in California	2015	U.S.A.	Wine Grape cultivation/ Open Field
Balafoutis et al.	Life Cycle Assessment of Two Vineyards after the Application of Precision Viticulture Techniques: A Case Study	2017	Greece	Wine Grape cultivation/ Open Field
Bosco et al.	Greenhouse gas emissions in the agricultural phase of wine production in the Maremma rural district in Tuscany, Italy	2011	Italy	Wine Grape cultivation/ Open Field
Litskas et al.	Determining the carbon footprint of indigenous and introduced grape varieties through Life Cycle Assessment using the island of Cyprus as a case study	2017	Cyprus	Grape cultivation/ Open Field

Russo and Mugnozza	LCA Methodology Applied to Various Typology of Greenhouses	2004	Italy	Various products/ Greenhouse

Appendix II- Necessary information

Input Category	Necessary Information
General Information	I. Greenhouse II. Geographical Location III. Crop yield IV. Grape Quantity V. Time frame
Greenhouse Infrastructure	I. Building parts II. Pieces per building part III. Material composition per piece IV. Quantity per piece V. Country/Region of Manufacturing and Import VI. Installation data (Machinery, Duration of use, energy consumption of machinery, etc.) VII. Functional lifetime of parts, materials, and machinery
Brite Solar PV System & Electricity Needs	I. Systems (trademark) II. Building Parts, pieces per building part and material composition III. Source of energy IV. Country/Region of Manufacturing and import V. Installation data (Machinery, Duration of use, energy consumption of machinery, etc.) VI. Duration of use and operation VII. Efficiency VIII. Energy Consumption IX. Functional life time of systems

Field Operations & Irrigation	I. Process II. Duration III. Employed machinery and tools IV. Trademarks of machinery and tools V. Country & Region of manufacturing and import of machinery, tools and irrigation system VI. Quantity of machinery and tools VII. Source of energy of machinery VIII. Duration of machinery use IX. Functional life time of machinery, tools and irrigation system X. Irrigation System (trademark) XI. Components and quantities of components XII. Water source XIII. Source of energy for irrigating XIV. Duration of use of irrigation system XV. Runoff system data
Fertilizers & PPP	I. Trademarks II. Composition and active substances III. Quantities IV. Packaging data V. Application data VI. Country/Region of Manufacturing and Import