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CHAPTER 7

Promote Integrated Policy Design to Overcome Social and Technical Challenges for Agrivoltaic Deployment

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Policy Highlights To achieve the recommendation stated in the chapter title, we propose the following:

- Provide an overarching shared definition of Agrivoltaics (AV) with a precise balance between the agriculture and energy components—general enough to guarantee agriculture will be kept as the primary activity but flexible enough to adapt to the specific conditions.

The original version of the chapter has been revised: The first author's family name has been updated. A correction to this chapter can be found at https://doi.org/10.1007/978-3-031-66481-6_13

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- Fund further Research and Development (R&D) through pilot projects to investigate different technical configurations and crucial parameters to improve the balance between energy production and farming.
- Identify an integrated scheme of incentives for AV to prevent agriculture from being abandoned in favour of energy production.
- Engage with local communities to develop local and national criteria for implementing AV, support the continuation of agricultural activity, raise local awareness, and foster active community involvement in AV projects to maximise regional economic benefits and avoid extractivist behaviours.
- Facilitate the dialogue between Social Sciences and Humanities (SSH) and Science, Technology, Engineering and Maths (STEM) communities by constructing a common definition of the AV policy problems at stake.

Keywords Agrivoltaics · Solar energy · Semi-structured interviews · Socio-technical · Europe

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7.1 Introduction: Agrivoltaic Deployment as a Socio-Technical Innovation Pathway

This chapter focuses on policy recommendations for the Agrivoltaic (AV) sector, which is considered a pivotal trigger for the energy transition. We adopt a socio-technical approach to consider the interplay among technological, economic, and societal components in deploying Renewable Energy System (RES) technologies. Energy transition has been widely recognised as a paradigmatic socio-technical innovation, involving the co-evolution of technological and societal (cultural, regulatory, and economic) components (Geels & Schot, 2007). The promotion of interdisciplinary dialogue among Technical and Social Sciences has been gaining relevance in identifying complex socio-technical challenges to feed the design and implementation of effective policies tackling this complexity. With this in mind, an interdisciplinary workshop was held in November 2022 in Torino (Italy) to bring together both the Social Sciences and Humanities (SSH) and Science, Technology, Engineering, and Mathematics (STEM) communities belonging to the Joint Programmes e3s and PV of the EERA consortium.[1] The focus was identifying the specific socio-economic and technological challenges for large-scale PV deployment, recognising AV as a promising and challenging socio-technical innovation requiring joint SSH-STEM research.[2]

Solar energy, in general, stands as a foundational element in the EU's journey towards cleaner energy under the European Green Deal and the RePowerEU plan (European Commission, 2019, 2022). However, in densely populated areas (e.g., Western Europe), competition between energy generation and farming to use large plots of land is a crucial issue in energy policy design. AV has excellent potential to address this competition, as it uses land for simultaneous solar energy production and agriculture production. This can reduce the competition between food and energy systems while helping meet energy and food demands (Gomez-Casanovas et al., 2023). Therefore, AV, where surface area is used for multiple purposes, including energy production, are vital for a successful low-carbon energy transition by promoting complementary, rather than competitive, relationships between critical land uses (Pascaris et al., 2021). AV represents a testbed to promote interdisciplinary and cross-sectoral dialogue and policy design.

The deployment of AV is a multifaceted process running on many scales (local, national, global) and various domains (technical, regulatory, cultural) that requires an equally multi-dimensional and integrated perspective in its analysis and the definition of policy-supporting tools (Casanova, 2023). AV deployment involves multiple actors, processes, and interests that might hamper, or even stop, the innovation pathways of AV. The different perspectives between project implementers and local communities regarding the trade-off between (1) land use for farming and energy production, (2) the balance between jobs lost and jobs gained, and (3) the procedural constraints of the authorisation processes are just a few examples of the dynamics that might slow AV adoption. All this clearly illustrates the need for an effective dialogue between STEM and SSH experts aiming to solve this complex matter.

This chapter draws upon a mixed, qualitative research methodology (literature review, questionnaire, interviews) implemented by an interdisciplinary team consisting of experts in STEM (Physicists and Engineers) and SSH (Sociologists, Economists, and Lawyers) aimed at refining what the scientific and policy communities have identified as the main challenges and possible solutions for AV deployment in Europe. A literature review was conducted to get the broader context of existing policies, regulations, and institutional frameworks that impact the deployment of AV. A questionnaire was conducted, with the questionnaire designed jointly by SSH and STEM researchers as it included both technical and social questions. Semi-structured interviews were conducted with various European stakeholders (policymakers, farmer associations, PV Agrivoltaic developers, and researchers) based on their disciplinary background (technical vs non-technical) and their role in the AV field (Sculio et al., 2024), to get an original and critical view of the growing knowledge of AV deployment obstacles and opportunities. Our policy recommendation was developed based on insights obtained through these three methods.

7.2 Challenges for AV Deployment

Based on the literature review, the challenges for AV deployment can be clustered into five main dimensions: Conceptual, Technological, Economic, Social and Environmental, and Institutional. The interview questions were informed by these dimensions. Each cluster is briefly described in this section, and the interview insights are reported.

Regarding the *Conceptual dimension*, a common definition of AV is not universally accepted and adopted in the policy and scientific domains. AV systems must integrate Photovoltaics (PV) with farming activities, which must be kept as the primary goal. The lack of definition leads to varying amounts of farming and electricity production. One interviewee remarked, "*If we only had electricity, I would not consider it Agrivoltaic anymore*" (I4). Another said, "*It is tough to find a definition because agriculture is so broad, but a not perfect standard (SPEC 91434*[3]*) or definition is much better than no definition*" (I1). This is a crucial societal and policy issue since defining an AV system and prioritising energy production versus farming determines how the supporting policies are defined. An interview participant commented, "*It is essential to separate free field*[4] *PV and AV. AV is different concerning subsidies, taxes, and the heritage of lands… one thing to prevent is pseudo-agriculture, so people pretend to have agriculture fields, but they only have PV*" (I3). Additionally, the "*EU does not require member states to have definitions in the Common Agriculture Policy*" (I5), so integrating AV into incentive schemes remains unclear.

As for the *technological dimension,* even though research on AV systems has increased, technical challenges must be addressed to maximise electricity generation, while minimising the negative impact on crop yield. Several aspects of this question refer to the trade-offs emerging through the integration with agriculture. On the energy side, "*it is not expected to have the optimum electricity production because PV settings should adapt to agriculture. On the farming side, the impacts depend on the selected crop and several site-specific factors such as the soil, area and climatic conditions*" (I4). Production might be affected in terms of productivity (i.e., the quantity of yield) and organoleptic and nutritional properties (i.e., quality of the yield).

In terms of the *Economic dimension*, there are many, diverse challenges for AV users that can be grouped around four main categories: (1) dealing with the financial aspects of AV related to funding installations, assessing the profitability of the investments, and considering the impact on the quality and quantity of crops; (2) expected but unpredictable changes in the price of land; (3) assessing the extent to which AV can mitigate the competition between energy; and (4) agriculture production impacting the income of the local communities (Al Mamun et al., 2022; Chatzipanagi et al., 2023). Given that the primary activity of farmers should be farming, attention is primarily paid to the impact of AV on farmers' income and farming production, both affected by three central dynamics that can be triggered by AV deployment. Firstly, the increase in the price of agricultural land that can host AV might result in barriers to expanding agriculture activities. Secondly, AV can have different adverse effects on farmers' income depending on the different crops, with greater decreases expected for arable than horticultural crops. Finally, a distortion might quickly arise in connection with the economic benefit, if the net income for farmers adopting AV increases to the point that they could give up the cultivation of crops and focus on electricity production. In addition to hampering the maintenance and profitability of agriculture activity, such dynamics might change the role and identity of farmers from being well-established and recognised actors in the food sector to being new (and underrepresented) actors in the energy sector. Considering the unpredictable socio-economic distortions that might arise from AV deployment, attention should be paid to guaranteeing that AV is always an additional, rather than the primary, source of income for farmers.

As for the *Social and environmental dimensions*,[5] AV deployment might impact the environment, landscape, adopters of AV, recipient communities, biodiversity, and the surrounding ecosystem (Casanova, 2023; Hu, 2023; Taylor et al., 2023). Regarding the effect on the landscape, opinions diverge due to both the objective diversity of AV systems under scrutiny, and the subjective perspective of the observer. It seems true that "*…in some rural landscapes - climate-friendly areas and beautiful landscape - people say that we do not have to put [PV] panels there because the artificialisation of the soil could alter the landscape*" (I5). However, it is also true that "*…the beauty and landscape are perceptions and people see it differently*" (I4), and not all modifications of the natural landscape are harmful.

Unlike other RES technologies, AV should, in principle, enable recipient communities to be more involved, but this potential is not adequately exploited. An optimistic view highlights that while "*local communities do not accept solar parks because big companies usually buy land and are the only ones profiting from it, AV could be different, and communities could directly benefit from energy production either as producers or direct users*" (I3). Yet, for local communities to actively participate in AV, special effort needs to be made to involve farmers and communities, as they "*need to know why the promoters intend to use the system, the benefits, and the trade-offs. We should be honest; it should be their decision to adopt it or not*" (I4). In short, given that public awareness and acceptance among farmers and rural communities are pivotal components influencing AV deployment, attention must be paid not only to which impacts are likely to be produced by AV deployment, but also to how these impacts are perceived by, communicated to, and discussed with the affected communities. Timely and effective engagement strategies should be put in place by the AV promoters.

Community engagement relates to the *Institutional dimension of AV*, which refers to regulations and policies. It has been recognised that involving people, not only helps increase acceptance, but can also play a role in defining effective regulations (Bryner, 2001) - "*farmers and people are critical and should be involved in the regulations. Suppose the farmer wants to install an AV. In that case, many regulations are costly, so they should ask a middle person to facilitate the interpretation of the regulations and find funds. This is why we should go in this direction; government and policies should follow this*" (I3). This uncertainty about the rules that are regulated by experts could be mitigated by involving the final recipients—this is typical of new policy fields such as AV deployment.

Heterogeneity among EU Member States produces a lack of harmonisation of legislation in the EU. In several Member States, land characterisation may change after the realisation of an AV installation, introducing legal obstacles for the farmer. Such a change may result in exclusion from the Common Agricultural Policy (CAP).[6] Moreover, farmers may lose agricultural subsidies. Uncertainties and financial consequences may result in a perception of legal insecurity and possible loss of income for the farmer or the investor. All stakeholders interviewed noted that AV is still poorly incorporated in the Member State's national strategic plans and policies, risking that AV deployment might fail to increase complementarity between energy and agriculture production.

7.3 Achieving Our Recommendation

The Joint Research Council (JRC) report on the potential of and challenges for AV in the European Union, which included 17 possible interventions at the EU level, was used as a stimulus to support interview discussions (see Sculio et al., 2024). Interview participants were asked to reflect upon and prioritise the policy options; in doing so, they highlighted shortcomings of existing policy options, identified additional policy recommendations, discussed implementation challenges, and commented on the interaction between policies. These discussions, coupled with the literature review, supported the identification of our policy recommendation to *promote integrated policy design to overcome social and technical challenges for agrivoltaic deployment*, supported by the following four sub-recommendations.

There is a need *to define AV and implement standardised systems across the EU to ensure harmonisation of policies, develop adequate standards for AV, and differentiate AV systems from traditional PV systems on agricultural land*. The latter is crucial to prevent greenwashing, as is streamlining permitting processes and prioritising grid connections. For this aim, STEM and SSH expertise must be carefully merged to clearly understand the expected balance of energy and agriculture production for a PV system to be considered AV and mitigate the risk of triggering a distortion in the pre-existing agriculture production and culture.

Further Research and Development (R&D) funding, using national and EU level funds, through pilot projects is needed to investigate different technical configurations and establish AV quality standards and parameters to improve the balance between energy production and farming, which could include farmers and researchers from PV and Agriculture. Here, the focus is on promoting real-world experiments that can grasp the interaction among the many site-specific variables in various socio-economic, environmental, and farming contexts. STEM expertise is crucial for designing, implementing, and monitoring projects, while SSH should engage and create a framework for social and economic impacts.

An adequately *integrated scheme of incentives* for AV needs to be established to avoid abandoning agriculture in favour of energy production, with specific attention paid to integrating AV projects into the CAP framework. It is essential to ensure the continuity of farming activities and land preservation post-AV deployment by assuring transfer rights will not be disadvantageous in case of farm inheritance, and to guarantee CAP subsidies for farms with certified AV systems. The promotion of AV through CAP strategic plans, coupled with dedicated financial support and capacity targets at the national level, underscores a commitment to fostering AV adoption. These delicate aspects need SSH expertise, mainly economic, with support from juridical and sociological fields for regulatory integration and assessing inequality.

Local communities must be effectively engaged, as the centrality of farmers and rural communities in AV promotion, economic benefits, and property security are highlighted alongside efforts to enhance public awareness and acceptance of AV initiatives. There are two ways in which communities need to be engaged. The first refers to the need to reinforce *AV deployment strategies by taking advantage of embedded local practical farming knowledge* to develop local and national criteria for implementing AV, and support the continuation of agricultural activity, define capacity targets suitable to the specific contexts, provide effective regulatory framework, and support spatial planning by identifying suitable agricultural land for AV deployment. The second refers directly to the *local awareness-raising and active involvement of the community in AV projects* to maximise benefits for the regional economy and employment, and to avoid predatory behaviours from a few specialised companies promoting AV plants from outside.

The dialogue between STEM and SSH expertise should be well-designed and continuous for the local engagement to be successfully implemented. SSH must put in place all the theoretical and methodological tools to assess local communities' needs and opportunities, and define the most suitable engagement strategies. At the same time, STEM is required to support the design and implementation of AV projects by integrating local knowledge and expertise to promote a co-design approach.

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Notes

1. European Energy Research Alliance (EERA) is a wide consortium comprising academia and research institutes from around the EU and is structured in 18 Joint Programmes. The two involved in both the workshop and the chapter are JP clean Energy Transition for Sustainable Society (e3s) and JP Photovoltaic Solar Energy (PV). More details at, https://www.eera-set.eu/.
2. Short proceedings of the Turin workshop are available at https://www.eera-e3s.eu/event/3366:let-the-sunshine-in-addressing-the-challenges-for-pv-exploitation-in-the-eu-17.html.

3. Details on the standard can be found here: https://www.normadoc.com/english/din-spec-91434-2021-05.html.
4. Ground-mounted PV systems, also known as free-field solar power plants.
5. We considered jointly the *Social and environmental dimensions*, as the scope of the chapter is mostly on the local impact of AV that allows to consider better the interaction among the different social and technical dimensions; therefore, we do not concentrate on the mitigating effect of AV in terms of the environment.
6. More information on CAP can be found at the following link: https://eu-cap-network.ec.europa.eu/common-agricultural-policy-overview_en.

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