DOI: 10.2478/vjbsd-2025-0005

CASE STUDY

ADVANCED AGRIVOLTAICS IN ITALY: INNOVATION, SUSTAINABILITY, AND REGULATION FOR THE FUTURE OF RURAL ENERGY

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This article offers a critical analysis of the evolving legal framework governing advanced agrivoltaic systems in Italy, with a focus on their structural integration into sustainable land use and rural energy policy. Distinct from conventional ground-mounted photovoltaics, these systems support the simultaneous performance of agricultural and energy-producing functions. The study examines recent regulatory interventions – most notably the Unified Renewable Energy Act and the NRRP incentive programme – while addressing persistent implementation challenges. Particular emphasis is placed on the legal qualification of agrivoltaics, procedural complexities, and the need for coherent governance strategies within a multifunctional territorial paradigm.

Keywords: agrivoltaic, rural energy, photovoltaic system, Italian law, advanced agrivoltaic systems, climate resilience

Technical and Regulatory Distinction Between Agrivoltaics and Photovoltaics

Advanced agrivoltaic systems[1] exhibit marked distinctions from conventional photovoltaic installations due to their structural configuration, which exerts a direct influence on land utilization and agricultural practices[2].

Agrivoltaic modules are installed on elevated supports, typically at a minimum height of 2.5 to 3 meters and are spaced apart to permit direct cultivation of the land beneath them[3]. This configuration facilitates the absorption of sunlight and precipitation by the soil, while simultaneously enabling the operation of agricultural machinery between the modules. This, in turn, ensures the continuity of conventional farming practices (De Luca, 2024).

Conversely, photovoltaic modules are installed directly on the ground, thereby creating an extensive surface that limits or entirely prevents agricultural activity. This results in the land being transformed from agricultural use to one dedicated exclusively to energy production[4].

The technical configuration of agrivoltaic systems is also referenced in both national and regional regulations[5], which promote the sustainable use of agricultural land, especially in areas of high landscape and natural value. Ministerial Decree No. 436 of December 22, 2023[6], establishes specific criteria for advanced agrivoltaics, requiring that modules be elevated and spaced

1 In Italy, the terms agrovoltaico and agro-fotovoltaico are widely employed, while in English the equivalents are agrivoltaics or agro-photovoltaics. In German, the term is agri-photovoltaik; in French, it is referred to as agrivoltaïque, agrivoltaïsme, or agri-photovoltaïsme; and in Japan, the concept is known as solar sharing. The concept of agro-photovoltaics was first introduced in the early 1980s by Adolf Goetzberger, who was then director of the Fraunhofer Institute for Solar Energy Systems (ISE) in Germany. In his seminal publication Potatoes under Panels (translated from the original German title), Goetzberger outlined the theoretical possibility of combining agricultural production with solar energy generation, utilizing the same space in a complementary manner. This approach, which was revolutionary at the time, laid the groundwork for the development of the advanced agrivoltaic systems that are known today. A couple of decades later, Italy emerged as one of the pioneers in the practical application of the agrivoltaic model. In Apulia, one of the first agrivoltaic systems in Europe was constructed, with a total capacity of 1 MW, thus marking a significant milestone in the field of renewable energy and the integration of agriculture and solar energy.

2 Another category of system distinct from agrivoltaic systems is represented by agrisolare installations. This term refers specifically to the installation of photovoltaic systems on buildings used for productive purposes in the agricultural, livestock, and agro-industrial sectors. The fundamental objective of this configuration is to promote the energy transition of productive agricultural enterprises, ensuring the environmental sustainability of their activities without affecting the use of agricultural land. In contradistinction to agrivoltaic systems, agrisolare does not entail the direct integration of energy production with agricultural activities on the ground. Instead, it is limited to the placement of photovoltaic modules on already existing built surfaces.

3 Agrivoltaic modules must meet specific technical and regulatory criteria to qualify as advanced systems under Italian legislation. According to Ministerial Decree No. 436 of December 22, 2023, the panels must be installed on elevated supports at a minimum height of 2.5 to 3 meters above the ground. These supports must not utilize concrete foundations or other structures that are difficult to remove, ensuring the reversibility of the installation. Furthermore, the construction methods must guarantee effective compatibility and integration with agricultural activities, providing support for plants or systems such as parcel irrigation, mobile or partial shading, and crop protection. Spacing criteria are also mandated to enable continuous cultivation of the land beneath the panels. The implementation of monitoring systems is obligatory, following guidelines established by the Council for Agricultural Research and Analysis of the Agricultural Economy (CREA) in collaboration with the Energy Services Operator (GSE). These monitoring systems evaluate the impact of the installation on crop productivity, water conservation, and overall agricultural functionality, ensuring compliance with hybrid land utilization principles.

4 This change often triggers concerns regarding landscape integrity, as highlighted in rulings by the Council of State, which emphasizes the lower visual and environmental impact of agrivoltaic configurations compared to traditional systems.

5 Including differentiated guidelines in regions like Emilia-Romagna and Apulia, which prioritize advanced systems in areas of high agricultural or environmental value. These regional frameworks reflect a broader effort to reconcile renewable energy objectives with the preservation of agricultural and landscape heritage.

6 Decree of December 22, 2023, No. 436, Support Scheme for Photovoltaic Systems on Agricultural Land (so-called "Innovative Agrivoltaic") – Implementation of Article 14, Paragraph 1, Legislative Decree No. 199/2021 – Mission 2, Component 2, Investment 1.1 of the National Recovery and Resilience Plan (NRPP).

apart to preserve the agricultural functionality of the land, and provides significant incentives for projects that meet these criteria. This regulatory approach is intended to promote a model of "solar sharing" in which the integration of energy production and agriculture is achieved in a genuine manner (Muratori, 2024).

Despite the numerous advantages offered by advanced agrivoltaic systems, the installation of such structures continues to face resistance from public administrations, which often invoke landscape protection and alleged issues related to changes in land use. While these arguments may be more understandable in the case of traditional ground-mounted photovoltaic systems – which, by their nature, prevent agricultural land from being used for purposes other than energy production – they appear less justified in the presence of innovative technological solutions such as advanced agrivoltaic systems. These systems adopt energy production models that allow for the hybrid use of agricultural land, thereby preserving and often enhancing the underlying agricultural activity.

The lack of a clear regulatory and administrative distinction between the two types of installations perpetuates a restrictive approach, potentially slowing progress toward ecological transition goals.

The distinction between agrivoltaic and traditional photovoltaic installations, both technically and legally, has been repeatedly affirmed in case law. Courts have emphasized that agrivoltaics represent a technological solution more integrated with agricultural and landscape requirements. The Council of State, in several rulings[7], has established that landscape (Casini, 2022; Tubertini, 2022; Fracchia, 2022; Gola, 2002/2023; Bartolini, 2024)[8] restrictions applicable to traditional photovoltaic installations cannot be automatically extended to advanced agrivoltaics. This position is founded on the recognition that the technical configuration of agrivoltaic systems (Goetzberger et al., 1982; Schindele et al., 2020; Proctoret al., 2021) – characterized by spaced support columns designed to hold photovoltaic panels without altering the characteristics of the underlying land – preserves and often enhances agricultural activity. Additionally, these systems have a lower landscape impact and ensure a more sustainable use of land compared to traditional ground-mounted photovoltaics.

Nonetheless, case law has clarified that agrivoltaic systems cannot be automatically exempted from landscape and environmental restrictions. It is incumbent upon the competent authorities to assess, on a case-by-case basis, the compatibility of the installation with the territorial context, evaluating its technical features designed to minimize land consumption and preserve the agricultural functions of the land.

In this context, the Council of State recently addressed the issue of "agricultural continuity" in agrivoltaic systems. This concept, however, remains inadequately defined. The judges of Palazzo Spada recognized that, although these systems may theoretically allow agricultural activities such as sheep grazing, olive cultivation, or beekeeping beneath the panels, insufficient attention has been paid to the actual implementation of these activities[9]. The court deemed it sufficient, albeit in a somewhat generic manner, to merely ensure the theoretical possibility of carrying out agricultural activities on most of the land occupied by the panels, without effectively verifying the practical impact on the rural environment.

This approach, however, fails to address the central issue of whether and to what extent agrivoltaic projects can concretely integrate energy production and agriculture in a sustainable manner. Consequently, there is a need to define stricter parameters and detailed evaluation criteria to ensure that each project is genuinely compatible with land conservation objectives and the functional integration of agriculture and photovoltaics.

This assertion is further substantiated by lower court rulings that have clarified the absence of buffer zones around protected assets does not inherently render an area unsuitable for agrivoltaic installations[10].

In such cases, it is imperative to conduct a comprehensive analysis of the specific project, examining its technical characteristics and evaluating the impact of the installation on both the landscape and natural resources. This evaluation must be conducted on a case-by-case basis to determine its compatibility with conservation requirements.

Notwithstanding the aforementioned judicial orientations, the implementation of landscape regulations in Italy remains intricate and frequently disparate. In numerous regions and municipalities, local authorities adopt restrictive approaches, necessitating the acquisition of additional permits or subjecting agrivoltaic installations to specific environmental assessments. While these practices aspire to safeguard the land, they frequently result in delays and bureaucratic encumbrances, impeding investment in agrivoltaic technologies in domains where they could offer the most substantial benefits.

In conclusion, although case law has clarified that advanced agrivoltaics deserve differentiated treatment compared to traditional photovoltaics, implementing these principles requires greater uniformity at the territorial and regulatory levels. It is therefore essential that a balance is struck between environmental protection and the promotion of renewable energy in order to encourage the dissemination of these innovative technologies while respecting agricultural and landscape values.

NRPP and the Regulatory Framework for Advanced Agrivoltaics

The National Recovery and Resilience Plan (NRPP), in implementing European directives, has allocated substantial financial resources to the promotion of advanced agrivoltaic systems, with the objective of preserving the agricultural functionality of the land.

The provisions of Ministerial Decree No. 63/2024[11], in conjunction with the Operational Rules of the GSE (Gestore dei Servizi Energetici), delineate the eligibility criteria and incentive mechanisms for agrivoltaic projects. To qualify for funding, installations must meet agricultural and landscape sustainability requirements, including a minimum elevation of photovoltaic panels between 2.5 and 3 meters above the ground level, and sufficient spacing between modules to enable continuous cultivation underneath.

7 See Italian Council of State, Decision No 8029 of 30 August 2023, (2023) 52. In Rivista giuridica dell'ambiente; Regional Administrative Court (TAR) of Apulia – Lecce, Judgment No 1200 of 4 November 2024.

8 Within the Italian legal system, the concept of the "landscape" as a subject is characterized by its autonomy, distinguishing it from related subjects such as urban planning (territorial governance) and the environment. This autonomy gives rise to a differentiated legal regime, characterized by a division of competences between the State, Regions, and local authorities, the scope of protection, and the procedural regime. This legal regime of landscape protection is enshrined in the Cultural Heritage Code and is part of the principles established by the Italian Constitution in Article 9, as amended by Constitutional Law No. 1 of 2022, which stipulates that the Republic protects the landscape and the historical and artistic heritage of the Nation.

9 Italian Council of State, Decision No 8258 of 11 September 2023.

10 Regional Administrative Court (TAR) Sicily – Palermo, Judgment No. 2475 of 26 August 2024. In Diritto Ambiente e Paesaggio no. 14, 2024.

11 Decree-Law No 63 of 15 May 2024, Urgent Provisions for Agricultural, Fishing, and Aquaculture Enterprises, as well as for Enterprises of National Strategic Interest (the so-called 'Agriculture Decree').

These technical criteria are mandatory for all operators seeking access to NRPP funds, which provide non-repayable grants covering up to 40% of the installation cost.

An additional economic incentive set forth in the GSE Operational Rules (Muratori, 2024) concerns the remuneration of energy generated by agrivoltaic systems. For installations that meet the requisite technical specifications, the GSE offers incentive tariffs that are calculated based on the portion of energy shared or fed into the grid. This ensures a substantial economic return for operators. This mechanism is analogous to the previous feed-in tariff[12] model, as it guarantees remuneration rates above the market average and complements the capital contributions available for installation

In order to ensure that the integration of energy sources does not have a detrimental effect on the agricultural utilization of land, the GSE stipulates the implementation of monitoring systems that must remain operational throughout the project's duration

Each incentivized installation is required to be equipped with a network of sensors to monitor soil moisture, permeability, and annual agricultural productivity. These systems are essential for assessing the impact of the installation on the surrounding environment and for recording real-time data on soil health and agricultural biodiversity. The data collected must be periodically submitted to the GSE, which uses it to verify ongoing compatibility between agricultural production and energy generation. In instances of non-compliance, operators may be subject to administrative penalties, including the partial or total revocation of incentives (De Luca, 2024).

The system of incentives and regulations under discussion places advanced agrivoltaic systems in a relatively superior position in comparison to ground-mounted photovoltaic installations. This is due to the fact that it promotes an energy production model that preserves the use of agricultural land and reduces landscape impact. In contrast to photovoltaic systems, agrivoltaic installations are regarded as multifunctional technologies and benefit from dedicated regulatory support that enhances their hybrid use and environmental functionality.

Characteristics and Differences Between Standard and Advanced Agrivoltaic Systems

The distinction between standard and advanced agrivoltaic systems is a pivotal factor in the regulation and evaluation of integrated energy solutions, significantly affecting the degree of integration between agricultural and energy production, access to incentives, and the feasibility of installing systems in constrained areas.

A fundamental distinguishing element between "standard" and advanced systems lies in the minimum height of the modules from the ground. While the Guidelines (Colantoni et al., 2021)[13] do not encompass any specific height requirements for standard agrivoltaic systems, they stipulate minimum heights of 1.3 meters for livestock activities and 2.1 meters for agricultural cultivation in the case of advanced systems. This technical disparity implies that, in contrast to advanced plants, standard systems are not obligated to implement innovative solutions or hybrid land use[14].

In advanced systems, the spatial configuration of the modules allows agricultural activities to be undertaken underneath the structures, thereby facilitating effective integration between agricultural and energy components. By contrast, standard systems are limited to a combined use of the land, allowing cultivation only in the portions left free between the rows of panels[15]. However, both types are required to meet minimum requirements, including allocating a minimum of 70 per cent of the surface area to agricultural activities and limiting the overall coverage of the modules to 40 per cent of the surface area.

Authorization Schemes and Reference Legislation

The regulation of advanced agrivoltaic plants is governed by a complex and constantly evolving legislative framework, the primary objective of which is to reconcile energy production from renewable sources with the protection of agricultural land and the landscape. Legislative Decree No. 199 of 8 November 2021, which transposes Directive (EU) 2018/2001 (RED II), constitutes the initial regulatory foundation, delineating the criteria for the classification of areas suitable for the installation of photovoltaic and agrivoltaic systems[16].

In accordance with Decree-Law No. 63 of 15 May 2024, which is colloquially referred to as the ‚Agriculture Decree' (Scalia, 2024), Article 20 of Legislative Decree 199/2021 was supplemented by Paragraph 1-bis. The purpose of this addition was to impose stringent limitations on the installation of ground-mounted photovoltaic systems in agricultural areas. These systems may now be installed only in specific contexts, such as degraded areas or areas already used by existing systems.

By contrast, advanced agrivoltaic facilities are exempt from these restrictions due to their design characteristics (Clarich, 2021; Cartei, 2022;

12 Tariffs are applied on an incentive basis for each kWh fed into the grid.

13 See also Linee guida in materia di impianti agrivoltaici (Guidelines on Agrivoltaic Systems) (27 June 2022) https://www.mase.gov.it/sites/default/files/archivio/allegati/PnRR/linee_guida_impianti_agrivoltaici.pdf 35 ff.

14 An "experimental agrivoltaic system" – also referred to as an advanced system – is, in essence, an agrivoltaic installation that, in accordance with the National Recovery and Resilience Plan (NRRP) and pursuant to Article 65, paragraphs 1-quater and 1-quinquies, of Decree-Law No 1 of 24 January 2012 (converted, with amendments, by Law No 27 of 24 March 2012), meets the criteria set forth under Article 2(b). These criteria require: the implementation of innovative integrated solutions with elevated photovoltaic modules, specifically designed to avoid interference with the continuity of agricultural and pastoral activities; and the installation of monitoring systems, consistent with the CREA-GSE guidelines, to evaluate the impact of the photovoltaic system on crops, water use efficiency, agricultural productivity across different crop types, and the continuity of operations of the affected agricultural enterprises.

15 For a detailed analysis of the negative environmental compatibility assessment regarding the construction of a photovoltaic installation on land falling within the production specifications for certain PDO and PGI products, see TAR Sicilia – Catania, Sez I, 6 February 2024, no. 630. The court found that the project submitted by the energy operator did not meet the criteria for agrivoltaic systems – neither in their standard nor advanced forms – as it failed to demonstrate compliance with the minimum requirements set out in the Guidelines of 27 June 2022, including the ratio between the surface area covered by photovoltaic modules and the area effectively allocated to agricultural cultivation.

16 The legislation stipulates that, in defining the relevant discipline for suitable areas, the decree takes into account the need to protect cultural and landscape heritage, agricultural and forestry areas, air quality, and water bodies. Priority is given to the use of built surfaces, such as warehouses, industrial buildings, and car parks, as well as areas designated for industrial, artisanal, service, and logistics purposes. Furthermore, the decree stipulates the verification of areas that are deemed unsuitable for repurposing for alternative uses, including agricultural surfaces that have become unviable for cultivation. This is undertaken in accordance with the characteristics and availability of renewable resources, network infrastructure, and electricity demand. Additionally, it considers the location of energy demand, potential network constraints, and the development potential of the electrical grid.

Strambi, 2021)[17] and are considered a priority for achieving the objectives of the NRPP and the National Plan for Complementary Investments (PNC). This recognition translates into a simplification of the authorization processes for such facilities, which can also be built in areas not classified as ‚suitable', provided they meet the requirements for the advanced category[18].

The regulatory framework for agrivoltaic systems has recently been enriched by the approval of the Unified Renewable Energy Act (Testo Unico FER; Tedioli, 2024)[19], which represents a significant tool for streamlining and rationalizing the renewable energy sector. The act aims to streamline the approval process for such systems, while acknowledging the strategic importance of advanced agrivoltaic systems in promoting environmental sustainability and safeguarding agricultural land.

Among the most significant new features, Article 6 introduces three simplified administrative regimes: free activity, simplified authorization procedure (PAS), and single authorization (AU). These regimes are applied in accordance with the power and location of the installations, but are subject to specific conditions and limits:

1. Free activity regime

This regime, applicable to agrivoltaic installations with a capacity of up to 5 MW that ensure the continuity of agricultural and pastoral activities, eliminates the need for approvals or authorizations, except in cases involving landscape or environmental restrictions. Such administrative simplification marks a significant step toward the broader adoption of agrivoltaic systems, particularly in agricultural areas not classified as suitable, provided specific criteria for biodiversity protection and the preservation of local agro-food traditions are met.

As outlined in the relevant legislation, under this regime, no declarations or approvals are required unless landscape restrictions apply. In such cases, the competent authority must render its decision within thirty days, instead of the usual forty-five-day period. For refurbishment or upgrading interventions on existing or previously authorized installations, landscape authorization is not required, regardless of the location of the installation.

2. Simplified authorization procedure (PAS)

This applies to installations with a capacity ranging between 5 MW and 10 MW, or in cases where non-absolute landscape restrictions are present. In order to comply with the PAS, stricter documentation requirements must be met, including the obligation to provide a surety bond to ensure site restoration at the end of the installation's operational lifespan[20].

As stipulated in Article 7, paragraph 2, of the Unified Renewable Energy Act (Testo Unico FER), PAS is mandatory when the project area falls within: a) areas subject to cultural heritage restrictions (Legislative Decree No. 42/2004); b) protected areas. Law No. 394/1991) or Natura 2000 sites; and c) other restrictions outlined in Article 20, paragraph 4, of Law No. 241/1990, such as the protection of landscape, environmental assets, and public safety.

An additional innovation introduced by PAS is the possibility of expropriating land designated for works associated with installations, pursuant to Article 8, paragraph 1-bis, of the Testo Unico FER.

Lastly, the legislature has established a maximum timeframe of one year for the commencement of work on installations authorized through PAS, representing a significant acceleration compared to the previous regulations, which allowed a three-year period exclusively for project completion.

3. Single authorization (AU)

This procedure is a prerequisite for installations with a capacity exceeding 10 MW or those located in areas subject to significant restrictions. The procedure may include an Environmental Impact Assessment (EIA)[21] and can be conducted through the Regional Single Authorization Measure (Provvedimento Autorizzatorio Unico Regionale, PAUR), in accordance with Article 27-bis of Legislative Decree No. 152/2006. However, regions retain the option to adopt the single procedure outlined in Article 9 of the Unified Renewable Energy Act (Testo Unico FER), equivalent to the single authorization provided under Legislative Decree No. 387/2003[22].

Advanced agrivoltaic installations have specific features and regulatory provisions. Projects located in agricultural areas with a capacity equal to or exceeding 12 MW are subject to a regional environmental screening process, unless they are situated in areas classified as suitable under Article 20 of Legislative Decree No. 199/2021.

A salient element enshrined in the Consolidated RES Act pertains to the unequivocal proscription of the artificial dissociation of the capabilities of facilities, with a view to evading the implementation of the Single Authorization (AU). In such circumstances, the regions are endowed with the prerogative to oversee the aggregation of capabilities emanating from the erection of multiple facilities within a congruent territorial milieu, thereby establishing the imperative to employ the AU to guarantee a more meticulous and transparent administration of authorizations.

The Operating Rules of Ministerial Decree No. 436 of 22 December 2023 (Agri-Voltaic Incentives Decree) remain a central reference, establishing technical criteria and methods for accessing incentives (Spina, 2024). In particular, the decree sets ambitious targets, including the installation of 1.04 GW of new capacity by 2026, financed through NRPP funds. The incentives encompass feed-in tariffs for shared energy and capital grants, which have the potential to cover up to 40 per cent of expenses. A specific reserve of 300 MW is allocated to farmers for installations up to 1 MW[23].

17 The exemption is explicitly provided in Article 5 of Decree-Law No 63 of 15 May 2024, which allows the installation of such systems as part of projects implementing investment measures under the NRRP (Mission 2, Component 2 – Investment 1.1).

18 As clarified in the response by the Ministry of Agriculture, Food Sovereignty, and Forestry (MASAF) to Parliamentary Question No 3-01225, where the land does not fall within one of the categories deemed "suitable" under the Agriculture Decree, only advanced agrivoltaic systems may be lawfully installed on agricultural land.

19 Legislative Decree No 190 of 25 November 2024, titled Regulations on Administrative Regimes for Renewable Energy Production (commonly referred to as the "Testo Unico FER" or the "Decree"), entered into force on 30 December 2024. From that date, Regions are granted 180 days to align their regulatory frameworks with the Decree's provisions.

20 The Procedura Abilitativa Semplificata (PAS), or simplified authorization procedure, applies to projects that do not require a ‚permit' and are not subject to an environmental impact assessment. Depending on the circumstances and the possible involvement of several administrative bodies, the duration of the procedure ranges from a minimum of 30 days to a maximum of 75 days.

21 In Italian: Valutazione di impatto ambientale (VIA).

22 The third ‚track' is the Single Authorization application, which must be submitted to the Region for plants below 300 MW and to the MASE for plants above this threshold. The Ministry is also responsible for authorizing all offshore installations: the Single Authorization for these does not require the prior consent of the region concerned.

23 The objective of the decree is to encourage the installation of a minimum of 1.04 GW of new capacity by 2026, with a quota of 300 MW allocated to farmers, with plants of up to 1 MW. These incentives, financed by NRPP funds, include capital grants and premium tariffs on shared energy.

However, the regulatory framework governing standard agri-voltaic plants[24] remains subject to interpretation. The author contends that these plants should be subject to the restrictions outlined in the Decree on Agriculture, as they bear similarities to traditional ground-mounted photovoltaic plants. This standpoint is founded on an interpretation of Article 65 of Decree Law no. 1 of 24 January 2012, which explicitly differentiates between traditional photovoltaic systems and advanced agrivoltaic systems with regard to access to incentives, while making no explicit mention of basic agrivoltaic systems. Conversely, there are those who advocate a broader interpretation of the ratio legis, emphasizing that the legislation should promote all forms of integration between energy and agriculture, including those that are not advanced.

The Unified Renewable Energy Act (Testo Unico FER) introduces a number of innovations, including the establishment of acceleration zones. The purpose of these zones is to expedite and simplify the authorization processes for renewable energy installations, as outlined in Article 12. The identification of these zones is to be conducted by the Energy Services Operator (Gestore dei Servizi Energetici, GSE) by 21st May 2025, with a view to prioritizing anthropized areas or locations that are deemed suitable for renewable energy development. Potential candidate areas include, but are not limited to, decommissioned industrial sites, parking lots, built-up surfaces, waste disposal sites, and degraded lands that are unsuitable for agricultural activities.

By 21 February 2026, regions will be required to adopt specific plans to define these acceleration zones, ensuring their alignment with Strategic Environmental Assessment (SEA) procedures. This planning phase will be pivotal in coordinating the newly introduced provisions with existing regional regulations concerning "Suitable Areas" (Aree Idonee), thereby guaranteeing a consistent application of the principle of environmental protection, as specified in Article 12, paragraph 2.

From a procedural standpoint, the introduction of acceleration zones promises a significant reduction in the time required for authorization processes. For agrivoltaic installations located within these zones, the applicable authorization regime depends on the procedural framework in use. In cases where the free activity regime or the Simplified Enabling Procedure (PAS) is applied, any landscape restrictions will necessitate a mandatory but non-binding opinion from the competent authority. Conversely, for installations requiring Single Authorization (AU), the issuance timelines are significantly shortened, facilitating a swifter and more efficient approval process.

Nevertheless, this innovation is not without its critical issues. The absence of integration between acceleration zones and the recently issued "Suitable Areas" Decree (Tedioli, 2024), coupled with the lack of uniform national criteria, poses a significant risk of generating disparities in application across regions. Such inconsistencies could compromise the overall efficacy of what is otherwise a potentially crucial tool for advancing the energy transition (Lucifero et al., 2019; Favaro, 2020; Boeve et al., 2021; Krämer et al., 2024) European Environment Agency, 2023).

The Testo Unico FER represents a pivotal step in the regulatory rationalization of agrivoltaic systems, consolidating existing principles while establishing a clear and consistent framework that carefully balances the imperatives of energy development and agricultural protection. In particular, the decree reaffirms the possibility of constructing advanced agrivoltaic systems even in areas classified as agricultural under urban planning regulations. However, this is subject to the condition that specific criteria are met, including the protection of biodiversity[25], the preservation of local agro-food traditions[26], and the safeguarding of the landscape context[27]. The practical implementation of these provisions will require meticulous harmonization with regional and local regulations, alongside a concerted effort to foster effective collaboration between industry operators and public authorities. Such measures are essential to maximize the potential of this innovative technology and ensure its alignment with broader sustainability and land use goals.

The SUER Platform[28] (Sportello Unico Energie Rinnovabili)[29] operates through an interoperable system that enables integration and data exchange with other digital platforms at national, regional, and local levels. This interoperability ensures that data and documents provided by operators or involved administrations can be transmitted, utilized, and updated automatically among various entities, thereby eliminating the need to submit the same information multiple times to different systems.

The SUER Platform facilitates a more streamlined and coordinated management of all applicable administrative regimes, ranging from notifications for free-building activities to Single Authorization (AU), including the Simplified Enabling Procedure (PAS).

Recent regulatory innovations have seen the emergence of the SUER Platform, a digital tool developed and managed by the GSE. The primary objective of the SUER Platform is to centralize and simplify authorization procedures for new renewable energy installations, including agrivoltaic systems. In the context of agrivoltaic projects, the platform offers the potential to reduce documentary burdens and expedite the approval process.

In the context of advanced agrivoltaic systems, the platform is designed to facilitate continuous monitoring of authorization procedures, with the objective of ensuring the attainment of the Integrated National Energy and Climate Plan (PNIEC[30]) goals and ecological transition objectives. It is further intended to provide personalized assistance to operators and administrations throughout the entire process, and to reduce bureaucratic burdens through its integration with other digital systems, thereby facilitating streamlined information flows and enhancing access to incentives.

This innovative approach promises greater efficiency and transparency in managing renewable energy projects and strengthens the alignment between administrative processes and national sustainability objectives.

24 The term ‚simple' agrivoltaics is employed to denote a configuration of photovoltaic panels installed in a linear arrangement on the ground, thereby permitting the cultivation of plants between the panels.

25 It is imperative that plantings ensure the protection and, if possible, the enhancement of the biological variety present in the area, whilst avoiding interventions that could potentially compromise natural ecosystems.

26 Projects must be compatible with the area's traditional agricultural activities, preserving crops, production techniques or other practices that characterize the area's agricultural and food identity.

27 In order to ensure the harmonious integration of the installations within the rural landscape, it is essential to minimize their visual impact and to respect the aesthetic and natural characteristics of the area.

28 The system is scheduled to be operational within 120 days of the adoption of the single models for authorization procedures, with the objective of enhancing the transparency and efficiency of the authorization process.

29 Ministerial Decree of 23 October 2024 (SUER Platform Decree), Ministry of the Environment and Energy Security.

30 The final version of the PNIEC, submitted to the EU Commission in June 2024, reiterates that Italy must achieve 131 GW of renewable energy capacity by 2030. Of this total, approximately 79.2 GW is expected to be generated from solar power, 28.1 GW from wind energy, 19.4 GW from hydroelectric power, 3.2 GW from bioenergy, and 1 GW from geothermal sources. Further insights can be obtained from https://www.mase.gov.it

By fostering seamless collaboration among stakeholders, the SUER Platform underscores its potential as a transformative tool for the renewable energy sector.

Finally, from a technical standpoint, the Operational Rules delineated in Ministerial Decree No. 233 of May 16, 2024, which was developed in conjunction with CREA, ENEA, GSE, and RSE, underscores the significance of innovative spatial configurations[31]. A notable element of these rules is the stipulation of a minimum height requirement of 2.1 meters for modules, a provision that facilitates the undertaking of agricultural activities beneath the panels, thereby enabling a hybrid utilization of the land.

This approach has been endorsed by recent jurisprudence, which has reaffirmed the need to assess the landscape and agricultural impact of installations on a case-by-case basis. This judicial stance underscores the importance of avoiding overly simplistic comparisons between advanced agrivoltaic systems and traditional ground-mounted photovoltaic installations, recognizing the distinctiveness and added value of agrivoltaic solutions (Gioia, 2023)[32].

Implementation Challenges and Regulatory Lessons from the 2024–2025 Incentive Cycle

The "AgriVoltaic Development" programme (Tedioli, 2025)[33] is part of the interventions financed under Italy's National Recovery and Resilience Plan (NRRP)[34]. The initiative was refinanced and regulated through Ministerial Decree No. 436 of 22 December 2023, and its implementation has recently been extended through the adoption of Directorate Decree No. 123 of 27 March 2025, issued by the General Directorate for Financial Incentives and Programmes of the Ministry of the Environment and Energy Security (MASE), which reopened the application window for accessing the relevant incentives.

The rationale underlying this initiative lies in the Ministry's clearly perceived need to overcome the critical issues encountered during the 2023 implementation phase, particularly the failure to exhaust the available funding despite a high number of applications. The reopening is intended to ensure a more efficient use of the remaining NRRP resources and to recalibrate access mechanisms to better align with actual market conditions. Accordingly, the measure seeks to accelerate investments in advanced agrivoltaic systems, in line with both the ecological transition goals and the multifunctional use of agricultural land[35].

From a functional perspective, the programme is designed as an integrated policy tool bridging the gap between renewable energy transition and the sustainable and productive enhancement of agricultural land. This convergence is not merely aspirational: it finds concrete legal grounding in both the European Green Deal and the binding principles set forth in Regulation (EU) 2021/241[36], establishing the Recovery and Resilience Facility, which requires that investment measures respect the principle of no net land take.

This structural approach has been further consolidated through the inclusion of advanced agrivoltaic systems within the framework of the new Consolidated Act on Renewable Energy Sources (so-called "T.U. FER")[37].

This legislative act assigns agrivoltaic installations a distinct legal status compared to conventional ground-mounted photovoltaic systems. Notably, Article 12(4) of the T.U. FER provides for streamlined authorization procedures for agrivoltaic installations, subject to compliance with the specific technical and environmental standards identified by subsequent ministerial decrees.

Such differentiation – both substantive and procedural – confirms the recognition of agrivoltaics as a strategically autonomous model of sustainable development, capable of combining renewable energy generation with the preservation of rural landscapes and agricultural productivity. Agrivoltaics is thus no longer perceived as a mere variant of photovoltaics, but rather as a standalone regulatory and technological paradigm with its own coherence within both EU environmental law and national agricultural policy.

This strategic importance is further reflected in the financial commitment made under the NRRP: a budget of €1.1 billion has been allocated to support the deployment of advanced agrivoltaic systems. This allocation signals the Italian government's ambition to transform agrivoltaics into a structural lever for the future of the agricultural sector, and a key instrument in achieving the climate and energy goals set out in the National Integrated Energy and Climate Plan (PNIEC), while aligning with the evolving trajectories of European agri-environmental law.

Objectives and Structural Issues in the First Competitive Procedure (2024)

The first operational phase of the "AgriVoltaic Development" measure was launched by the Gestore dei Servizi Energetici (Energy Services Operator, GSE) through the implementation of Ministerial Decree of 12 September 2022. The related online application window was open from 4 June to 2 September 2024. The initiative drew significant attention from stakeholders, with a total of 643 applications submitted for a cumulative capacity of 1,547.9 MW. Of these, 540 projects were deemed eligible and ranked within the available incentive quotas (GSE, 2024).

Despite the substantial interest and the fact that the capacity requested exceeded the initially available quota of 1,040 MW, the outcome of the procedure highlighted several structural weaknesses that hindered the full allocation of the financial resources – which amounted to more than €1.1 billion under the NRRP[38].

A significant number of projects that were initially deemed eligible and placed in a favorable position in the ranking were subsequently

31 The guidelines also include a requirement for an agronomic report demonstrating the maintenance of agricultural productivity in the long term.

32 In particular, Council of State rulings nos. 8260 and 8263 of 11 September 2023 censured administrative measures that ignored the substantial differences between these two types of plants (see also T.A.R. Puglia – Lecce, 12 February 2022, no. 248 and 11 April 2022, no. 586).

33 This measure was introduced by the Decree of the Minister for Ecological Transition of 15 June 2022 and subsequently governed in operational terms by the Ministerial Decree of 12 September 2022.

34 More specifically within Mission 2, Component 2, Investment 1.1, which aims to increase the capacity for renewable energy generation.

35 Applications must comply with the criteria set forth in the implementing decree and must be submitted in accordance with procedures that ensure full coexistence between crop cultivation, livestock farming, and energy generation systems. To this end, Article 3 of Ministerial Decree No 436 of 22 December 2023 explicitly requires that installations eligible for incentives be equipped with environmental, climatic, and agronomic monitoring systems, in order to assess the actual impact on agricultural productivity and land use.

36 See, in particular, Article 5(3)(c) of Regulation (EU) 2021/241. From this perspective, agrivoltaics is not conceived as a mere placement of photovoltaic panels on agricultural land, but rather as an integrated model functionally aligned with the resilience of rural systems, capable of contributing to decarbonization goals while simultaneously supporting the competitiveness of agricultural enterprises.

37 Cf. subpara. Authorisation schemes and reference legislation

38 Cf. art 2, Ministerial Decree No 436 of 22 December 2023.

withdrawn, not finalized, or excluded, due to a combination of administrative[39] and market-related challenges. Among the latter, increased implementation costs – driven by inflationary pressure and supply chain disruptions – undermined the bankability of many proposals. Moreover, applicants faced uncertainties regarding the technical definition and legal scope of "advanced agrivoltaic systems,"[40] which impose stringent integration requirements between agricultural activity and energy production through technologically complex and often costly solutions[41].

These difficulties prompted the Ministry to reopen the application window through Directorate Decree No. 123 of 27 March 2025, aimed at reallocating the unspent resources in a more targeted manner. The new call is open from 1 April to 30 June 2025, and submissions must be made through the GSE's dedicated digital platform (Portale Agrivoltaico).

The rationale for the reopening – though expressed in general terms – clearly refers to the dual objective of maximizing the utilization of residual NRRP funding[42] and adapting the procedural design to evolving market dynamics. It is not merely a corrective technical measure, but rather a strategic response to ensure the selection of mature projects capable of achieving financial closure and construction within the tight NRRP deadlines, which expire on 30 June 2026[43].

Withdrawn, Rejected, or Non-Implemented Projects

A further structural issue concerns the significant number of projects that, despite having been ranked as eligible, were not ultimately developed, thereby leaving a considerable portion of the financial allocation unused. According to official data released by the GSE, a notable share of selected applicants either withdrew from the incentive scheme or failed to submit the required supporting documentation, undermining the actual feasibility of project execution.

Multiple factors contributed to this outcome. Some applicants encountered delays or obstacles in securing the necessary permits, often due to interpretive uncertainty on the part of competent authorities regarding the classification of "advanced agrivoltaic systems." In other cases, projects were hampered by flawed financial planning, including overestimated revenue projections that proved unsustainable in light of rising material costs and the operational burdens associated with dual-use integration – especially on plots with marginal agronomic value or regulatory constraints.

Compounding these challenges was a widespread lack of clarity surrounding the technical eligibility of certain agrivoltaic configurations, particularly in relation to: agronomic monitoring systems (e.g. required sensors, data collection platforms); module elevation or rotational support structures; the actual feasibility of agricultural coexistence beneath or around the photovoltaic arrays.

One of the most problematic provisions – Article 4(3) of Ministerial Decree No. 436/2023 – requires applicants to ensure either the preservation or the improvement of agricultural productivity. This condition, while consistent with EU principles on land use neutrality, has proved extremely difficult to comply with in practice. It presupposes a detailed agronomic design already at the application stage, often in the absence of any historical yield data (e.g. on previously uncultivated land or following ownership changes) (CREA, 2024).

In light of these widespread and well-documented issues, the Ministry's decision to reopen the call in 2025 appears to be grounded in a systematic analysis of inefficiencies that emerged during the first round. Not only is the reopening aimed at "maximizing the use of residual funds," as expressly stated in the decree, but it also reflects an effort to align administrative procedures with actual implementation conditions and to prioritize projects that are already mature and capable of meeting the NRRP's strict timeline.

Mandatory Agricultural Integration as an Eligibility Criterion

One of the defining features of the "advanced" agrivoltaic model, as outlined in Ministerial Decree No. 436 of 22 December 2023, is the strict requirement of functional integration between agricultural activity and solar energy production. Access to capital grants under the NRRP is conditional upon demonstrated compatibility between the photovoltaic installation and the continuous and effective performance of agricultural operations on the same land.

This principle is rooted in Article 65(1)(d) of Regulation (EU) 2021/241, which mandates the preservation of agricultural land use when deploying measures financed through the Recovery and Resilience Facility. In accordance with this obligation, the decree requires applicants to submit, already at the initial application stage, a comprehensive agronomic plan drafted by a certified professional. This plan must not only demonstrate the theoretical possibility of dual use but also provide technical and economic proof of feasibility, taking into account soil characteristics, crop types, and the interaction with the photovoltaic structures[44].

Multiple operational issues have arisen in this context. Firstly, there is significant territorial variability in the availability of historical agronomic data and in the applicants' ability to document agricultural productivity trends. As a result, fulfilling the requirement of "productivity invariance or improvement" – as set out in Article 4(3) of the decree – is particularly challenging, especially in cases involving newly cultivated land or plots previously left fallow.

Secondly, uncertainty persists regarding the level of detail required in the agronomic plan. According to GSE guidance, the plan must include a year-by-year crop rotation schedule, indicating: surface areas and species to be cultivated; cultivation techniques and machinery to be used; irrigation methods; the deployment of monitoring technologies capable of verifying both productivity and the synergy between crops and solar structures[45].

Although such equipment is commercially available, it entails additional costs that are often prohibitive for small and medium-sized farms.

Another often overlooked but legally significant issue concerns the nature of the title granting legal availability of the land. In many cases, applicants are not the landowners but operate under agricultural lease or loan agreements. For this reason, the contractual title must explicitly authorize, in addition to farming, the installation of an agrivoltaic plant in compliance with NRRP regulations. As agrivoltaic installations may significantly alter the structural and functional characteristics of the land, generic lease clauses are insufficient and have led to several rejections. Even more problematic are cases where lease agreements explicitly prohibit energy use of the land, especially within simplified lease regimes under Law No. 203/1982.

39 This refers, in particular, to delays in permitting procedures, interpretative uncertainties regarding the classification of agrivoltaic systems, and urban planning incompatibilities.

40 As defined in Article 4 of Ministerial Decree No 436 of 22 December 2023.

41 See also the FAQs published by the GSE in the months following the opening of the 2024 application window.

42 Cf. the aforementioned Directorate Decree, recital No 5.

43 Article 24 of Regulation (EU) 2021/241.

44 Annex 2, point 1.3 of Ministerial Decree No 436 of 2023.

45 Annex 2, point 1.6 of Ministerial Decree No 436 of 2023.

Furthermore, Article 10(2) of the decree stipulates that the incentive is contingent upon maintaining the plant in operation for at least twenty years. Accordingly, the applicant's legal entitlement to the land – whether based on real rights, lease, or gratuitous loan – must cover the entire duration of the incentive scheme. Contracts that do not meet this criterion or lack automatic renewal clauses have been deemed ineligible unless supplemented by formal declarations from the landowner.

Complicating matters further are overlapping legal constraints derived from agricultural law, land use planning, and environmental protection, such as pre-emption rights, common land regimes (usi civici), or landscape conservation restrictions. Failure to assess these aspects at the planning stage has often led to project exclusion, not due to technical deficiencies, but because of legal inadequacies in the documentation.

Therefore, the legal structuring of land rights is not a mere formality but a substantive requirement for eligibility. Numerous exclusions have been recorded due to insufficient lease terms, missing agrivoltaic clauses, or inconsistencies with binding agrarian rules. This reality underscores the need for multidisciplinary coordination between agronomists, legal experts, and energy consultants – a practice that, while once optional, has now become essential for successful access to public incentives.

Reconfiguring the Surface Right for Advanced Agri-Voltaics: From Exclusive Use to Functional Coexistence

One of the most intricate legal challenges raised by the deployment of advanced agri-voltaic systems in Italy concerns the compatibility between this dual-purpose land model and the traditional civil law instrument of the diritto di superficie (surface right), as regulated by Article 952 of the Italian Civil Code. This right, originally designed to derogate from the principle of accessio (Article 934 c.c.), allows a party to construct and retain ownership of buildings or installations on another's land. Historically, the surface right has been extensively used in conventional ground-mounted photovoltaic (PV) projects, where its exclusive nature grants the energy operator full and sole control over the land for the duration of the installation. Such exclusivity, while suited to PV fields that exclude any other productive use of the soil, becomes structurally inconsistent with the normative requirements of advanced agri-voltaics.

Under the regulatory framework introduced by Ministerial Decree of 22 December 2023, no. 436 and further detailed by the GSE's Operational Rules of 16 May 2024, no. 233, advanced agri-voltaic plants are characterized by mandatory and monitored coexistence between agricultural activity and solar energy production. The agricultural function must remain primary, traceable, and uninterrupted, with the photovoltaic infrastructure physically and functionally integrated to support such continuity. This entails not only spatial compatibility (e.g., elevated modules, adequate spacing) but also legal compatibility in the form of land titles that preserve the usability of the soil for farming purposes. In this context, the conventional diritto di superficie, typically construed as an exclusive and long-term real right of enjoyment, must be re-examined and recalibrated.

Recent doctrinal interpretations and contractual practices suggest a reconceptualization of the surface right as a functional and coexistent legal instrument. This approach involves limiting the right's object to only those portions of land physically occupied by PV structures (modules, cabling, foundations), excluding any blanket exclusivity over the entire plot. Moreover, specific clauses should be incorporated to impose obligations of non-interference with agricultural practices, to reserve cultivation rights to the landowner or a third-party operator, and to ensure shared monitoring obligations aligned with the CREA-GSE guidelines. From a civil law perspective, such redefinition is fully legitimate, provided the content of the right is clearly determined, publicly registrable, and consistent with the social function of real rights (see Cass., sez. trib., ord. 23 April 2024, no. 10930). These modified surface rights also retain full economic and legal transferability, and they remain eligible for use as guarantees in project financing frameworks.

On the fiscal side, the legal evolution of the diritto di superficie in agrivoltaic settings has triggered significant implications. The transfer or constitution of such a right is subject to a registration tax of 9% under Art. 1, Tariff I, d.P.R. 131/1986, regardless of whether the land is classified as agricultural. However, following the 2024 Budget Law, income deriving from the establishment or transfer of surface rights – including for land held for over five years – must now be treated as taxable miscellaneous income (redditi diversi) under Art. 67 of the TUIR. This reform overturned the previous principle that excluded long-held land from capital gains taxation and was recently clarified by the Revenue Agency in its responses to official queries (interpello nos. 224/2024 and 129/2025). Additionally, where the surface right is paired with usufruct or similar rights, or where the income surpasses thresholds defined under legislative decree no. 99/2004, the agricultural nature of the enterprise itself may be jeopardized. The risk is particularly acute in cases where proceeds from non-agricultural uses of the land exceed the 10% cap on ancillary income, potentially resulting in the loss of status as a società agricola, with direct repercussions on tax regimes and eligibility for subsidies.

In sum, the surface right – if restructured as a non-exclusive, purpose-specific, and spatially limited legal construct – can play a pivotal role in enabling compliant and economically viable agri-voltaic installations. Far from being obsolete, this centuries-old legal tool is undergoing a doctrinal and contractual renaissance, adapting to the demands of multifunctional land use, environmental sustainability, and energy transition in the rural economy.

The Role of the GSE in the Post-Admission Phase: Assessing Technical and Agronomic Coherence

Admission to the ranking list under the agrivoltaic incentive scheme does not automatically entitle the applicant to receive public funding. Rather, it constitutes the first stage of a multi-phase evaluation process in which the Energy Services Operator (GSE) plays a central role as the implementing body. After the initial selection, the applicant must undergo a second technical-agronomic review, the outcome of which determines whether the project will be granted access to the incentive scheme through the formal signing of a performance-based funding agreement.

During this post-admission phase, the GSE is responsible for assessing both the engineering design of the photovoltaic system and the technical viability of the agronomic component, based on the criteria set forth in Ministerial Decree No. 436/2023 and its annexes[46]. The evaluation includes a cross-check of: declared data in the application; content and internal consistency of the agronomic plan; soil characteristics and climatic conditions; system layout and potential interference between structural elements and arable surfaces.

The review is not merely formal or documentary in nature. Instead, it is a qualitative technical assessment aimed at verifying: the actual compatibility between the plant configuration and agricultural activities; the agronomic rationale for the chosen crop types; the appropriateness of proposed cultivation methods given the site-specific pedoclimatic conditions; and overall compliance with the productivity preservation requirement.

46 In particular, see Annex 2, point 1.3 et seq.

Failure to ensure internal coherence within the project documentation – or the submission of generic, non-contextualized agronomic information – may lead to the exclusion of the project, even if it was previously ranked as admissible[47].

The GSE has explicitly stated that this post-admission review is mandatory, comprehensive, and applies to every applicant, regardless of size or project category. It is not conducted by random sampling, nor is it subject to discretion. Rather, it constitutes an essential filtering mechanism designed to ensure that only projects with verifiable, high-quality agricultural integration are ultimately eligible for public support. In this sense, the GSE's role in the post-ranking phase confirms the structural centrality of agriculture in the Italian conception of "advanced" agrivoltaic systems.

Post-Admission Supporting Documentation: Obligations, Contents, and Operational Challenges

Following admission to the ranking list, applicants are required to submit a complete set of supporting documents, without which the incentive agreement cannot be formalized, and the corresponding funds cannot be disbursed. This documentation plays a pivotal role in the second-level assessment conducted by the GSE, which is designed to verify the internal consistency between what was declared at the application stage and what has actually been designed and planned in technical and agronomic terms.

Among the documents to be submitted is the final engineering project of the photovoltaic system, which must include precise layout diagrams, structural drawings, and technical specifications. Equally essential is the revised agronomic plan, which must be signed by a qualified professional and must clearly illustrate the type and rotation of crops to be cultivated, the cultivation methods and machinery intended for use, the irrigation techniques to be adopted, and, above all, the compatibility of the proposed agricultural activities with the physical configuration of the photovoltaic system. The agronomic plan must also describe the monitoring systems in place to ensure ongoing verification of agricultural productivity and the actual integration between energy production and farming operations.

A further document of crucial legal relevance is the declaration of compliance with urban, planning, and landscape regulations, which must confirm that the project is legally admissible under applicable land use rules and environmental constraints. Finally, the applicant must provide the legal title to the land, which must expressly authorize both the conduct of agricultural activities and the installation of an agrivoltaic system for a period that is consistent with the 20-year operational timeframe prescribed by the incentive regime.

One of the main challenges reported by stakeholders concerns the short time window allowed for the submission of this additional documentation, which often requires new technical elaborations or substantial revisions of previously submitted materials. This issue has been particularly acute in the case of medium- and large-scale projects, where the agronomic plan originally attached to the application has frequently proven inadequate or lacking in detail, requiring full revision and renewed professional validation.

The GSE has also stressed the importance of coherence between the technical documentation and local spatial planning instruments. It has been made clear that even a project that has secured a Unified Authorization (AU) may still be excluded from the incentive scheme if it conflicts with territorial constraints such as hydrogeological risks, landscape protections, or agricultural zoning policies. In other words, authorization for construction or grid connection is not sufficient in itself; applicants must also demonstrate that the project aligns with broader territorial, environmental, and agronomic planning frameworks, as required under Article 20 of Legislative Decree No. 199/2021.

All documents must be submitted digitally, bearing a qualified electronic signature, and accompanied by the relevant self-declarations under Presidential Decree No. 445/2000. Failure to submit the full documentation within the prescribed deadlines results in automatic exclusion from the procedure, and the corresponding quota of incentives is reallocated to other applicants through roll-down mechanisms in the ranking list.

GSE Clarifications: Practical Guidance on the Implementation of the Agrivoltaic Decree

Although not formally binding in a legal sense, the clarifications issued by the Gestore dei Servizi Energetici (GSE) are of significant interpretative value, as they reflect the operative framework the implementing authority intends to apply when assessing compliance with Ministerial Decree No. 436 of 22 December 2023 (commonly referred to as the "Agrivoltaic Decree"). These clarifications – many of which were published as responses to frequently asked questions (FAQs) – shed light on several technical and legal issues that are pivotal to understanding how the incentive scheme is actually administered.

One of the key points addressed concerns the eligibility of applicants. The GSE has unequivocally stated that the project owner must be a professional farmer as defined by applicable national legislation. Third parties who are not recognized as agricultural operators are excluded from participating in the scheme, although consortia and cooperatives composed exclusively of eligible farmers are allowed to apply. Moreover, an agricultural holding may consist of either a single cadastral parcel or multiple non-contiguous parcels, provided that evidence of operational unity and business coherence is submitted.

Significant attention has also been devoted to the agronomic component. The GSE reiterated that the submitted agronomic plan must demonstrate both the continuity of agricultural activity and its effective integration with energy production. It is not required that the entire surface beneath the modules be cultivated, but the cultivated area must be agronomically meaningful, relative to the scale and design of the project. Interestingly, land that is not currently under cultivation may still be considered eligible, as long as the plan includes a concrete and credible proposal for agricultural reactivation.

Another essential topic addressed is the obligation to implement agronomic and energy monitoring systems.

The GSE has confirmed that beneficiaries will be required to report data throughout the entire duration of the incentive, using a dedicated digital platform. The data must include, inter alia, crop types, yields, farming techniques, any treatments applied, and how agricultural operations interact with the photovoltaic infrastructure. A static agronomic plan submitted at the application stage is insufficient: applicants must demonstrate ongoing compliance with the dual-use objectives, or risk forfeiting the incentive.

Further clarification has been provided with regard to the design of the photovoltaic system, particularly the support structures. These must be conceived in such a way as to ensure mechanized agricultural operations and must not impede access to the cultivated area. Both fixed and movable systems are permitted, provided that they are specifically engineered to support dual-use integration. Notably, the GSE has emphasized that structures

47 Cf. Article 7(5) of Ministerial Decree No 436 of 2023.

mounted on greenhouses or that merely allow for incidental planting do not qualify as advanced agrivoltaic systems.

The GSE has also responded to procedural questions about the application process. For instance, it has confirmed that possession of all relevant permits is required at the time of application; it is not sufficient to have merely initiated the permitting process. Likewise, missing or essential documentation cannot be integrated after submission, except within the narrow limits allowed by the decree. The current call applies exclusively to the incentive regime established by Decree No. 436/2023, and the compatibility with other aid schemes (e.g., under the CAP or the NRRP) must be evaluated on a case-by-case basis, according to the specific rules on cumulation.

Taken together, these clarifications demonstrate the GSE's strict but coherent approach to the implementation of the agrivoltaic incentive scheme. They reflect a consistent commitment to upholding the agricultural integrity of supported projects, reaffirming that the dual-use requirement is not ancillary, but a structural condition for eligibility. Far from being a mere technical formality, the agronomic integration must be planned, implemented, and monitored throughout the entire project lifecycle. This interpretative stance reinforces the idea that advanced agrivoltaics in Italy is conceived as a genuinely hybrid model, requiring not only technical compatibility but also functional synergy between land-based energy production and agricultural productivity.

Beyond the Call for Proposals – Towards a Systemic Governance Model for Advanced AgriVoltaics

The reopening of the application window for agrivoltaic incentives marks a significant turning point in the institutional consolidation of Italy's advanced agrivoltaic model. Far from being a mere technical adjustment to a previously flawed procedure, the measure reflects a broader awareness of the implementation barriers that emerged during the initial 2023 call and constitutes an effort to adapt the regulatory framework to the operational realities faced by agricultural operators and energy developers.

Yet, beyond the procedural dimension, a fundamental need remains: the development of a coherent and integrated governance framework for agrivoltaics – one that cannot rely solely on time-limited NRRP schemes or on the fragmented evolution of administrative case law. What is still lacking is a systemic legal vision capable of reconciling the dual imperatives of ecological transition and agricultural sustainability.

Costs of Installations and Financing Solutions

Despite the numerous advantages of advanced agrivoltaic systems, regulatory and financial challenges often represent significant obstacles for potential investors and farmers. The stringent requirements imposed by the GSE are a primary barrier to the adoption of this technology, particularly by small and medium-sized agricultural enterprises (SMEs). These include specifications for module configuration, environmental monitoring obligations, and high upfront installation costs, which are only partially covered by NRPP funding. This underscores the necessity for supplementary subsidies or financing mechanisms to facilitate access to incentives without imposing unsustainable financial burdens (Muratori, 2024) on businesses. Potential measures include the introduction of progressive financing systems[48] or targeted incentives specifically designed for SMEs.

48 The utilization of subsidized funds or the implementation of an incentivized leasing system would facilitate the amortization of costs over a more protracted period.

To address these challenges, innovative financing solutions are gaining traction, such as long-term energy purchase contracts, commonly known as Power Purchase Agreements (PPAs). These instruments, which have gained prominence on the global stage, empower energy producers by ensuring a predetermined price for electricity over a period of 10 to 15 years, thereby providing a stable and predictable revenue stream.

Agrivoltaic installations represent a particular area of benefit for farmers, as they can be financed through PPAs, thus eliminating the need for traditional bank loans. This mechanism not only facilitates the adoption of agrivoltaic technology by agricultural SMEs but also serves to reduce financial constraints.

Technical Challenges, Maintenance, and Innovative Solutions

The elevated and spaced configuration of agrivoltaic modules, while advantageous for agricultural integration, introduces technical complexities in both construction and maintenance. Support structures must be significantly more robust than those used for traditional photovoltaic panels to withstand mechanical stresses and weather conditions. This increases installation costs and necessitates regular maintenance to ensure structural integrity and operational efficiency. Additionally, maintaining energy efficiency and the safety of agricultural operations requires frequent technical interventions. These include cleaning the panels and adjusting their tilt angles to optimize solar capture while minimizing excessive shading of the underlying soil. Such intensive management can lead to higher operational costs over time, potentially limiting the economic sustainability of the installation, particularly in regions with moderate agricultural profitability.

Durability and Long-Term Sustainability

A critical challenge associated with advanced agrivoltaic systems is their durability and environmental sustainability over the long term. Designed to operate on elevated structures, these systems are exposed to adverse environmental conditions, such as wind, rain, thermal fluctuations, and ultraviolet radiation, which accelerate wear and corrosion. These issues necessitate both routine and extraordinary maintenance, potentially incurring significant costs that could impact the overall profitability of the project and the energy efficiency of the installation.

Another key concern pertains to the sustainability of materials utilized for support structures and photovoltaic modules. These materials must not only be durable but also recyclable and environmentally friendly to avoid disposal issues at the end of the system's operational life. Disposing of modules and metallic components poses a considerable challenge, particularly as environmental regulations become increasingly stringent (Quaranta, 2024).

Current research efforts are focused on the development of innovative and more sustainable materials, such as corrosion-resistant metal alloys, advanced protective coatings, and biodegradable polymers for certain components[49]. Concurrently, technical solutions are being tested to reduce

49 The utilization of more resilient and sustainable materials, such as anti-corrosion steels or ecological alloys, could be incentivized by future legislation. This would serve to reduce the environmental impact of material deterioration. Some pilot projects in Italy are experimenting with the use of biodegradable materials for support structures. It is hypothesized that this could become standardized through ad hoc incentives, with the aim of promoting an entirely sustainable agri-voltaic supply chain.

maintenance needs, including self-cleaning surface treatments for panels and remote monitoring systems capable of detecting faults or malfunctions in real time.

The transition to more advanced materials and technologies will require time, substantial investments, and coordinated efforts among institutions, industry, and research entities. However, enhancing the durability and sustainability of agrivoltaic systems is imperative to ensure the long-term success of this technology, making it not only economically viable but also aligned with the objectives of the circular economy and ecological transition.

Social Acceptability and Risk Perception

In addition to the challenges posed by regulatory and technical obstacles, agrivoltaic systems face challenges related to social acceptability (Disconzi). While these systems are designed to preserve the agricultural functionality of the land, some segments of the population perceive them as a threat to the rural landscape and local biodiversity. This perception partially stems from the limited availability of long-term studies on the environmental impacts of such installations, particularly concerning their effects on wildlife and the ecological integrity of agricultural areas. Furthermore, residents in rural areas often voice concerns that these structures may modify the landscape or hinder local recreational activities, such as rural tourism, thereby potentially compromising the cultural value of the territory.

In this context, it is imperative to differentiate between acceptability and acceptance (Corrias et al., 2019). As emphasized by sociological studies, acceptability signifies a predisposition – either favorable or unfavorable – towards the introduction of a technological innovation, whereas acceptance is the outcome of a sustained process over time. Ensuring broad acceptability necessitates a proactive and transparent approach, with particular emphasis on involving local communities during the initial stages of project design and authorization.

At present, environmental impact assessment procedures do not always include structured public consultation processes. Making such processes mandatory, especially for projects located in sensitive areas or regions of high agricultural value, would represent a significant step forward. Community participation should not be merely symbolic; it is crucial to ensure that public proposals receive tangible consideration, thereby strengthening trust between citizens, operators, and policymakers.

At present, environmental impact assessment procedures do not always include structured public consultation processes. However, the mandatory requirement of such consultations, particularly for projects located in sensitive areas or regions of high agricultural value, would represent a significant step forward in enhancing local community involvement. It is essential to emphasize that this participation should not be conceived merely as a formal right to legal-administrative opposition, but as an opportunity to transparently and proactively gather and incorporate citizens' opinions. Furthermore, it is imperative to ensure that community involvement is not merely symbolic; it is crucial to guarantee that the concerns and proposals of citizens are meaningfully reflected in the final decisions. This approach would strengthen the trust between operators, public administrations, and local populations, fostering a more collaborative and transparent decision-making process.

Finally, a governance model that fosters continuous interaction between companies, institutions, and citizens can play a pivotal role in mitigating social conflicts. This approach should ensure transparent communication about administrative processes and the environmental and economic benefits of the project, as well as mechanisms to guarantee that the advantages generated by the installation are distributed equitably.

Such mechanisms could include, for instance, economic incentives for local communities, territorial development programs, or reduced energy costs for residents in the area. These measures would help strengthen the sense of belonging and foster greater acceptance of the project among the population. In this context, agrivoltaics, with its ability to integrate energy production and agriculture, represents a unique opportunity to build a sustainable and inclusive energy transition (Salvia, 1998; Fracchia, 2012).

Technological Innovation and Optimization of Agrivoltaic Systems

In the field of agrivoltaic systems, bifacial solar cells (BSCs) represent a cutting-edge technology for enhancing the efficiency of such systems. These cells have the capacity to capture solar radiation from both sides, thereby increasing energy production without the need for additional land area. The light reflected from the ground, known as "albedo", serves as an additional source of radiation that can be converted into energy by BSCs. This feature is particularly advantageous in agrivoltaic installations, where the soil is often left uncovered and permeable to support crop growth, thereby enhancing light reflection. The use of BSCs can also improve the efficiency of crops that require variable levels of shading. I n experimental settings, these cells have been installed at specific tilt angles to optimize the reflection onto their rear side, achieving energy production increases of up to 20% compared to traditional solar panels. This innovation enables additional energy generation without compromising the land available for cultivation, thus preserving the multifunctionality of agricultural land.

Another technology that has been implemented in advanced agrivoltaic systems is solar tracking, which enables the modules to follow the sun's movement throughout the day. This system, commonly referred to as tracking, offers significant advantages by increasing the energy output of the panels by 10% to 30%, depending on environmental conditions and light intensity. In agricultural contexts, solar tracking proves particularly valuable for managing shading on the underlying soil. The tilt of the panels can be adjusted to maximize direct sunlight exposure for crops while minimizing any negative impact the structure may have on the photosynthetic processes of plants. Solar tracking systems are especially effective for crops with high light requirements, such as vegetables and orchards. In some pilot installations, light sensors automatically adjust the modules based on light intensity and weather conditions, providing a level of flexibility that allows the system to adapt to the seasonal needs of the crops. This technology is aligned with the objectives of the National Recovery and Resilience Plan (NRPP), which promotes synergy between energy production and the optimization of agricultural land use.

Water scarcity is a major environmental concern, and advanced agrivoltaic systems are being developed to address this issue. Some installations are equipped with rainwater harvesting systems, which channel water collected on the panel surfaces directly to the crops below. In areas affected by water stress, this integrated irrigation system reduces reliance on external water resources, making agrivoltaic systems viable even in arid regions.

A particularly promising innovation is the use of irrigation water as a cooling system for the panels, a technique which enhances energy efficiency during the hottest periods while subsequently allowing the water to be reused for irrigating the soil. This approach integrates energy management with water resources, increasing agricultural resilience under drought conditions[50], and facilitates the reclamation of marginal or abandoned agricultural land, making it productive once again.

In regions such as Apulia and Sicily, the implementation of these technologies has been shown to support traditional high-value crops, including vines and olives, without compromising their quality or yield. Furthermore, the integration of controlled shading with integrated irrigation systems has been demonstrated to have a positive impact on the agro-food supply chain[51].

In addition to the benefits already described, an additional advantage for agricultural enterprises is the opportunity to electrify their machinery fleet, thereby reducing reliance on agricultural diesel and increasing energy self-consumption. This transition not only contributes to more sustainable farming practices but also significantly lowers operational costs. Furthermore, the electricity generated by agrivoltaic installations can enhance the efficiency of integrated processing chains by reducing energy costs associated with the processing and storage of agricultural products.

Another rapidly growing sector within advanced agrivoltaics is the use of artificial intelligence (AI) models for monitoring and optimizing system performance. AI systems can collect and analyze data on climate, water use, and agricultural yields, adapting in real-time the orientation of the panels, shading management, and water usage. This approach enables more precise system management, minimizing waste and maximizing both agricultural and energy production. Furthermore, AI models have the capacity to forecast the energy demands of the installation and optimize energy input to the grid based on demand fluctuations. Additionally, data collected by AI systems can enhance maintenance planning: temperature and humidity sensors connected to smart networks perpetually monitor the health of the installation, allowing anomalies to be detected early and reducing the risk of malfunctions. These innovations have the potential to transform advanced agrivoltaics into an even more reliable and sustainable technology, fostering integrated and predictive system management.

It is evident that the development of the agrivoltaic sector exerts a direct impact on technological innovation and the creation of new production chains, thereby driving demand for specialized components for agrivoltaic systems. The growing market for bifacial modules, elevated support structures, and solar tracking systems has encouraged technology companies to develop tailored solutions aimed at enhancing system efficiency without increasing production costs[52].

The expansion of agrivoltaic supply chains is also fostering the establishment of a network of highly specialized professionals, including farmers, technicians, and agronomists, who collaborate to optimize available technologies[53]. The construction of these systems requires qualified personnel for design and installation, with expertise in renewable energy, agricultural engineering, and agronomy. Once installed, these systems require regular maintenance, involving technical interventions on photovoltaic modules, management of support structures, and monitoring of the underlying agricultural activities[54]. This dynamic process is instrumental in fostering an innovation-oriented agricultural supply chain, thereby positioning agrivoltaics as a highly competitive and sustainable sector over the long term.

Income Diversification for Agricultural Enterprises and Sustainability in Rural Areas

Advanced agrivoltaic systems serve as a strategic tool for diversifying the income streams of agricultural enterprises, offering dual sources of revenue: agricultural production on the one hand and the sale of generated energy on the other. This diversification is particularly advantageous in rural areas marked by economic instability, where price volatility in agricultural markets and the impacts of climate change pose significant risks to the sustainability of traditional farming activities.

Agrivoltaics stabilizes agricultural income by reducing reliance on seasonal crops, with income from energy sales, supported by incentives such as premium tariffs provided by the GSE, able to offset potential losses during periods of lower agricultural yields. The integration of agricultural and energy production fosters self-consumption within enterprises, with electrification of agricultural machinery or energy efficiency improvements in processing activities reducing operational costs and enhancing competitiveness. Finally, the integration of ESG (Environmental, Social, and Governance) criteria is increasingly prevalent, with advanced agrivoltaic systems serving as a model for economic, social, and environmental sustainability. These systems underscore the pivotal role of agricultural enterprises in promoting the energy transition and safeguarding rural landscapes[55].

Renewable Energy Communities (CER): an Inclusive Model for the Energy Transition

Renewable Energy Communities (CERs) represent a strategic evolution in Italy's energy landscape, offering a new model of decentralized and inclusive management of energy produced from renewable sources. Article 2 of Directive (EU) 2018/2001 (RED II)[56] defines a CER as a legal entity

50 The implementation of advanced agri-energy initiatives has been demonstrated to enhance the resilience of agricultural enterprises by providing a stable source of income, independent of the variability of agri-food markets. The integration of agricultural production with energy production has been shown to mitigate economic risk associated with extreme weather events, which are becoming increasingly frequent and have the potential to compromise crop yields. Furthermore, advanced agrivoltaic systems facilitate the adoption of more sustainable agricultural practices, such as precision farming, which optimizes the use of water and energy resources, thereby enhancing overall land productivity.

51 The widespread adoption of agrivoltaics has the potential to result in a reduction in arable land of approximately 9,900 hectares, which is equivalent to 0.08% of the national utilized agricultural area (UAA). However, the advantages of water conservation, shading and the favorable microclimate facilitated by this technology for specific crops may offset the diminished land usage. These benefits would limit the loss of agricultural production to around EUR 44 million by 2030, thanks to a simultaneous increase in crop yields.

52 There has been an increase in collaborative endeavors between agricultural enterprises and research institutions, with pilot projects investigating the utilization of innovative materials and cutting-edge technologies to enhance the energy efficiency and environmental sustainability of plant production.

53 With funds earmarked for research and development, the NRPP encourages such collaborations and aims to establish specialized technology clusters that can provide technical support to farmers and reduce dependence on imported technologies.

54 A study by Coldiretti (2024) has revealed that for every 10 MW of agrivoltaic capacity installed, up to 50 jobs can be created in the sectors of construction, maintenance and agricultural management. Furthermore, the study suggests that the installation of such capacity may also create opportunities for young professionals in areas experiencing depopulation

55 The ability to document and certify the benefits generated in terms of reduced emissions, climate resilience and local community development has been identified as a key advantage of agrivoltaic plants. This has opened up new financial instruments and incentive policies based on ESG parameters for operators.

56 The implementation of this directive at the national level began with the adoption of Law No 8 of 2020, which aimed to evaluate its effectiveness, and was subsequently followed by the promulgation of Legislative Decree No 199 of 8 November 2021, which consolidated the regulatory framework by introducing significant innovations. Article 31 of Legislative Decree No 199/2021 sets out the key characteristics that

based on open and voluntary participation, autonomous and effectively controlled by shareholders or members located in the vicinity of renewable energy production facilities.

CERs comprise a diverse range of participants, including citizens, local authorities, small and medium-sized enterprises (SMEs), cooperatives, research institutions, and third-sector organizations[57]. These stakeholders collaborate[58] to produce, consume, and share renewable energy, pursuing goals that extend beyond mere economic profit to include the creation of social and environmental value. By reducing dependence on centralized grids and fossil fuels, CERs contribute to a more sustainable and resilient energy system.

The legislator has not imposed rigid legal forms for CERs, allowing flexibility in their organizational structure; however, the regulatory framework emphasizes that CERs must prioritize environmental, economic, and social benefits for their members and the local community over profit-making objectives. In practice, CERs predominantly adopt associative structures, often governed by dedicated statutes, or cooperative models, with these frameworks providing clear guidelines for resource management and reinvestment of profits to serve collective interests.

In accordance with Article 32, paragraph 1, letter c), of Legislative Decree No. 199/2021, the relationships between a Renewable Energy Community (CER) and its members must be governed by private law contracts, allowing the cooperative to be structured based on the specific needs of its members. This regulatory flexibility enables CERs to adopt the following configurations: 1) Consumer/User Cooperatives, where members access shared energy services in exchange for a fee[59]; 2) Production Cooperatives, where members contribute renewable energy and benefit economically from incentives provided for distributed self-consumption[60]; 3) Mixed Cooperatives, which combine elements of the first two types, balancing energy consumption and production within the community.

The choice among these configurations affects not only contractual arrangements but also fiscal and mutualistic aspects (Capelli, 2022–2023). Specifically, qualifying a CER as a cooperative allows access to certain tax benefits, such as the partial exemption of profits allocated to indivisible reserves, enhancing the community's economic sustainability. Furthermore, regulations stipulate that any surpluses derived from incentive tariffs designated for non-entrepreneurial consumers or allocated for social purposes must be explicitly governed, as outlined in Ministerial Decree No. 414/2023.

This flexible regulatory framework, which is characterized by a paucity of stringent rules on internal contractual models, supports the statutory autonomy of Renewable Energy Communities (CERs) and allows for the customization of operational methods based on the specific needs of the territory and their members. This approach enhances the ability of CERs to fulfil their mission of delivering environmental, economic, and social benefits to local communities while simultaneously promoting widespread energy self-consumption and facilitating the ecological transition.

As previously mentioned, the fundamental principle underpinning CERs is one of maximum openness, meaning that participation in the community must be open and voluntary for all members, without the imposition of excessively restrictive rules for admitting new participants. Consequently, legal forms such as consortium companies[61], which impose limitations on the transfer of shares or increases in share capital, are considered incompatible with this principle[62]. It is also important to note that, in cases where public entities are part of a CER, the Court of Auditors (Corte dei conti) has focused its oversight activities on ensuring compliance with the principle of maximum participation[63].

In the context of a Renewable Energy Community (CER), installations can be either directly owned by the Community itself or provided by a third party, which may also manage them on its behalf. According to Article 30, paragraph 1, letter a), point 1, of Legislative Decree No. 199/2021, third parties are authorized to perform activities such as installation, operational management – including maintenance and meter monitoring – provided they act in accordance with the instructions of the renewable energy prosumer. Furthermore, third parties that provide or manage installations on behalf of the CER can have energy-related services as their primary economic activity. This arrangement contributes to the professionalization and optimization of the Community's energy operations, enhancing its overall efficiency and functionality.

Renewable Energy Communities (CERs) are obligated to allocate the energy they produce primarily for on-site direct consumption or for distribution among its members, in accordance with the stipulations outlined in Article 31, paragraph 2, letter c), of Legislative Decree No. 199/2021. These stipulations enumerate the following conditions:

1. the production facilities must be under the control and availability of the CER, with a maximum incentivized capacity per individual installation not exceeding 1 MW;
2. the energy produced must be utilized within the geographical boundaries of the same primary substation, ensuring physical proximity between production and consumption;
3. the installations must be operational after the entry into force of Legislative Decree No. 199/2021.

In addition, as outlined in the GSE Technical Rules, an external producer with an installation connected to the same primary substation as the CER

Renewable Energy Communities (CERs) must possess: they must produce renewable energy for shared consumption among their members and, within the rationale of the legislative framework, may also sell self-produced and stored energy to third parties outside the CER.

57 Article 3-septies of Decree-Law No 57 of 2023 establishes the possibility for Regional Energy Communities (RECs) to be constituted as Third Sector Entities, Social Enterprises, or Environmental Protection Organizations, thereby facilitating their integration within the local territory and enabling the pursuit of broader objectives such as social cohesion and inclusion.

58 It is evident that the actors involved in an energy community can be categorized as follows: consumers, consumer-producers (also known as prosumers), and external producers (non-members of the CER). The latter category refers to individuals or entities who own and operate a plant that is made available to the CER. The responsibilities of the external producer include the design, construction and maintenance of the plant.

59 In accordance with the provisions set out in Article 2512(1)(1) of the Italian Civil Code.

60 In accordance with the provisions set out in Article 2512(1)(3) of the Italian Civil Code.

61 The augmentation of the maximum power output of installations for CERs to 1 MW, in conjunction with the extension of the connection perimeter to the primary cabin, has resulted in a substantial broadening of the model's application scope. This development has rendered the model more appealing to a diverse range of stakeholders, encompassing local authorities, citizens and agricultural enterprises.

62 In this sense, the Regional Control Section for Tuscany, in Resolution No. 77 of 2023, found the consortium company to be an unsuitable legal form for the establishment of a Renewable Energy Community (CER).

63 The Regional Control Section for Friuli-Venezia Giulia, in its Resolution No. 52 of 2023, also emphasized the need for continuous monitoring of the corporate transaction to ensure that the underlying assumptions of sustainability, appropriateness, and compliance with the principles of efficiency, effectiveness, and economy in administrative action are preserved over time.

is permitted to assign a mandate to the Community's Representative. This configuration enables the electricity produced and fed into the grid by the external producer to be incorporated into the calculation of shared energy, thereby expanding the avenues for energy collaboration within the Community.

The incentive system for CERs is recognized as one of the most significant tools for advancing the energy transition in Italy, combining capital grants with premium tariffs to encourage adoption. The specific provisions of these incentives are delineated by Ministerial Decree No. 414 of December 7, 2023, promulgated by the Ministry of Environment and Energy Security (MASE), and are further reinforced by regulations including Legislative Decree No. 199/2021 and ARERA Resolution No. 727/2022/R/EEL.

One of the most significant measures introduced is the provision of incentive tariffs, which apply to the share of self-consumed energy generated by renewable energy installations within CERs. Incentivized energy is defined as the amount of energy virtually shared each hour among Community members located within the segment of the electricity grid served by the same primary substation. These incentives, valid for a period of 20 years from the commencement of operations, are designed to encourage self-consumption and energy sharing, thereby promoting a more decentralized and participatory energy model.

In addition to tariffs, the MASE Decree establishes provisions for capital grants, with the potential to cover up to 40% of expenses incurred in the construction of renewable energy installations within CERs. These grants hold particular significance for communities situated in small municipalities with populations of less than 5,000 inhabitants, where they can play a pivotal role in stimulating local investments.

It is imperative to note that applications for these grants must be submitted by 31 March 2025, with the stipulation that approved installations commence operations within 18 months of approval, and in any case, no later than 30 June 2026.This measure is supported by the National Recovery and Resilience Plan (NRPP), with the objective of generating at least 2 GW of new capacity by 2026, leveraging a total budget of €2.2 billion[64].

To ensure the effective and consistent management of CERs, ARERA[65] introduced the TIAD (Testo Integrato Autoconsumo Diffuso[66]) through Resolution No. 727/2022/R/EEL. This technical document establishes rules to facilitate collective self-consumption and energy sharing, promoting innovative configurations and simplifying administrative procedures[67].

Additionally, the Implementing Decree envisaged under Article 8 of Legislative Decree No. 199/2021 outlines the criteria for accessing incentives, detailing both the methods for granting premium tariffs and the requirements for non-repayable grants. Together, these measures encourage the establishment of robust and sustainable CERs that integrate advanced renewable technologies while actively engaging local communities.

Ultimately, the current regulatory and incentive framework represents a significant opportunity for Renewable Energy Communities (CERs). Beyond contributing to the ecological transition, CERs promote inclusive energy models deeply rooted in local contexts, capable of generating economic, social, and environmental value. At the regional level, many local administrations are enacting laws to support CERs, identifying local authorities as key promoters of this model. These regional regulations encourage the use of renewable energy sources in rural communities, fostering energy self-sufficiency and driving economic development in marginal areas.

Ministerial Decree No. 414/2023, issued by the Ministry of Environment and Energy Security, which establishes the incentive tariff for renewable energy installations integrated into CERs, has further enhanced the appeal of this model for both public and private stakeholders[68].

The innovation of Renewable Energy Communities (CERs) lies in their potential to transform local communities into active participants in the energy transition, fostering the development of shared infrastructures such as agrivoltaic systems that integrate energy production with agricultural sustainability. The synergy between CERs and advanced agrivoltaic systems maximizes territorial benefits: while the installations reduce land consumption through elevated and multifunctional structures, CERs ensure that the energy produced remains within the communities, generating both economic and social value.

It is therefore vital to understand CERs not merely as an innovative energy model, but as a paradigm of sustainable development that links ecological transition, social inclusion, and territorial enhancement. The success of CERs is predicated on the implementation of a clear regulatory framework, supported by targeted incentive policies and the full engagement of local communities, so that they can become a cornerstone of Italy's energy transition.

Management and incentives for agrivoltaic energy

The incentive system for advanced agrivoltaic installations is legally based on Ministerial Decree of December 22, 2023 (commonly referred to as the "Agrivoltaic Incentives Decree") and the Interministerial Decree of June 19, 2024 ("FER 2"). These decrees regulate access to incentive tariffs for agrivoltaic systems and those employing innovative or high-cost generation technologies. The provisions outlined in these decrees are operationalized by ARERA Resolution No. 468/2024/R/efr of November 12, 2024, which establishes the rules for the acquisition and management of electricity produced by such installations.

64 According to data provided by the National Association of Italian Municipalities (ANCI), seven months following the implementation of the new regulations, the Gestore dei Servizi Energetici (GSE) received over 430 applications for a total capacity of 60 megawatts, thereby signifying the dynamism of the sector. Furthermore, applications for the NRPP contribution for plants located in municipalities with a population of less than 5,000 exceeded 630, for a total capacity of approximately 55 megawatts. These figures underscore the efficacy of the incentives introduced, and also highlight the growing awareness of local administrations and citizens regarding the economic, social and environmental benefits of CERs. Nevertheless, it is imperative to ensure a streamlined authorization process and adequate technical support to enable the timely implementation of approved plants and to maximize the positive impact of these initiatives on the territory.

65 The Italian Regulatory Authority for Energy, Networks and Environment (ARERA) performs regulatory and supervisory functions across the electricity, natural gas, water services, waste cycle, and district heating sectors. Established by Law No. 481 of 1995, ARERA is an independent administrative authority tasked with promoting competition and efficiency in public utility services, while safeguarding the interests of users and consumers. Its mandate involves striking a balance between the economic and financial goals of operators and broader social objectives, such as environmental protection and the efficient use of resources. ARERA also acts in an advisory capacity to the Government and Parliament on matters within its jurisdiction, particularly in relation to the definition, transposition, and implementation of EU legislation. Notably, the Authority's operations are financed not through the State budget, but via contributions levied on the revenues of regulated operators.

66 Integrated Text on Distributed Self-Consumption.

67 For further insight, an examination of the GSE Operating Rules is recommended, which advocate for local utilization of energy generation, thereby fostering an inclusive and sustainable growth model.

68 In accordance with Article 31(2)(b) of Legislative Decree No 199 of 2021, the sale of energy exceeding self-consumption is permitted, including through renewable electricity trading agreements, either directly or via aggregation.

Installations that are incentivized through the provision of all-inclusive fixed tariffs are obligated to sell the entirety of the electricity injected into the grid to the Energy Services Operator (GSE), even when the incentivized energy constitutes a fraction of the total production[69]. This obligation ensures a centralized management of energy by the GSE, which is responsible for placing the purchased energy on energy markets, in accordance with the Testo Integrato Dispacciamento Elettrico[70] (TIDE), effective from January 1, 2025.

Terna[71], in collaboration with the GSE, is tasked with defining operational procedures for integrating incentivized energy production units into the GSE's dispatching contracts, ensuring guaranteed management throughout the conventional operational life of the installation as defined by the ministerial decrees[72]. Any modifications to the dispatching contract by the producer must receive prior approval from the GSE. Non-incentivized energy, meanwhile, will be managed under standard market conditions, while imbalance charges will be applied to incentivized energy, with certain exceptions for isolated installations. Furthermore, the GSE will allocate any charges or revenues resulting from participation in the Intraday Market (MI) in accordance with the criteria outlined in Article 9 of Annex A to ARERA Resolution No. 280/07. Administrative costs related to the management of incentive tariffs and activities of verification and control will be covered by the Fund for New Renewable and Assimilated Energy Plants[73].

This integrated management system offers both benefits and obligations for agrivoltaic operators. On the one hand, the incentive tariffs established by the Ministerial Decrees of December 22, 2023, and June 19, 2024, provide a stable and predictable revenue stream, enhancing the bankability of projects. Conversely, operators are obligated to ensure the prompt submission of production and energy injection data to the GSE, in accordance with the Testo Integrato Misura Elettrica (TIME) regulations. The latter stipulates a maximum retrieval period of five years for historical data requested by the GSE.

Despite the intricacy of the regulatory framework, its objective is to achieve a balance between the efficiency of the energy market and the economic sustainability of advanced agrivoltaic systems. It is therefore vital to acknowledge the simultaneous support of this regulatory framework for the achievement of energy transition goals for 2030 and beyond.

The Versatility of Agrivoltaic Systems in Energy Markets

Advanced agrivoltaic systems also provide specific advantages in terms of flexibility within energy markets. In contradistinction to ground-mounted photovoltaic panels, which are designed primarily to generate energy for sale to the grid, advanced agrivoltaic systems enable a more dynamic management of energy production, including the capability to store and distribute energy based on local demand. The GSE has expressed support for initiatives that allocate a portion of the energy produced for self-consumption, with the objective of reducing operational costs for agricultural enterprises and enhancing the overall energy efficiency of the system.

In this regard, select pilot installations in Italy are integrating storage systems to accumulate energy production and release it during periods of high demand or low irradiation[74]. This adaptability confers a competitive advantage upon agrivoltaic operators, enabling them to respond to market fluctuations and optimize revenues, particularly during periods of heightened electrical grid demand and escalating energy costs.

ESG and Integrated Sustainability: Measuring Environmental and Social Value

The integration of Environmental, Social, and Governance (ESG) (Conte, 2022)[75] criteria has profoundly impacted the manner in which agricultural enterprises, including those engaged in agrivoltaics, approach sustainability. These criteria, which have already been firmly established in the industrial sector, are progressively gaining importance in the primary sector. Consequently, agricultural businesses are being encouraged to measure and document their environmental, social, and governance impacts. Agrivoltaic systems, in particular, exemplify a seamless integration of environmental and economic sustainability. They not only facilitate income diversification but also contribute to mitigating greenhouse gas emissions and enhancing climate resilience.

Advanced agrivoltaic systems, through their integration of agricultural and energy production, deliver substantial advantages in terms of social responsibility. These systems can incorporate innovative practices such as carbon farming, which contributes to carbon sequestration[76] in soils and supports the achievement of climate neutrality goals outlined in the 2030 Agenda[77]. Participation in Renewable Energy Communities strengthens the connection between agricultural enterprises and local communities,

69 In accordance with Article 10(1)(a) of the Ministerial Decree of 22 December 2023 and Article 9(1)(a) of the Ministerial Decree of 19 June 2024.

70 The Integrated Framework for Electricity Dispatching is a reform initiative designed to revise the regulatory framework governing electricity dispatch in Italy. It is conceived as a comprehensive regulatory instrument that consolidates existing provisions – primarily those contained in ARERA Deliberation No 111/06 – with newly introduced regulatory innovations. This framework serves as the foundational document upon which additional key components of the electricity system will be built, including the capacity market, the remuneration mechanisms for storage capacity, and the regulatory discipline of essential services.

71 Terna S.p.A. is a transmission system operator (TSO) based in Rome, Italy. It operates through Terna Rete Italia, that manages the Italian transmission grid and Terna Plus which is in charge of new business opportunities and non-traditional activities in Brazil, Chile, Peru and USA (2023).With 75,140 kilometers (46,690 mi) of power lines or around 98% of the Italian high-voltage power transmission grid, Terna is the sixth largest electricity transmission grid operator in the world based on the size of its electrical grid. Terna is listed on the Borsa Italiana and is a constituent of the FTSE MIB index.

72 Article 10 of the Ministerial Decree of 22 December 2023.

73 In accordance with Article 10, paragraph 10.1(b) of the TIPP – ARERA Resolution No 618/2023/R/com.

74 One of the earliest examples in Italy is situated in the Comiso (Ragusa) area, where two industrial-scale projects (agrivoltaic on greenhouse, plus traditional ground-mounted photovoltaics) with a total capacity of 1,000 kW, combined with 1,200 kWh total storage capacity, have recently been completed.

75 ESG is an evaluative approach used to assess an organization's commitment to social objectives that extend beyond the sole pursuit of shareholder profit maximization. Within the ESG framework, social objectives include the achievement of defined environmental goals, the support of targeted social movements, and the systematic integration of diversity, equity, and inclusion (DEI) principles into corporate governance.

76 The efficacy of ‚carbon sequestration' is contingent upon its integration with regenerative and organic farming practices; conversely, its effectiveness is negated when employed in conjunction with intensive farming.

77 The 17 Sustainable Development Goals (SDGs) are the world's best plan to build a better world for people and our planet by 2030. Adopted by all United Nations Member States in 2015, the SDGs are a call for action by all countries – poor, rich and middle-income – to promote prosperity while protecting the environment. They recognize that ending poverty must go hand-in-hand with strategies that build economic growth and address a range of social needs including education, health, equality and job opportunities while tackling climate change and working to preserve our ocean and forests.

generating tangible benefits and fostering an inclusive model of rural development.

From a governance perspective, the adoption of ESG criteria helps businesses improve transparency and management efficiency, attracting investments and facilitating access to credit through specialized banking programs. However, it is critical to ensure that ESG requirements do not become a bureaucratic burden, which could disadvantage small agricultural enterprises and diminish the sector's competitiveness. If effectively implemented, the integration of ESG parameters in agrivoltaics can become a strategic advantage, promoting the economic and environmental sustainability of Italy's agricultural sector.

The Role of Advanced Agrivoltaic Systems in Italy's Ecological Transition

Advanced agrivoltaic systems represent a pivotal component of Italy's strategy for the ecological transition, with the overarching objectives being to reduce greenhouse gas emissions and to promote the sustainable utilization of energy resources. As delineated in the Integrated National Energy and Climate Plan (PNIEC), Italy's target is to augment its photovoltaic renewable energy capacity by 70% by 2030[78], with a substantial proportion of this production being attributed to agrivoltaic systems[79]. The multifunctionality of these systems is in alignment with the need to valorize local resources while simultaneously reducing reliance on imported fossil fuels – a critical factor for the country's energy security. Italy aspires to implement a "solar sharing" model, where agricultural areas are not merely converted into energy production sites but remain productive[80]. This approach ensures the preservation of biodiversity and agricultural resilience in regions vulnerable to extreme climate change events[81].

Environmental Challenges, Soil Protection, and Sustainable Management

Whilst advanced agrivoltaic systems represent a state-of-the-art and sustainable technology, they also pose significant challenges related to sustainable land use and environmental conservation. The installation of panels alters the microclimate of the underlying soil, as the modules create shaded areas that reduce the amount of direct sunlight reaching the plants. While solar tracking technologies can adjust this shading, careful management is required to prevent impairment to crop photosynthesis[82]. To address this challenge, some pilot projects have adopted configurations with spaced and variably angled modules, allowing for adaptation of shading to the needs of seasonal crops. This technological approach, in combination with light and moisture sensors, ensures high agricultural productivity even under partial solar coverage.

Furthermore, the benefits of agrivoltaics extend beyond the provision of controlled shading. This technology provides a tangible solution to counter the effects of climate change, which over the past decade has caused 146 extreme weather events with significant damage to Italian agriculture (Legambiente, 2024). Agrivoltaic systems help reduce soil evaporation, maintain optimal moisture levels, and support crop health. Furthermore, the shade provided by the panels offers protection against extreme weather conditions, such as hail, heatwaves, and frost, thereby increasing crop resilience and enabling more efficient water management through rainwater recovery systems. Another critical challenge pertains to the impact of photovoltaic module supports on the soil. These structures must be installed in a manner that does not compromise soil permeability, which is essential to prevent erosion and reduce the risk of soil water depletion[83].

Finally, agrivoltaics demonstrate that the perceived "land-use conflict" between photovoltaics and agriculture can be overcome through virtuous integration. Some studies (Adeh et al., 2019) have highlighted yield increases of 20% to 60% in crops such as aromatic herbs, vegetables, and fruit, attributable to the partial shading provided by panels. This synergy between renewable energy and agriculture represents a sustainable development model, combining environmental conservation, productive efficiency, and climate adaptation.

Conclusions

Advanced agrivoltaic systems represent a pioneering and strategic solution within the renewable energy landscape, offering a model of integrated sustainability that successfully combines environmental, energy, and agricultural needs. As highlighted in this analysis, this technology provides a tangible response to contemporary challenges posed by the climate crisis, energy security concerns, and the decline of rural areas. By enabling a multifunctional and efficient use of land, advanced agrivoltaics preserve soil productivity while simultaneously generating clean energy.

However, the implementation of advanced agrivoltaic systems is not without complexities. Effective governance is essential to balance the promotion of renewable energy with the protection of landscapes and natural resources, and this requires a clear and consistent regulatory

78 However, Italy has set itself an ambitious target of over 131 Gigawatts of energy to be produced from renewable sources by the year 2030. This represents an increase of 73 GW in new capacity compared to 2021, with solar technologies accounting for almost 80 per cent of this increase.

79 The integration of agricultural land use with energy production, as exemplified by the advanced agrivoltaic model, facilitates the optimization of agricultural land utilization, particularly in rural areas grappling with issues of abandonment and diminished economic productivity.

80 The European Commission's Joint Research Centre asserts that allocating 1.06% of the European Union's utilized agricultural area (UAA) to agrivoltaics would suffice to attain an installed photovoltaic capacity of nearly 944 GW by 2030. This target is almost double the initially set goal of 590 GW. The potential of this initiative is significant, as it presents an exceptional opportunity to decarbonize Europe by substantially reducing CO2 emissions without compromising agricultural production.

81 The development potential of agrivoltaics in Italy is very high: indeed, last year, agrivoltaics was the technology that grew the most, with projects amounting to almost 16 GW, approximately 41% of the total mapped, and with a valuation of about 12 billion euro. If this growth trend continues, it is predicted that by 2030, the installed capacity of agrivoltaics in Italy will reach approximately 22 GW, which is equivalent to 58% of the new ground-mounted plants that will be constructed by 2030.

82 A study conducted by Althesys demonstrates that, in exchange for a reduction in cultivable land area – estimated at approximately 0.08% of the national utilized agricultural area (UAA), along with a corresponding decrease in CAP-related subsidies, the simultaneous increase in agricultural yields – attributable to the presence of elevated photovoltaic panels that promote water conservation, shading, and improved microclimatic conditions – would largely offset the reduced land use. According to the study, the resulting loss in production would be contained to approximately €44 million by 2030, while additional income from land rent is projected to exceed €320 million.

83 Research in the field of environmental studies has demonstrated that the utilization of rigid or inadequately treated structures over an extended period can result in the deterioration of soil quality. To address these concerns, the GSE Operating Rules mandate the employment of eco-friendly materials for support structures and promote the adoption of elevated configurations, thereby facilitating optimal soil management..

framework that overcomes regional disparities and provides legal certainty for operators. At the same time, a fair incentive strategy is crucial to ensure access for small-scale agricultural entrepreneurs, preventing the indiscriminate appropriation of agricultural land by entities outside the primary sector.

From a technical standpoint, advancements in bifacial modules, solar tracking systems, and integrated irrigation solutions have precipitated a qualitative leap, enhancing energy efficiency and reducing environmental impact. These features distinguish advanced agrivoltaics from traditional photovoltaics, making them competitive not only as a source of energy but also as a tool for territorial regeneration. However, as previously mentioned, it is imperative to guarantee that genuine and continuous agricultural activity occurs beneath the panels. Failure to ensure this continuous agricultural activity may result in the overlap with traditional photovoltaics, potentially leading to the loss of the agricultural function of the land.

Furthermore, advanced agrivoltaics have been identified as a means of combatting rural abandonment and promoting territorial cohesion. The integration of agricultural and energy production offers a unique opportunity to diversify agricultural income and encourage participatory models, such as energy communities, actively involving local populations in resource management. Nevertheless, sustained efforts are necessary to prevent agrivoltaics from becoming a pretext for replacing high-quality agriculture with a production model focused exclusively on energy generation. Such a transition could potentially compromise the agricultural sector's custodial role in preserving land and biodiversity.

The ultimate success of advanced agrivoltaics is contingent on the harmonious integration of innovation and tradition, thereby facilitating an ecological transition that is inclusive, sustainable, and respectful of local particularities. The future of energy and agriculture may be found in this technology, providing a balance between economic progress, environmental protection, and the enhancement of rural landscapes. The challenge for policymakers will be to translate this potential into reality through the implementation of regulatory policies, targeted incentives, and a long-term vision that ensures the virtuous integration of the energy and agricultural sectors.

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