**THE AGRIPHOTOVOLTAIC SECTOR AS A POSSIBLE IMPLEMENTATION TOOL IN SICILIAN ENERGY TRANSITION**

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**Abstract:** The energy transition represents a crucial topic for achieving the objectives of the 2030 Agenda which aims to promote sustainable development. The promotion and use of the latter is strongly incentivated by numerous European and national interventions, including Recovery and Resilience Plan, Energy and Climate Changes National Plan and the broader European Green Deal. The goal of this research is to highlight the great potential of the photovoltaic sector, showing how its versatility and adaptability constitute an important strength compared to other renewable sources. In particular, the paper investigates the process of integration between photovoltaics and agriculture that is occurring in the Sicily region, giving rise to agrifotovoltaics. After presenting the strategies proposed by the Environmental Energy Plan of the Sicily Region to address the green revolution and the energy transition of the island, the paper shows the main features of some projects for the construction of agricultural parks and agricultural plants. Furthermore, the current social debate that creates friction between the various stakeholders regarding the exploitation of the soil is actual, but the integration between the two sectors could trigger a virtuous circle that puts agricultural and livestock farms as the main beneficiaries of the economic and environmental advantages deriving from the agrifotovoltaics.

**Keywords:** Energy Transition1, Agriphotovoltaic Sector2, Circular Economy3, Sustainability4

**1.1** **Introduction**

Among the various typologies of renewable energy sources, a primary role could be reserved to photovoltaic sector, since for its technical characteristics and potential of integration with other technologies or activities, it is able to guide the energy transition. The goal of the present study is to analyze the photovoltaic sector, tracing its main dynamics, with a particular referential to the reference legislation in Sicily.

One of the starting points is the National recovery and resilience plan (NRRP), the document that each member state must prepare to have the access on next generation UE founds (PETERS et al., 2020), a tool introduced by the European Union for post-pandemic Covid-19 recovery (Assessorato dell’Energia Regione Sicilia (b),2019). The plan was created following the guidelines issued by the European Commission and is divided into three princes: digitalization and innovation, ecological transition and social inclusion (Servizio studi Senato, 2021). The European should achieve objectives at 2030 and 2050 are very ambitious (International Energy Agency, 2021). They aim for a progressive and complete decarbonization of the system ("net-zero") and a strengthening the adoption of circular economy solutions, to protect nature and biodiversity and guarantee a fair, healthy and respectful food system ". The mission is based on four parts:

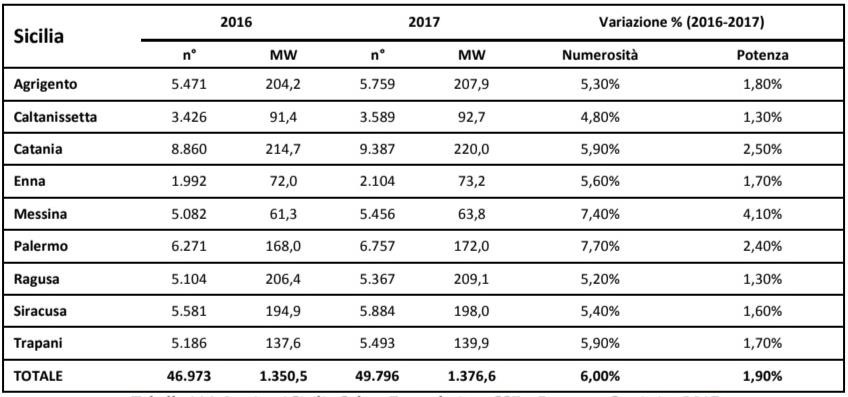
* M2.C1. Circular Economy and Sustainable Agriculture
* M2.C2. Renevable Energy, Hydrogen and Sustainable Mobility
* M2.C3. Energy efficiency and redevelopment of buildings
* M2.C4 Protection of the territory and water resource

It is evident that the role of renewable energy sources is central to the implementation of each individual component (Decreto Legislativo n.199, 8 novembre 2021). As regards in detail, photovoltaic and sunny energy, there are large investments both in the field of circular and sustainable agriculture (C1) and in the C2 concerning "renewable energy, hydrogen, network and sustainable mobility". Italy is among the countries with the highest direct consumption of energy in the food production of the European Union (third after France and Germany). Total energy costs represent over 20% of the variable costs for farms, with higher percentages for some productive subsectors (Confagricoltura, 2021). The proposed intervention aims to achieve the objectives of modernization and use of roofs of buildings for productive use in the agricultural, zootechnical and agro -industrial sectors for the production of renewable energy, thus increasing sustainability, resilience, green transition and energy efficiency of the sector and contribute to the welfare of animals (Dupraz et al., 2011). As part of the Mission C2, with the aim of increasing the share of energy produced by renewable energy sources and in line with the European and national objectives (Regolamento UE n.2221, 23 dicembre 2020), 1.1 billion euros have been allocated for agro-vault development. The agricultural sector is responsible for 10% of greenhouse gas emissions in Europe. With this initiative, the topics of sustainable agricultural production and energy production by renewable sources are addressed in a coordinated manner with the aim of spreading agro-vault systems of medium and large size. The investment measurement aims to make the agricultural sector more competitive, reducing energy supply costs, and at the same time improving climatic-environmental performance, therefore, to install a production capacity from agro-vault plants with a production capacity of 1.04 GW, which would produce about 1,300 GWh per year, with a reduction in greenhouse gas emissions estimated at around 0.8 million tons of CO2 (Elamri et al., 2018).

Since 2014 Sicily was characterized by a conspicuous slowdown relating to the installation of new plants, as a consequence of the exhaustion of the incentive availability derived from the 5th energy account. The solar photovoltaic, in line with the national trend, is certainly the most common technology. In fact, 100% of the municipalities of the Sicilian region has at least one. Its power equal to 1,238mw is able to produce electricity equal to the needs of about 620,000 families (table 1). 21 Municipalities have in these years invested in the photovoltaic sun in public building structures. In terms of installed power, the Municipality of Catania is the one with the greater installed power, with 766 kw overall.

* 1. **Review of the literature**

By placing the look on the regulatory context of the photovoltaic sector, the institution in charge is the Italian electrotechnical committee (CEI 85-25: 2008). The CEI is an association of private law, without profit, responsible in the national field of technical standard in the electrical engineer, electronic and telecommunications.

**Table 1**: Sicilian photovoltaic solar systems per province.

**Source**: PEARS

The main rules that apply to the sector are the following: CEI EN 61215: Photovoltaic Siliconian photovoltaic modules for terrestrial applications. Qualification of the project and homologation of the type (CEI 85-25: 2008); CEI EN 61646: Photovoltaic movie modules for terrestrial uses. Project qualification and type approval (CEI EN 61646: 2012; [CEI EN 62446-1](https://my.ceinorme.it/index.html?locale=it&detailsId=0000016627): 2016,); CEI EN IEC 61730-1: Qualification for the safety of photovoltaic modules. Security prescriptions; CEI EN IEC 61730-2: Qualification for the safety of photovoltaic modules. Prescriptions for tests (CEI EN IEC 61730-2: 2018); CEI EN 62108 concentration photovoltaic modules and systems. Qualification of the project and type approval (CEI EN IEC 61853-3: 2018); CEI 0-16: Reference technical rule for the connection of active and passive users to the networks at and Mt of the distribution companies of electricity (CEI 0-16: 2019,); CEI 0-21: Reference technical rule for the connection of active and passive users to the BT networks of the electricity distribution companies (CEI EN IEC 61853-4: 2019,). On February 7, 2012, in the regulatory context of Presidential Decree 1 August 2011, the circular of the Ministry of the Interior was published - Department of Fire Brigade regarding the installation of photovoltaic systems. Although photovoltaic systems do not fall within the activities subject to fire prevention controls, the installation could result in fire risks for the occurrence of interference with the combustion products ventilation system or for the propagation of flames inside or all external of the buildings. To avoid this, the photovoltaic system must be installed on incombustible coverage and elements. In addition, the location of the modules and electrical pipes must always allow the correct functioning and maintenance of any smoke and heat evacuators present, as well as considering the existence of possible fire -conveying routes (Scuderi et al., 2022). The photovoltaic system must then be equipped with an emergency command device.

* 1. **Materials and Methods**

In recent years there was an international debate concerning the scarcity of natural resources and the sustainable use of what the environment makes available. Among these is the soil, a resource of fundamental importance, dispute more and more from various activities that require massive exploitation such as those typical of the primary sector, but essential also for the development of energy from renewable sources (Agostini et al., 2021). In this context, Agrifotoltaic is inserted, a new and promising technology capable of guaranteeing integration and synergy of agriculture and production of renewable energy from photovoltaic systems. Starting from the analysis of the regulatory context, the lack of a structured and well-defined rule can be deduced (Regolamento UE n.1999). The design phase of an agrivoltaic system is much more complex and articulated, which requires the multidisciplinary skills of experts who can evaluate the environmental impacts of the photovoltaic structures on crops and the territory. Although the diffusion is still quite limited, there are multiple studies that have been highlighting the massive benefits for several years now that an installation of this kind can guarantee, in terms of surrender, quality and quantity of crops. The beneficial effect is also evident in terms of the reduction of emission of CO2, water savings and fighting to desertification (Del Borghi et al., 2022). Designing an agrivoltaic system requires transversal skills ranging from engineering to agronomy up to new technologies. For this reason, the presence of a multidisciplinary team of which can evaluate and develop technical and agronomic solutions to maximize the result of coexistence between photovoltaic and agriculture (AFV) is required, reflecting, for example, on the structure, height and distance between Panel modules and on the percentage of expected shading in relation to climate change in the various months of the year. The fundamental prerequisite for the construction of any AFV system is a detailed description of the site that includes the description of the soil (agricultural, industrial, abandoned quarries, landfills), the surface and the type of plant cover, the slope, the type of exposure to Solar rays, the presence of institutional constraints. In this regard, it is important that the ground is not affected by urban, environmental and landscape constraints (Walston, 2016). The installation of photovoltaic panels on an agricultural land change the cultivation methods mainly for two reasons: reduction of direct radiation available to crops; limitations to the movement of agricultural machines for the footprint of the support structures (Dinesh and Pearce, 2016). The total or partial coverage of a crop with photovoltaic panels determines a modification of the direct radiation available to crops and, to a lesser extent, the other microclimatic conditions. A species sown with a high cultivation density will be most affected by the obstacles due by the structure compared to a species characterized by low crop density, arranged in rows (fruits, lives, vegetables cultivated with guardians), which frequently benefits from support structures for itself or for irrigation systems (localized irrigation, antibrin irrigation) or protection (anti -frusal networks). Therefore, the choice of possible species to be cultivated below of photovoltaic covers is linked to numerous physiological aspects of the plant, and agronomic relating to the cultivation techniques. It should also be considered that an appropriate adjustment of the slope of the panels during the cultivation season could guarantee the optimization of the coexistence of the solar panel over the agricultural crop (Zingale et al., 2022). Photovoltaic coverage could also protect crops from adverse climatic phenomena (hail, frost, strong rains) and, in periods of greater radiation, a protection given by the panel can also reduce the occurrence of water stress, for the reduction of the evapo-transposition of the crops (Solar power Europe, 2020).

One of the main differences in agro-photovoltaic systems compared to the traditional photovoltaic system is the possibility of growing conventional crops under photovoltaic panels. An agro-photovoltaic system is a system, frequently with sun chase, built on mechanized support structures. The latter are mounted the main horizontal axes on which the secondary axes that support solar panels are hinged. The structure, also known as tracker, can have two different configurations, mono -axial and biassial. The monoassial solar pursuers are the most common and capture solar radiation by revolving around their axis during the course of the day, while the biassial pursuers have two rotation axes, perpendicular to each other, which allow, through a sophisticated electronic system, to place i Panels constantly focused on the direction of the sun, when the hours of the day and seasons vary. The structures vary from a minimum of 2.2 meters up to a maximum of 5 meters in height and have an average interference distancing of 6 meters. The plant therefore allows not to compete with the agricultural use of the land, since, in every type of configuration, the arrangement, the appropriate fixed or mobile geometries, the height and the distancing are such as not to affect the normal activity agricultural. In addition, it is possible to increase the interval between the trackers to leave free corridors at rest for cultivation changes and for programmed maintenance practices with the support of Precision Farming techniques.

* 1. **Results and discussions**

In the regions with more favorable conditions for extensive breeding and pasture, agrivoltaic integration can encourage production and self -supply -sidelines of the Foragera basic, allowing to increase the livestock making it more appropriate to corporate skills and therefore to the best enhancement of the grazing surfaces (Amaducci et al, 2020). The key point is the search for balance between profitability of photovoltaic installation and agricultural production. The Sicilian region is also active in this area, where the energy plan aims to triple photovoltaics production, passing from 2 TWH to 6 TWH by 2030 with investments that will bring the region from 1.5 GW to 4 GW of power. The Government, through the funds allocated by the NRRP, aims to make the agricultural sector more competitive, reducing the energy supply costs (today estimated to over 20% of the variable costs of companies and with even higher tips for some herbivorous and granivor sectors), and at the same time improving climatic-environmental performance (Caruso et al 2021). Specifically, the objective of the investment is to install a production capacity from 2 GW agrovoltaic plants, which would produce approximately 2,500 GWh per year, with a reduction in greenhouse gas emissions estimated at around 1.5 million tons of CO2.

Due to its position at low latitudes, climatic characteristics and territorial availability, Sicily is one of the Italian regions where the greatest investments in agrovoltaic are concentrated. In particular, in most of the Sicilian districts there is a strong commitment to try to build plants of various sizes and powers. Specifically, the installation of 2 plants in the province of Agrigento for a power of 79 MW, 8 plants in the province of Catania for a total power of 153 MW, a plant in the province of Caltanissetta for a power of 185 MW, 4 plants in the province of Enna for a capacity of 128 MW, 9 plants in the province of Palermo for a capacity of 723 MW, 2 plants in the province of Ragusa for a capacity of 63 MW and 5 plants in the province of Syracuse for a capacity of 252 MW.

To these are added a plant that falls territorially in the provinces of Palermo, Agrigento and Trapani for a power of 71 MW, a plant that falls territorially in the provinces of Palermo and Trapani for a power of 141 MW and a plant that falls territorially in the provinces of Catania and Enna for a power of 40 MW. The strong attractiveness of Sicily is evidenced by the commitment of various international players who have chosen the Sicilian territory as a hub of experimentation and investment for the agricultural sector. Specifically, Amazon, with the aim of 100% managing its business with clean energy by 2025, has signed an agreement with the company energy for the construction of two new agro-photovoltaic plants in Mazara del Vallo and Paternò with a capacity production of 104MW. The project will also save the environment over 62,000 tons of CO2 every year, the equivalent that can be achieved by planting over 3.1 million trees. 80% of the energy produced will be destined for Amazon and 20% will be placed on the market, contributing to the energy needs of about 20,000 households.

* 1. **Conclusions and future perspectives**

Risks and criticalities related to the installation of photovoltaic systems are primarily attributable to the availability of the land. The application of large installations, for surfaces in the order of tens or even hundreds of hectares, is an intervention of significant environmental and landscape alteration, whether it is established on previously cultivated land, or involving surfaces in non-productive conditions. The economic and environmental sustainability of agriculture and its social acceptability will therefore depend on the ability to build a system of rules within which effective projects of landscape and environmental integration can find space. The risk and criticality scenario also includes problems arising from the difficulty and uncertainty of the authorization process, from the regulatory vacuum that characterizes the legislative context and from a tendency towards obstructionism and social skepticism towards agrifotovoltaic systems.

Taking advantage of the benefits deriving from the installation of agrivoltaic systems results in a strong push towards innovation in agricultural processes, which are made environmentally sustainable and more competitive, among the most relevant:

* Reduce soil evaporation and recover rainwater
* Protect crops from extreme weather events by offering shade and weather protection
* To recover part of the abandoned agricultural land, allowing the achievement of the decarbonisation objectives.
* Reduction of the water requirements of crops
* Create agro-energy communities to distribute economic benefits to citizens and agro-energy companies in the area.
* Create new jobs and increasing agricultural income by combining renewable energy production with agriculture and pastoralism.

In light of the benefits previously analyzed, the cost item must be interpreted taking into consideration not only the economic aspects, which certainly have an impact on company financial statements, but also the ecological and environmental gain in terms of sustainability.

The structures necessary for an agrivoltaic installation have a very high cost and require a strong commitment on the part of the farms that have to bear the economic outlay. With this in mind, an incentive system is desirable so that the incentive tools can be expanded both from direct investments and from external interventions. If on the one hand the costs can be around 30-40% more than a traditional ground-mounted photovoltaic system, on the other hand the agronomic advantages deriving from the shading created by an agrovoltaic system must be included in the global evaluation of the economic convenience, which allows a substantial reduction in plant transpiration and therefore requires less water. Consequently, the spread of agro-photovoltaics in Sicily could allow the emergence of high environmental and economic sustainability farming systems, also increasing the link between agricultural production and the territory. The fulcrum of this process is the Sicilian entrepreneurial reality: the agricultural sector has ample scope to establish itself as a new delivery model for Sicilian farms (Sturiale and [Scuderi,](https://www.scopus.com/authid/detail.uri?authorId=55621175200) 2016). The latter will thus have the opportunity to integrate photovoltaic generation into the business, with a view to which electricity production, soil and vegetation maintenance are efficiently combined and competing in achieving production, economic and environmental objectives.

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