CLIMATE CHANGE MITIGATION THROUGH A SUSTAINABLE SUPPLY CHAIN FOR THE OLIVE OIL SECTOR

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LIST OF SUTAINABLE PRACTICES TO DEVELOP THE CERTIFICATION STANDARD

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THEIR MITIGATION POTENTIAL IN TERMS OF TON OF CO_2 EQUIVALENT

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Contract Number: LIFE15 CCM/IT/000141

Duration: 01/07/2016 - 31/12/2019

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1 EXECUTIVE SUMMARY

The project OLIVE4CLIMATE was developed observing the great impact of the agricultural sector in the total emissions produced by human activities. The attention was then focused on the olive groves since this cultivation is an essential part of the agricultural sector of the European Union, especially in the Mediterranean area.

On this context, the project wants to highlight the strong connection between sustainable agricultural techniques and climate change mitigation through the evaluation of the Carbon Footprint (CF) associated to the production of 1 liter of extra virgin olive oil. This process is going to be tested in the Mediterranean countries with heterogeneous environmental conditions and with significant olive cultivation records, in three heterogeneous geographical contexts: Italy, Greece and Israel.

The carbon sequestration (sink) performed by the olive groves will be evaluated as olive plant biomass and GHG emission avoided thanks to the best practices implementation. The olive grove sustainable management will produce an environmental benefit quantifiable by CO_2 equivalent tonnes (in this project defined as "sustainability credit" and as such monetised). From this perspective, the Carbon Footprint and the evaluation of the Carbon sequestration can become important "green" marketing tools for the olive groves that could be included in the voluntary carbon market.

In this document, several strategies for creating a sustainable olive oil sector and promoting products deriving from integrated and organic cultivation methods will be presented. The objective of these techniques will be the improvement of the net balance between absorbed and emitted CO_2 and then determine the capability of the olive groves as an instrument for climate change mitigation.

2 INTRODUCTION

Olive tree (*Olea europaea L.*) is one of the most widespread agricultural tree species in the world, reaching 10.65 Mha of cultivated area (ISTAT data referred to 2016), especially in Europe. In recent years' olive cultivation has been also successfully introduced in other countries such as California, Australia, Argentina and South Africa.

For the Europe Union, the olive sector is an essential part of the agricultural sector. In particular, it represents a significant slice of the agricultural economy in the southern Europe countries. The EU is also the world leader in the olives production (almost 46% of the total worldwide production coming from Europe) and it is the first exporter in the countries that do not produce olive. In terms of area, the olive trees occupy 51% of the total cultivated land in Spain, the 23% in Italy and 17% in Greece (FAOSTAT data 2018).

Since the agriculture sector is responsible for 10% of the greenhouse gases emissions in the EU, the relationship between agriculture and climate change is undeniable (*Eurostat Statistics explained - Greenhouse gas emission statistics - emission inventories*). The agricultural sector is also particularly vulnerable to the climate change effects. Nowadays, the combined challenge of mitigation and adaptation to climate change under the new climate scenarios has to be faced. The Common Agricultural Policy 2014-2020 (CAP) asks to fully exploit the agriculture potential to mitigate climate change and adapt to its consequences, increasing the positive contribution of the sector to the carbon sequestration.

However, even though olive production is widely diffused, there is still little knowledge regarding the fixation capacity of atmospheric CO_2 of the olive groves and their greenhouse gases mitigation effect. In particular, while the carbon sequestered by the forestry sector has been object of extensive studies, information about the carbon amount from agricultural systems is extremely limited, because it is considered only their productive role instead of the ecological role.

The desertification is another phenomenon to be considered for the carbon sequestration. This is a direct consequence of climate change and it affects very large areas where the land has lost its productive capacity as a consequence of both to human activities and natural causes. According to the European environmental policy supporting the increase of soil carbon content, the project defines the olive grove land management techniques to mitigate climate change, to restore its organic matter and, therefore, to operate to absorb CO_2. The adoption of agricultural techniques that cause an increase of the carbon content in the soil (e.g. green cover), allow to get other indirect benefits including the reduction of inputs of fertilizers.

Moreover, the project aims to define alternative strategies for the extraction phase, including the use of renewable sources, the increase of the energy efficiency of the machines, the recovery and reuse of the production wastes or by-products (such as pruning and pomace) in order to reduce the emissions associated to the transformation stages realized in the olive mill.

The actions proposed for supply management are additional measures, compared to a "*business as usual*" scenario (BAU). These actions create sustainability credits compared to the baseline scenario (or baseline) that can be verified and subsequently sold.

The possibilities to sell the sustainability credits, generated by the ecosystem services of the olive grove and the good practices implemented in it, offer the possibility to preserve olive groves with low profitability but with important environmental and landscape functions.

3 THE PROJECT ACTION: DEVELOPMENT OF A CERTIFICATION STANDARD FOR SUSTAINABLE OLIVE GROVE MANAGEMENT AND THE CREATION OF SUSTAINABILITY CREDITS

Aim

The main objective of this action is the development of the standard for the sustainable management of olive groves and the creation of “sustainability credits”. This action is planned to assess the potential climate change mitigation action of the olive groves in terms of ton of $CO_{2\text{-eq}}$.

The definition of sustainability credits deriving from the sustainable management of olive grove is one of the strategies that it will be implement to achieve the recognition of ecosystem services of olive groves as contributor to climate change mitigation. In particular, through the value given to the most representative ecosystem service performed by olive groves (the carbon sequestration), the value generated from the agro-ecosystems in the economic field will increased. In particular, it will be created a standard that will offer visibility to the effect of the carbon sequestration obtained by the sustainable management of olive groves in term of corresponding generated carbon credits. The evaluation of such Carbon credits can be an important competitive and green marketing tools that can include olive cultivation in the perspective of climate change mitigation.

The method

This activity will be carried out according to the following Tasks:

• **Task 1**: Estimation of the potential climate change mitigation action in the olive grove management. This estimation of the mitigation potential and of emission reductions will be enlarged to the Mediterranean olive groves.

• **Task 2**: Elaboration of the technical documentation requested by the "sustainable management of olive groves standard and the generated sustainability credits", and the "report guidelines" for the standard implementation in the company pilot areas. All the documents will be based on the evaluation of the impact of sustainable management practices, that will allow a quantitative assessment of the carbon sink and related sustainability credits, and according to the relative International Standard Organization standard for auditing and for Green House Gasses certification (ISO 14000 technical norms).

• **Task 3**: Training of company staff aimed to implement the certification standard into the pilot companies. This task foreseen the result dissemination and communication among stakeholders, with a final public consultation about the certification standard for sustainable olive grove management.

• **Task 4**: Creation of a "suppliers and buyers register" for voluntary sustainability credits generated by sustainable olive groves management.

In compliance with the action aim, in the following paragraphs, a list of sustainable management techniques with their mitigation potential is reported.

4 SELECTED BEST PRACTICE

Reduction of The Use of Fertilizers

Pruning Residues Used for Energy

Pruning Residues Used as Soil Improver

Green Cover

Conservation Tillage

Olive Pitting Machine

Photovoltaic System

REDUCTION OF THE USE OF FERTILIZERS

Description

Balanced Nutrition contributes significantly to achieve a good relationship between vegetative and reproductive activity of plants. The olive tree absorbs most of the nutrients necessary for its development from the ground. The main purpose of fertilization is to improve or to preserve the fertility of the soil and the administration of some deficient nutrients using low environmental impact products (such as those allowed in organic agriculture). The fertilizer composition is determined taking into account the fertility level of soil, nutritional status of plants and factors affecting plant nutritional needs (eg plant age, tree productive potential, irrigation, etc.). Useful tools to determine the amount of nutrients are soil analysis, foliar diagnostics, calculations of trees removal and visual observation of plants.

A proper fertilization also considers how the nutrients uptake changes during the vegetative season:

• Nitrogen is absorbed throughout the vegetative season, with a greater intensity from full bloom to hardening of the stone;

• Phosphorus is absorbed especially in the first part of the vegetative season (the need is generally modest);

• Potassium is absorbed since the beginning of vegetative season and used in high quantity during fruit growth and oil synthesis.

Nitrogen fertilizers are the most commonly used fertilizers with a consequent greater impact on the environment.

According to various Integrated Production Disciplines the maximum quantity of fertilizer usable for the main crops of the territory is defined respecting the minimum quantity required to obtain quantitatively and qualitatively acceptable productions. This is due to limit the pollution of water by excess fertilizer elements. Table 1 (first column) shows average nitrogen fertilizer values currently used in olive cultivation.

In a context of sustainable farming practices, a 15% reduction of respect to the values reported in the Integrated Production Disciplinary is proposed (Table 1, second column). This practice as the other proposed below (management of pruning material and/or green cover and/or conservation tillage) will not reduce the production expected quantities. This N additional compared to the quantities currently used would further reduce N2O emissions and would ensure compliance with the principle of additionality with respect to *Business as Usual* (BAU).

Calculation method

Nitrogen emissions (N_2O) deriving from the use of fertilizers are distinguished by direct and indirect emissions. These emissions are calculated and converted into CO_2 equivalent using the methodologies and the emission factors provided by the IPCC (2006). Direct emissions are calculated on the basis of the quantities of nitrates fertilizers used (IPCC, 2006 - Vol. 4, Chapter 11 - Equation 11.1). Indirect emissions are calculated by taking into account two processes: 1) the NH_3 and NO_x volatilization due to fertilizer application and the subsequent rendering of these gases such as NH^{4+} and NO^{3-} in soils and waters (IPCC, 2006 - Vol. 4 Chapter 11 - Equation 11.9); 2) NO_3-SO_2 emissions following leaching and surface sliding (IPCC, 2006 - Vol. 4, Chapter 11 - Equation 11.10).

Tab.1 Credits generated by the 15% reduction in the use of nitrogen fertilizers from the average values currently used

Crop type	**Fertilizer used kg N/ha**	**Fertilizer reduction (15%) kg N/ha**	**Generated credit t CO_2/ha/year**
Olive grove	Medium/Low production 40 High production 80	35 69.5	**0.03** **0.07**

Positive impacts: reduction of emissions in the production and transport of fertilizers; reduction of water pollution; savings in the purchase and consumption of fertilizers.

Negative impacts: potential risk of production reduction/yields/hectare.

Environmental synergies: reduction of N leaching would improve water biodiversity and air quality (ND, NEC Directive, WFD, Habitats Directive).

PRUNING RESIDUES USED FOR ENERGY OR AS FERTILIZER

Description

Agronomic practices commonly used in olive growing include annual or biennial pruning operations. The amount of biomass resulting from the pruning operations is extremely variable depending on the variety, the training system, the density of plants per hectare, the pruning timing and the reference geographic area. Table 2 shows the average biomass values annually produced by pruning operations derived from existing literature (Sofo et al., 2005; Canaveira et al., 2018).

Generally, pruning is burnt on site or chipped and released on the ground or underground. The pruning burned into the field must be considered as a carbon loss by the ecosystem, otherwise if these residues are left into the ground as mulch and fertilizer improve the carbon balance. Another strategy to reduce gas emissions in the atmosphere is the use of pruning for energy purposes instead of fossil fuels. This change of use of pruning results in a reduction of use fossil fuels with a consequent reduction of CO_2 emissions in the atmosphere.

Calculation method: pruning residues used for energy

The CO_2 avoided emissions by the use of pruning as biomass for energy purposes are calculated on the basis of the methodologies and emission factors existing in the literature. The amount of wood biomass derived from annually pruning expressed in t d.m. ha^{-1} is associated with a coefficient which expresses the calorific value of the biomass, equal to 4.300-4.400 kcal / kg d.m. (source: ENEA 2008). The energy generated from pruning produced per hectare is calculated from kcal to KWh using a conversion factor (1 kWh corresponds to 859,8 kcal).

The CO_2 avoided emissions are calculated as a result of pruning biomass use for energy purposes using a reference emission factor for the thermoelectric power industry in Italy of 410.3 g CO_2 / KWh (ISPRA, 2011).

Tab. 2 Usable pruning residues, energy production and credits generated by avoided emissions due to the use of pruning for energy production (the avoided emission also take in account the pruning transport and chipping)

Annual pruning (t d.m./ha)	**Energy production from biomass (kW/ha/year)**	**EMISSIONS AVOIDED**

		(t CO_{2eq}/ha/year)
1,7	8.502	3,49

Positive impacts: reduction of emissions deriving from combustion (considering the replacing of pruning burning on site), soil organic improvement or reduction of soil disturbance (considering replacing of digging residues); increased biodiversity.

Negative impacts: increased operating costs due to the chipping and transport of pruning material; lower organic matter return into the ground if it is alternative to the practice of chipping residues.

Environmental synergies: CO_2 emissions avoided, reduction of fuel-related costs and independence regarding energy prices for farmers. This measure is directly linked to the EU climate and energy package (20-20-20 strategy).

Calculation method: residues used as fertilizer

The use of pruning as soil improvers, as well as replacing the use of fertilizers, implies the return to ground of a portion of carbon previously subtracted from pruning operations (Chiriacò et al., 2018 under review, Favoino and Hogg, 2008, Mondini et al., 2007). The increase of carbon in the soil as a result of pruning residues chipped and released on the ground or underground is calculated on the basis of the methodologies and emission factors existing in the literature. In the practice of landfilling, it is considered that part of the carbon contained in the buried residues is emitted as a result of the respiration processes of the soil, while another part remains in the soil increasing its carbon stock. However, changes in carbon stocks in the soil as a result of changes in agronomic management occur in a non-linear manner over the next 20 years (IPCC, 2006; Chiti et al., 2018). For this reason, individual measures would not be representative, but it is instead important to refer to studies that examine changes in carbon in the soil by taking historical series at least twenty years from which to extract average annual values. For the purposes of the present project, an average annual increase of organic carbon in the soil has been considered following the breaking or spreading of olive pruning residues derived from the literature (Freibauer et al., 2004; Triberti et al., 2008; Bos et al., 2017) included in a range between 0.16 and 0.40 t C / ha / year, corresponding to a mitigation potential equal to 0.59-1.47 t CO_2 / ha / year.

Tab. 3 Usable pruning residues, SOC variation and credits generated by the use of pruning as soil improver

Pruning (t d.m./ha)	**SOC variation t C/ha/anno**	**Credits t $CO_{2\,eq}$/ha/anno**
1,7	0,16-0,4	**0,59-1,47**

Positive impacts: reduction of emissions due to the production and transport of fertilizers, improvement of the soil structure; biodiversity increasing.

Negative impacts: higher operating costs due to the pruning shredding; increase in ground disturbance due to the residues burial.

Environmental synergies: less use of chemical fertilizers based on nitrogen and phosphorus with increase in biodiversity and air and water quality (ND, NEC Directive, WFD, Habitats Directive).

GREEN COVER

Description

A permanent grove is required to maintain the chemical-physical and microbiological fertility of the soil and the reduction of superficial erosion, which are extremely dangerous for soil loss and nutrient leaching. A temporary or perennial green cover is an applicable when the olive grove is located in an area with a good level of rainfall allowing the right contribution to the herbaceous species. Green cover can be considered as a real lawn covering the soil in the tree crops, where all biomass is periodically shed and left on the ground. In addition to the significant ecological benefits such as limiting nitrate leakage losses by adjusting the availability of nitrogen in the soil, improving soil structure, promoting water absorption, increasing soil porosity and bearing capacity, increase of biodiversity, higher system stability with reduction of phytosanitary measuresetc; green cover allows to maintain and increase the level of organic matter in soils. This results in a moderate increase in soil organic carbon (SOC) influencing the carbon balance in respect to BAU, with a contribution up to 50% to the main crop in some orchards / vineyards (Libro bianco, 2012). The permanent and spontaneous green cover (to be preferred) provides the covering of the soil for the entire vegetative cycle that is never affected by mechanical processing and it is particularly suitable in loose soils (with good drainage) and inclined soils. Spontaneous or plant species intentionally grown with a shallow root system to prevent competition with the olive roots for water and nutrients (eg *Poa pratensis* and *Poa annua*) are preferable. Natural green cover has to be preferred because it reduces the emission due to soil working and seed transport.

Calculation method

The increase in CO_2 absorption generated by the application of the natural green coverage is estimated on the basis of organic carbon data in the soils (SOC) deriving from literature with a range from 0.32 ± 0.08 to 0.6 t C / ha / year (Freibauer et al., 2014; Poeplau and Don, 2015; Libro bianco, 2012).

The practice of green cover in olive groves generates an increase in organic carbon in soils (SOC), which ranges on average from 1.17 to 2.20 tonnes of CO_2 / ha / year (IPCC, 2006 – Vol. 4 cap. 2 – Eq. 2.25).

Positive impacts: Soil stabilization and consolidation and increased water reserves; reduction of nitrate leakage losses by adjusting the availability of nitrogen in the soil; minor soil disturbance due to minor soil work; Improvement of structure, soiliness and soil bearing capacity; increased biodiversity.

Negative impacts: potential risk related to competition with the main species. Increase of emissions due to artificial introduction of cover crop species, due to soil working, transport of seeds, etc)

CONSERVATION TILLAGE

Description

Sustainable soil management is required to maintain the soiol chemical-physical and microbiological fertility and to reduce the superficial erosion extremely harmful to soil loss and nutrient leaching. Minimal and superficial processing (conservation tillage) are some applicable actions for an optimum soil management, especially when green cover cannot be applied due to poor rainfall. The adoption of conservative agronomic practices reduces the CO_2 emissions by increasing the stock of organic matter in the soil. Studies show the beneficial effect of Conservative Agriculture on the rate of organic matter into the ground (White Paper, 2012). In addition to mitigating effects on global warming, carbon storage in the soil is a desirable objective to support crop production and growth, to improve product quality, to increase water efficiency, to recover degraded soils, promoting ecosystem health (White paper, 2012).

Minimun tillage consists in leaving 30% of the soil covered by residues deriving from the mowing of cover crops. Soil is undisturbed between the harvesting and the subsequent sowing. The soil processing proposed are:

- simple surface machining with disc harrow or deep milling 8-20 cm;
- milling or machining with disk harrow only on the row (strips from 5 to 10 to 20-30 cm) between rows there are not worked, the depth varies from 30 to 5 cm.

Calculation method

The practice of minimum tillage in permanent crops generates an increase in organic carbon in soils (SOC), measured on the basis of the organic carbon data in the soils (SOC) derived from literature ranging from 0.55 to 1.10 tonnes of CO_2 / ha / year (Freibauer et al., 2014; White paper, 2012).

Positive impacts: soils stabilization and consolidation; increase of water reserves; low soil disturbance; structure improvement, soli porosity and bearing capacity; increased biodiversity.

Negative impacts: potential risk associated with reduced productivity and greater competition of spontaneous herbs with culture.

• **Other benefits:** reduction in expenditure for the Farmer (high petrol prices). This measure is directly linked to the climate and energy package (Strategy 20-20-20)

OLIVE PITTING MACHINE

Description

Olive kernels or stones are usually considered a waste. In recent years, however, it is increasingly considered as a co-product obtained during the transformation process of the olive fruits through an olive pitting machine. In particular, kernels can be reintroduced into the life cycle of olive oil, or other products, with important environmental benefits. In fact, even if the introduction of a new machine along the production cycle can lead apparently to a worse condition, the use of the stones as "fuel" for the heating of the water used in the process constitutes a greater benefit by balancing the higher electrical consumptions.

To understand the impact of the olive pitting machine it is possible to observe the result obtained in a study conducted in some Umbrian companies (Italy).

The study shows that the machine has an average consumption of about 0.12 kWh per kilogram of kernel produced or, reporting the consumption to 1 liter of EVO oil, about 0.05 kWh per liter. This amount corresponds, on average, to an overall increase in energy consumption of approximately 25%.

Reporting this value in terms of primary energy, to remove 1 kg of stones are necessary 1.1 MJ. This conversion it is necessary to highlight the benefits of this process. Considering the lower calorific value (LCV), i.e. the amount of heat evolved when a unit weight of the fuel is completely burnt, the kernels have a LCV of about 16.5 MJ per kg of product.

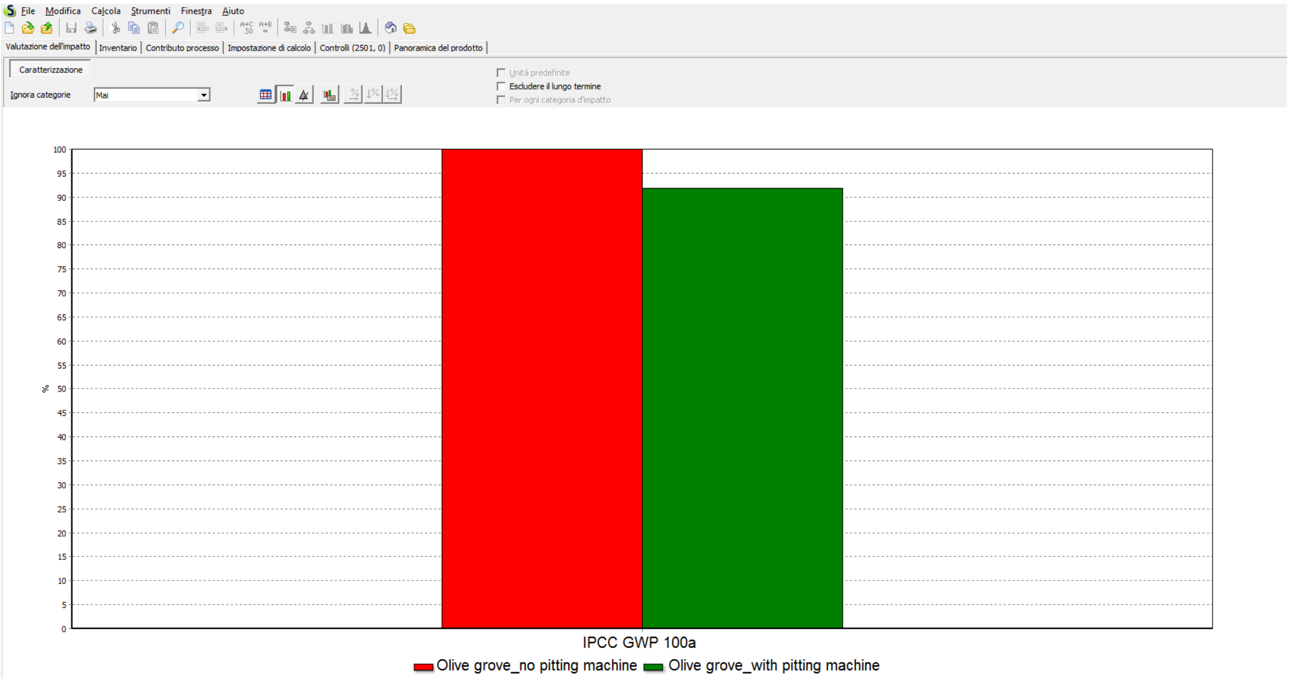
By comparing these values it is evident that the energy released through the combustion process of the material is much greater than the one required for its extraction. The process is therefore energetically very convenient.

By using the stones as a biomass for boiler feed and therefore for thermal energy production, it is possible to cancel the natural gas, or other conventional fuels, consumption with a significant reduction of the climate change gases emission and the energy demands of the production process.

Calculation method

The reduction of the CO_2 emitted by the application of an olive pitting machine has been estimated using SimaPro software. The software allows to convert the energy consumption (thermal, electric, diesel, petrol, etc.), the total amount of raw materials, etc. in an equivalent amount of greenhouse gasses.

Two different models have been developed. In the first model, without the olive pitting machine, the thermal energy requirements have been covered by a traditional boiler using natural gas. In the second model, instead, the thermal energy requirements have been covered by burning the olive kernels in a biomass boiler. All the other processes were not changed.



Comparing the results obtained, the percentage reduction of CO_2 emissions is about 9%. In terms of tCO_2 equivalent the difference between the models is about 1.4 tCO_{2e} per year.

PHOTOVOLTAIC SYSTEM

A photovoltaic system, also PV system or solar power system, is a power system designed to supply usable solar power by means of photovoltaics. It consists of an arrangement of several components, including solar panels to absorb and convert sunlight into electricity.

Farm buildings often have significant surface areas. Where there is exposition to solar radiation, photovoltaic panels could be installed to produce renewable electricity. Sometimes, electricity consumed from the grid could be replaced by the local renewable electricity produced (balance between the activity of the farm and the size of the installation).

The advantages associated with this technology are:

• Absence of polluting emissions during operation (avoided emissions: 0.5 ÷ 0.7 kg CO_2 per kWh product).

• Saves fossil fuels.

• Reliability of the systems since they have no moving parts.

• Minimized operating and maintenance costs.

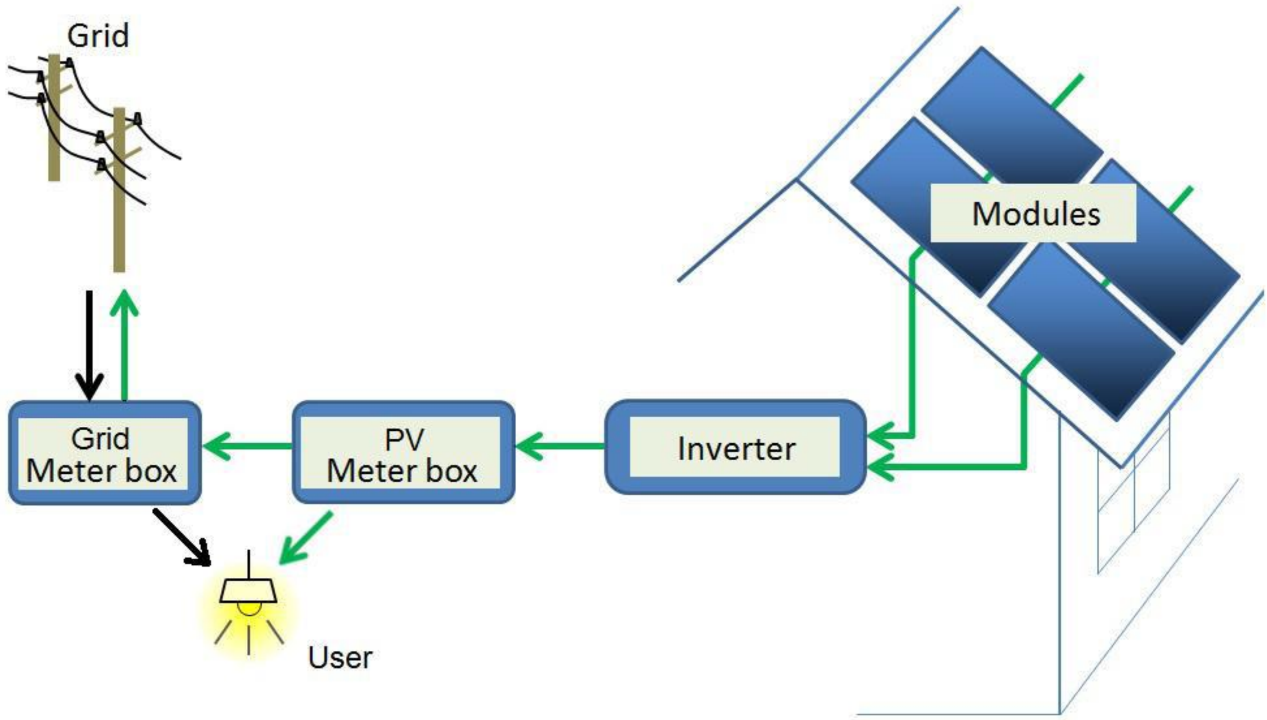
The principal disadvantages are:

• Solar energy has intermittency issues.

• Solar energy panels require additional equipment (inverters) to convert direct electricity (DC) to alternating electricity (AC) in order to be used on the power network.

• Solar panels efficiency levels are relatively low (between 14%-25%).

The most commonly used solution, is the one connected to the national utility grid. In this solution the energy produced by the PV system can be shared with the national utility (if the energy produced is greater than the one consumed) and the user become a producer. Vice versa, if the consumption is greater than the production, the user can always cover the needs through the utility grid.



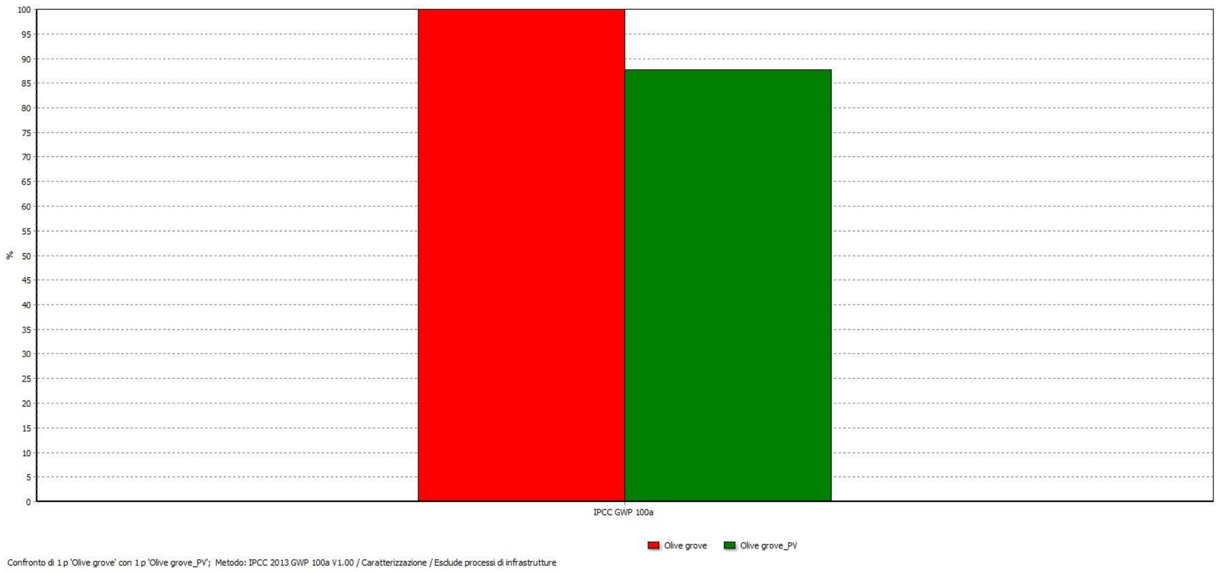
Calculation method

The potential cut of CO_2 emission due to the application of a PV system has been determined using SimaPro software.

As aforementioned, two different models have been developed:

• The first one without PV system (red).

• The second one with a PV system (green) that covers all the electrical needs of the oil mill.



Comparing the results obtained, the percentage reduction of CO_2 emissions is about 12%. In terms of tCO_2 equivalent the difference between the models is about 8.8 tCO_2e per year1.

However, this results are referred to specific geographical condition and, therefore, specific production. To determine exactly the % reduction of CO_2 emission a specific study has to be performed for the area selected considering:

• The climate and geographical condition of the regional selected.

• The installation way and then the corresponding parameters.

• The real consumption of the user and therefore the total power of the plant.

[1] The data are referred to a PV system installed in Umbria region (Italy) with a pic power of 12.5kW, tilt angle 30°, facing south.

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