Beyond social acceptance: justice implications in Agri-PV

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Executive Summary

Existing social sciences research on agrivoltaics (Agri-PV) and its implications for society is recent and limited, primarily focusing on social acceptance and opposition to the implementation of Agri-PV. This underlines the need for a novel perspective that goes beyond the concept of acceptance to explore the environmental and energy justice implications of Agri-PV. The concepts of environmental and energy justice in the clean energy transition involves embeddedness, equitability, meaningful engagement, and the fair distribution of costs and benefits related to energy projects that affect human health, well-being, and the environment. This deliverable summarizes the results of qualitative research on the environmental and energy justice implications of Agri-PV in four regions of the European Union (EU). By adopting multiple qualitative methods, including an interpretative literature review, semi-structured interviews in Catalonia, North Brabant, South Tyrol and Wallonia, and two foresight workshops conducted in Barcelona and Bolzano, the study explores the distributional, recognitional, and procedural justice implications of Agri-PV deployment as part of the clean energy transition in the EU.

The results highlight that Agri-PV is perceived to have potentially positive benefits on agricultural productivity through combined use of land, and protection of soil from the adverse impacts of climate changes. Agri-PV can offer additional revenue sources for farmers facing low revenues from agricultural production. However, the potential for double revenue generation could lead to new power imbalances in the agricultural sector. For example, farmers leasing their fields to energy companies for Agri-PV installation might lose control over their land. Additionally, differences in investment capacity might exacerbate disparities between small and large farmers, as well as between those with more or fewer resources or land suitable for Agri-PV installation. The findings also suggest that the lack of a clear and commonly agreed definition of Agri-PV hinders the understanding of the technology by local stakeholders and its effective implementation, creating discrepancies between local, national and European scales. Although residents, local communities and local farmers potentially bear the negative impacts of Agri-PV systems, they tend to be excluded from decision-making processes, which appear to favor agricultural organizations, local authorities and investors holding economic power. Exclusion from decision making and negative aesthetic impact of uncontrolled agricultural landscapes transformation are main drivers of opposition and resistance by residents and local communities as well as sources of injustice. Additionally, the combined land use favored by Agri-PV is perceived to contribute to the increase of land prices, which affects land ownerships for local farmers, residents and communities. This also has intergenerational consequences, as younger and future generations may be deprived of land and landscape value due to current Agri-PV projects.

To address the environmental and energy justice implications identified in the study, the report emphasizes the need for a balanced distribution of the benefits of Agri-PV, and to compensate for socio-economic and environmental costs it may entail. It also advocates for the inclusion of farmers, residents and local communities in the early stages of the Agri-PV development, potentially as co-designers or co-owners of the plants within energy communities or cooperatives. Moreover, clear and harmonized regulatory frameworks, supported by subsidies or other programs, are required at national and EU level to favor Agri-PV deployment. Although some countries, like Spain and the Netherlands, have already implemented national regulatory frameworks for Agri-PV, these are not always supported by adequate funding or effective implementation that ensure sustainability, environmental and energy justice. Finally, clearer understanding and explicit considerations regarding biodiversity (e.g., bird migrations, insects, native species), impact on ecosystem services (e.g. water, soil quality, air quality), impact on human health and well-being (e.g., pollutions, use of pesticides) must be included in regulatory frameworks to ensure environmental justice.

List of Abbreviations

Abbreviation	Meaning
AD	Advantages
Agri-PV	Agrivoltaics
CAP	Common Agricultural Policy
DIS	Disadvantages
DSO	Distribution System Operators
EC	Energy Community
EU	European Union
GDP	Gross Domestic Product
IMP	Implications
LIM	Limitations
NbS	Nature based Solutions
NIMBY	Not in my back yard
RES	Renewable energy source(s)
RE	Renewable energy
PESTLE	Political, Economic, Social, Technological, Legal and Environmental
PhD	Doctor of Philosophy
PV	Photovoltaic
T	Task
TWh	Terawatt hours
UK	United Kingdom
UN	United Nations
USA	United States of America
WP	Work Package

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1. INTRODUCTION

This deliverable summarizes the research activities conducted in Task 6.1 "*Exploring justice implications of Agri-PV*" of the Symbiosyst project. The task is part of Work Package (WP) 6 "*Agri-PV value-chain involvement beyond market value*" which aims to integrate social and environmental considerations in the development of Agri-PV projects. The general aim of the task was to move beyond the concept of social acceptance of renewable energy technologies, by applying an environmental and energy justice perspective to the topic and further investigate the just transition implications of the practice of agrivoltaics. To achieve this, the tasks entailed first a literature review to check the state of the art of the knowledge about the topic, and second a set of semi-structured interviews with experts, to expand the knowledge with different perspectives. Third the identification of suitable foresight methods and the implementation of a dedicated foresight workshop formed part of the activities, to describe envisioned futures and justice implications on Agri-PV. The workshops were implemented in two different contexts (in Barcelona, Spain, and in Bolzano, Italy) to explore the potential future implications and desired visions for Agri-PV by 2040, as well as to test the methodology for collaboratively shaping visions of the 'what should be' or needs to be, in the context of a just transition and Agri-PV.

The purpose of this research is thus to provide novel insights into the environmental and energy justice implications of Agri-PV, and to suggest future research directions as well as recommendations to policymakers and local authorities for ensuring that the deployment of this technology will occur within the framework of a just clean energy transition across Europe.

The document is structured into six chapters to systematically present the research findings and analyses.

Chapter 1 introduces the research by explaining the reasons and needs to study environmental and energy justice in Agri-PV. It sets the stage for understanding the importance of addressing the distributional, recognitional and procedural dimensions of justice when considering integrating photovoltaic systems with agricultural practices.

Chapter 2 summarizes the literature review conducted to frame the research and to assess the current state of knowledge on social acceptance and justice in relation to the deployment of Agri-PV. This chapter provides a comprehensive overview of existing studies and identifies gaps that this research aims to address.

Chapter 3 forms the core of the research activity conducted, detailing the interview process that represents the main data source of the analysis. It describes the qualitative method used for data collection and presents the results of a comparative analysis among the four case studies. This chapter offers in-depth insights and novel perspectives into the perceptions and experiences of different stakeholders concerning Agri-PV projects in the four regions of South Tyrol (Italy), Catalonia (Spain), Wallonia (Belgium) and North Brabant (The Netherlands).

Chapter 4 describes the first foresight workshop conducted in Barcelona with Symbiosyst project partners. This workshop aimed to define key drivers and future visions for Agri-PV in Italy, Spain, Belgium and the Netherlands, and the EU, providing a collaborative method to explore potential scenarios and strategies.

Chapter 5 summarizes the replication of the foresight workshop conducted by Eurac Research in Bolzano with internal researchers from diverse academic backgrounds. This chapter highlights the interdisciplinary perspectives and the integration of various academic insights into the research process to grasp multiple dimensions of justice in relation to Agri-PV.

Chapter 6 concludes the document by summarizing the main insights derived from the different research activities. It provides a list of recommendations for policymakers and outlines areas for future research, ensuring that the findings contribute to informed decision-making and the sustainable development of Agri-PV systems.

The results of the research are expected to inform T4.1 "*Design for sustainability and Eco-design*" for the development of KPIs to assess and monitor the sustainability of Agri-PV projects, including social and environmental aspects. The results will also be used in T6.2 to draft the "*Guidelines for landscape integration of agrivoltaics*". Additionally, the foresight workshop methodology reported in the document will be further improved and tested in T6.4 "*Supporting the interaction with stakeholders and fostering participation*". The task entails the design of stakeholder engagement activities that will be organized at local and national levels in accordance with WP8 "*Dissemination, communication, and training*".

2. LITERATURE REVIEW

2.1 FROM SOCIAL ACCEPTANCE TO ENVIRONMENTAL AND ENERGY JUSTICE

The challenges ahead to transition energy systems towards a sustainable low-carbon economy and society, which operates within planetary boundaries and takes into due consideration aspects of inequality and justice, are complex. Although the development and implementation of technological solutions – ranging from the energy efficiency of individual technologies to the roll-out of renewable energy and related infrastructure - are at the forefront, there is growing awareness that those technological solutions, along with changing consumer behavior, and increasing citizens' acceptance, are not sufficient for achieving deep decarbonization. The key question in socio-technical transition has become how to govern the transition in a way that is both socially and environmentally just.

According to a recent perspective on how research on the social acceptance of renewable energy technologies has been evolving, this occurred in three major waves [1]. The authors argue that the first wave was much focused on emphasizing the existing social impact of the deployment of renewable energy infrastructure, such as the construction of major wind parks in Germany and Denmark in the early 1980s. The related researchers emphasized the necessity of getting a better understanding of not-in-my-backyard (NIMBY) attitudes, analyzing those who supported such developments and who were opposed, to 'overcome opposition' to renewable energy technologies. Albeit the line cannot be drawn neatly, according to the authors, the following second wave started to be critical of the NIMBY focus and to develop alternative frameworks. This included, for example, those arguing that oppositions had much to do with 'place-protective' actions, whereas others were more interested in socio-psychological aspects. The research on the latter was interested into how renewable energy technologies were perceived, including the distribution of benefits, and how the transition could be eased. The study states that the third wave of research questioned the opposition as only being something to understand to find a way to overcome it, especially considering what kind of world perspectives and narratives have been driving the deployment of renewable energy technologies.

The study [1] was not specific to any defined renewable energy technology but synthesized the main findings across various deployments of renewable energy sources. Although some insights in relation to PV are available, there is still a gap in getting a better understanding of what social acceptance of the technology is and how to go beyond it to critical considerations, especially by addressing environmental and energy justice, at the nexus of agriculture and energy production. This leads the authors of this deliverable to revise the existing literature on the topic of agrivoltaics and its social implications, using an environmental and energy justice framework.

2.2 METHODS

The revision of the existing literature on the topic of justice implication of agrivoltaics began in March 2023 by conducting a comprehensive search through two major academic databases: Scopus and Google Scholar. The primary keywords used in this search were "Agrovoltaic", "Agrivoltaic" and "Agri-PV." To explore intersections with justice frameworks, researchers also attempted a search using the mentioned keywords + "Justice," but this yielded no relevant results. This is illustrative of the novelty of the topic, and the very early stage of research on justice and Agri-PV in the first half of 2023.

The second attempt consisted in screening the titles of the academic articles resulting from the search by the only key words "Agrovoltaic", "Agrivoltaic" and "Agri-PV" to ensure they were relevant to the topic, i.e. that they investigated agrivoltaics form a social science perspective and not merely from a technical point of view, that led to the identification of 16 papers through Scopus and 6 papers in Google Scholar. Aside from this literature search focused on agrivoltaics, supplementary scoping review was conducted to find papers on climate and environmental justice frameworks, since relevant literature covering the concept of energy justice was already well known.

In the next step, the abstracts of the 22 papers obtained from the initial search were screened to further refine the selection. This step was crucial in identifying the most relevant studies that directly addressed the core themes of the review. As a result of this screening process, the number of papers was narrowed down to 11 papers, to be entirely read.

The final step involved a snowball literature search. This technique entailed reviewing the references of the selected papers and identifying subsequent papers that either cited these key studies or were cited by them. This iterative process was essential for uncovering additional relevant research and ensuring a comprehensive understanding of the topic. This led to the selection of additional 3 papers.

The order of reading of the identified papers was prioritized based on their focus, i.e. beginning with those that investigated the topic of agrivoltaics from a social science perspective, context (i.e. Europe first, USA secondly and any other geographical context next), and author, namely if an article by a specific author was deemed as insightful on the topic, other of the same author were read next.

2.3 RESULTS

The literature review on social acceptance and environmental and social justice related to Agri-PV reveals a nascent but growing body of work. The research conducted spans from 2020 to 2023, indicating a relatively recent interest in the topic. Some key authors were identified, mainly focusing their works on two geographical areas, the USA [2] and Europe, specifically Germany [3], [4].

Agrivoltaics is often proposed as a solution to the land use conflict between agricultural production and electricity generation. However, this approach tends to overlook the social dimension [2], [5], and, when considered, it is presented as a matter of social acceptance or opposition of agrivoltaics projects [2], [3], [4], [5], [6], [7]. In this regard, a study [7] identified the factors that influence the social acceptance of renewable energy production technologies, i.e. the local externalities produced by RES (e.g. aesthetics, noise, and impacts on local ecosystems) and insufficient public involvement. One of the primary drivers of opposition to agrivoltaics systems is its negative impact on the landscape [4]. Among the other barriers to the diffusion of agrivoltaics there are concerns regarding the end-of-life impact of photovoltaic installations, concerns regarding the permanent infrastructure interfering with agricultural production and future farming practices, uncertainties regarding the operation and business plan, uncertainties regarding regulations [2], [6].

Environmental and energy justice frameworks are gathered together by the just transition framework, that integrates all different tenets, addressing distributional, recognitional, procedural, and restorative issues [8]. While the environmental justice framework originated in the 1980s, the energy justice scholarship emerged more recently [9]. The distributional dimension of justice focuses on the equitable distribution of both the benefits, such as access to renewable energy or green spaces, and burdens, like the exposure to air and water pollution or the negative impacts of climate change, claiming that marginalized and vulnerable communities are disproportionately affected by negative impacts, while wealthier citizens gain from the benefits of socio-ecological transformations [8], [10]. The recognitional dimension of justice aims to acknowledge and respect the different perspectives, interests and needs of all communities, especially those who have been ignored or marginalized in energy policy discussions, environmental decision-making processes and climate change negotiations, including human and non-human forms and considering the issue of intersectionality [10]. Furthermore, procedural justice advocates for transparent, inclusive, and participatory decision-making processes regarding environmental and social issues, that also acknowledge the impacts on future generations [10]. Finally, the restorative justice tenet, which is the least investigated to date, aims to bring attention to need to repair the harm and damages caused by fossil-fuels industry, applying the polluter pays principles [8].

As the conducted literature review highlighted, such principles have never been applied to Agri-PV before. Hence, as preparatory activity for the design of the protocol of the experts' interviews, the justice lens has been applied to scrutinize and categorize the above-described social implications of Agri-PV. Thus, the distributional dimension of Agri-PV could highlight the uneven allocation of economic and environmental burdens and benefits, leading to significant injustices. In such unjust distribution there could be some subjects that would be disadvantaged, such as tenant farmers are particularly vulnerable, as they often lack decision-making power over Agri-PV installations, thus missing out on the economic advantages of combined land use that Agri-PV offers [7]. Additionally, local communities could face the adverse visual impacts of Agri-PV infrastructure, which can diminish the aesthetic value of the landscape and potentially reduce tourism rates, thereby harming the local economy [2], [4], [6], [11]. Environmental harms would also extend to non-human entities, as flora and fauna might suffer due to changes in land use, raising concerns about the rights of ecosystems [7], [11], [12]. On the recognitional dimension, marginalized voices, such as those of tenant farmers and local communities, are often overlooked in the decision-making process regarding the implementation of Agri-PV projects, and their interests and needs are neglected. The procedural dimension emphasizes the importance of inclusive stakeholder engagement in Agri-PV decision-making processes, such as workshops with citizens and other stakeholders to be realized even before installation of Agri-PV systems, which are crucial for establishing local criteria and planning frameworks that are perceived as legitimate [3], [6], [7]. Moreover, there is an inherent conflict between private property rights and the concept of farmland as a public good, reflecting deeper societal tensions [5].

3. EXPERTS' INTERVIEWS

3.1 METHODS

3.1.1 Interview Protocol

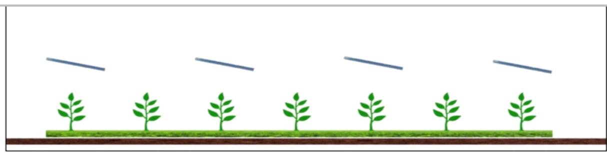
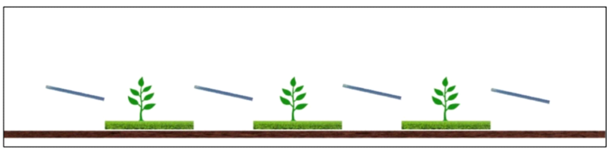
Based on the literature review, an interview protocol was designed and structured into six distinct sections (Table 1: Blocks, sub-blocks, and purposes of the interview protocol). Each section was developed to explore specific environmental and energy justice aspects of the deployment of Agri-PV. The first section served as an ice-breaking moment where each expert was asked to introduce themselves and explain their activities and experience related to Agri-PV. This initial part aimed to create a dialogue, establishing context and confidence before entering the core topics of the interview. The second section focused on the definitions of Agri-PV and the experts' perceptions of three different configurations of Agri-PV systems (Table 2), aiming to investigate general understanding, attitudes, and knowledge of this innovation. The third section delved into the perceived landscape impact, assessing how these systems are perceived to affect agrarian and rural landscapes and how landscape changes might influence residents and local communities. The fourth section examined the environmental and justice implications of Agri-PV, focusing, among others, on distribution of costs and benefits, recognition of different stakeholders' interests and needs, inclusivity and fairness of the decision-making processes associated with Agri-PV projects. Finally, the fifth section collected additional insights, opinions and ideas of the interviewee concerning Agri-PV and justice. To be noted that the protocol, and specifically the individual questions and sub-questions, and their order, had not to be strictly followed. The interview protocol was intended as a useful tool for the interviewer and has been used according to the flow of the actual interview. The questions asked during the actual interview have been tailored to the interviewee's role, expertise, and to the geographical scope (e.g., local – demo site – or national) referenced by their expertise.

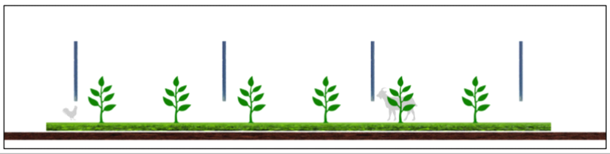
Interviews lasted around one hour each, or less if the interviewer considered that it could not offer any new relevant insights. Before the actual interview, the protocol of the interview, above described, was sent to the interviewee, clarifying that the questions asked would align with the interviewee's expertise. Additionally, before the actual interview, the GDPR forms were sent to the interviewee and their signature requested. The interviews have been conducted in person or via Teams and have been recorded with the interviewee's consent, according to an informed consent procedure. Different researchers conducted the interviews in the different contexts, as, if possible, it was deemed crucial that the interviews were conducted in the original mother tongue of the interviewees, i.e. Italian, Spanish, English, French.

Table 1: Blocks, sub-blocks, and purposes of the interview protocol

Block	Purpose
A – Icebreaking question	To profile the interviewee while creating a comfortable atmosphere conducive to conversation
B – Definitions of Agri-PV	To analyze the understanding and knowledge of the interviewee on Agri-PV
C – Landscape impact	To explore the perceived landscape impact of Agri-PV on residents and local population
D – Justice implications	To examine understandings and aspects of environmental and energy justice concerning Agri-PV
E – Final considerations	To collect additional and free considerations by experts on Agri-PV

Table 2: Description of the three spatial configurations included in the interview protocol. Source: MiTe 2022, Alessandra Scognamiglio, ENEA.

Spatial configuration	Description	Image
Type 1	PV modules are installed above the crops and it allows continuity of agricultural activities (and livestock) underneath the photovoltaic modules. There is a high integration between crops and the PV system.	
Type 2	PV modules are installed by alternating crops and PV modules and it is not allowed to perform agricultural activities underneath the photovoltaic module. There is a lower integration between crops and the PV system.	

Type 3	PV modules are installed in vertical position and it does not significantly affect agricultural activities. There is a middle integration between crops and the PV systems.	

3.1.2 Selection of the case studies

The case studies were selected as they serve as demo cases for the Symbiosyt project, while representing different agricultural, climatic, geographical, morphological, and cultural contexts in Europe. These differences allow for exploring different understandings and meanings of the concept of justice in relation to Agri-PV. Four prototypes of Agri-PV systems will be constructed and validated in Laimburg, South Tyrol (Italy), in Barcelona, Catalonia (Spain), in Bierbeek, Flanders (Belgium) and in Lierop, North Brabant (The Netherlands). Although in Belgium the region of Flanders is the location of the demonstration site, Wallonia was selected over Flanders as a case study for the interviews because its economy is primarily agrarian, offering a more relevant and focused perspective on socio-economic, environmental and landscape implications of Agri-PV, unlike the more industrial and service-oriented economy of Flanders.

- **Belgium - Wallonia**: With its continental climate and predominant agricultural sector, Belgium was considered to offer a perspective on integrating Agri-PV in regions with moderate sunlight and unbalanced population distribution between urban and rural areas. Agri-PV is currently forbidden in Wallonia although currently under discussion among local policymakers and stakeholders.
- **Italy – South Tyrol:** With a unique combination of Alpine and Mediterranean climates, South Tyrol is specialized in high-value and partly intensified agricultural production such as apples and wines. The diverse morphology of the region (valley and mountains), the scarce availability of agricultural surfaces, and the specialization in fruit production by small and larger farmers classified it as suitable location to study the justice implications of Agri-PV systems.
- **Spain - Catalonia**: Catalonia's semi-arid climate, brings significant challenges related to water scarcity and land use. Studying Agri-PV systems in Catalonia was deemed interesting to offer insights into how these systems can mitigate environmental and climatic stress, improve water use efficiency, and support sustainable agricultural practices while contributing to provide additional incomes to local farmers.
- **The Netherlands – North Brabant**: With its innovative agricultural techniques and dense infrastructure based on greenhouses, North Brabant presents a unique case for closed Agri-PV. The province focuses on technological advancements, land use optimization, renewable energy production and agricultural production represent an important case study to explore the justice implications related to the adoption of Agri-PV systems.

By analyzing the justice implications of Agri-PV in these four countries, the study aims to capture country-specific and common perceptions and attitudes, providing insights into the social acceptance, distributional, recognitional and procedural implications of Agri-PV projects across Europe.

3.1.3 Selection of the interviewees

Potential interviewees were identified through the project network and snowballing techniques, i.e. by asking each interviewed expert to provide additional contact information. This method ensured to identify five experts or stakeholders in each country with relevant experience and knowledge in Agri-PV, either at local or national level. Five main "general sectors" of expertise were identified by the research team as relevant to the study (Table 3):

- Energy
- Policy
- Agriculture
- Civil society
- Research

Table 3: Targeted sectors and description of required experts

General sector	Specific categories
Energy	PV experts, Agri-PV experts
Policy	Local and supra-local decision-makers
Agriculture	Small, large farmers, and farm organizations
Civil society	Community organization and environmental organization
Research	Academics with expertise in social and environmental justice and experts in environmental law

The above strategy permitted conducting a total of 5 interviews in each of the four countries. The research team contacted multiple experts across the five sectors and arranged interviews with those who responded to the invitation. In Belgium, experts of each sector of expertise were involved. In Italy, two experts of the energy sector, one local policymaker, one representative of the local farming association and one representative of an environmental organization in South Tyrol were interviewed, but no experts with academic background. In Spain, the research team interviewed one national policymaker, two representatives of two distinct farmers associations in Catalonia, one representative of an environmental association managing natural parks in Catalonia, and one professor in energy engineering. No representative of the energy sector responded to the invitation mail. In the Netherlands, two representatives of the horticulture and greenhouse sector were interviewed, as well as one representative of the energy sector, one representative of an NGO working on co-design approaches for RE projects and on PhD student working on Agri-PV landscapes. No Dutch policymaker was interviewed. In general, more agricultural experts and environmental associations were approached and less energy and academic ones. Although the research team is aware that the underrepresentation of some sectors might produce biases in the definition and perception of Agri-PV in some countries, the sample can still be considered well-balanced.

Table 4: Description of interviewed experts per sector and per country

Sector	BELGIUM Wallonia	ITALY South Tyrol	SPAIN Catalonia	THE NETHERLANDS North Brabant
Energy	• Partner and co-founder of a PV start-up	• Agri-PV company manager • Agri-PV consultant		• Senior researcher and consultant in PV and Agri-PV system engineering
Policy	• Local policymaker	• Local policymaker directing the landscape and nature department	• National policymaker directing agricultural department	
Agriculture	• Local farmer association representative	• Local farmer association representative	• Farmer association representative • Small farmer association researcher	• Project manager of farmers and horticulturist association • Greenhouse growing expert
Civil society	• Agronomist with experience in international cooperation and EU funded projects	• Environmental protection association representative	• Manager of natural agricultural park	• Design association specialised in co-creation for renewable energy projects
Research	• Academic researcher in the field of social sciences		• Professor in engineering	• PhD student working on Agri-PV and landscape

3.1.4 Interview process

The interview process was structured into four steps to ensure a systematic and scientifically robust approach:

1. **Arrangement of interviews**: once the interviewees were identified, the research team contacted them via email, inviting them to participate in the interview. The email explained the purpose of the questions and the interview process. Online interviews (18 interviews) or in-person interviews (2 interviews) were scheduled at

convenient times for each participant. Consensus and privacy form, prior the interview, were signed by each participant to ensure GDPR compliance and acknowledgement of the interview process and objectives.

2. **Recording of the interview**: each interview was recorded to ensure accurate capture of the information provided by the interviewee and to allow the interviewer to lead a natural conversation with the expert. This allowed for a detailed review and analysis of the discussions.
3. **Transcription and translation in English**: the recorded interviews were transcribed verbatim and, when not conducted in English, translated into English to allow all the members of the research team to understand the content of the interviews, and to perform the analysis. This step focused on ensuring the accuracy and integrity of the data, allowing for a comprehensive understanding of the content.
4. **Formatting and anonymization of the interview for comparative analysis**: the transcribed and translated interviews were systematically formatted to facilitate comparative analysis and were anonymized to consent the analysis of the included information in accordance with GDPR. This step ensures consistency and enables the identification of common themes, differences, and insights across the various interviews.

3.2 CASE STUDIES OVERVIEW

3.2.1 Belgium: Wallonia


Figure 1: Geographical position of Wallonia (source: Wikipedia)

Wallonia (Waloneye/Wallonie) is one of the three regions of Belgium, located in the south-east of the country with a total area of 16,844 km². The population is approximately 3.6 million people, predominantly French speaking (98%) with a minority German speaking (2%). Wallonia's GDP is around €126 billion, with a per capita GDP of approximately €34,500 [13]. Historically, Wallonia has been a major industrial region with strengths in steel, coal, and glass. It has evolved to include modern industries like mechanical engineering, chemicals, and biotechnology. The services sector and tourism also contribute significantly to the economy. Agriculture provides a small contribution to Wallonia’s GDP (0.8%) with around 12,000 farms facing difficulties in terms of income, with farmers earning lower income compared to workers in other sectors [14]. Wallonia’s rural territory consists of around 30% of forests and 43% of agricultural land. Livestock farming, meat and dairy production are the main specializations, followed by cereals and crops. As for the landscape, Wallonia features rolling hills, dense forests, and river valleys. The region is investing in renewable energy sources, particularly wind and biomass, and emphasizes energy efficiency in buildings and industrial processes. Agri-PV is currently forbidden in Wallonia by local policies regulating PV installation [15]. The new government elected in June 2024 will strictly regulate the development of renewable energy in agricultural areas (agrivoltaics, biogas, etc.) and it will examine any mechanism that allows for the protection of land with a food production function [16].

3.2.2 Italy: South Tyrol


Figure 2: Geographical position of South Tyrol (source: Wikipedia)

South Tyrol (Südtirol/Alto Adige) is an autonomous province located in the north-east of Italy, with a total area of 7,400 km². It counts a population of approximately 531,000 inhabitants, including German-speaking (62%), Italian-speaking (23%) and Ladin speaking (4%). The province has a GDP of around €25 billion and a per capita GDP of €46,000, among the highest in Italy [16]. Tourism is a major industry counting for 8.2% of the provincial GDP, followed by the service sector. Agriculture accounts for 5% of the provincial GDP and it is characterized mostly by small enterprises (17,000) owning less than five hectares of land. Agricultural production is specialized in fruit cultivation (48%), with apple orchard and vineyard representing the primary crops [17]. Agriculture is limited due to the morphological characteristics of the territory. As for the landscape, South Tyrol is predominantly alpine, featuring extensive forested areas, alpine pastures, and agricultural valleys. South Tyrol is a leader in renewable energy production in Italy: it produces 6.6 TWh of energy from renewable sources, with 88% of green electricity coming from hydroelectric power plants [18]. Agri-PV is currently forbidden in South Tyrol, although recent regulations open to the installation of Agri-PV for research purposes [19].

3.2.3 Spain: Catalonia

Catalonia (Catalunya/Cataluña) is an autonomous region located in northeastern Spain, with a total area of approximately 32,113 km^2. With a population of over 8 million people, Catalonia has both Catalan and Spanish as official languages, with Catalan being 94,3% [20]. The region has a GDP of around €255 billion and a per capita GDP of

Figure 3: Geographical position of Catalonia (source: Wikipedia)

approximately €32,500, making it one of the wealthiest areas in Spain [21]. The Catalan economy is strongly industrialized (37%), particularly in the automotive, chemical, pharmaceutical, and food processing sectors. The services and tourism sectors (60%) are also important sectors, with Barcelona, the capital, and the Mediterranean coast being major tourist destinations. Agriculture, forestry, and fishing counts only for the 3% of the total economy, and the total amount of land devoted to agricultural use is 33% [22]. The region has a diverse landscape with the Pyrenees mountains in the north, a Mediterranean coastline, and the Catalan Central Depression characterized by agricultural plains. Land use includes urban areas, industrial zones, agricultural land, and protected natural areas. Traditional agriculture, which used to specialize in Mediterranean crops like olives and grapes (for wine production), are being supplanted by fruits and vegetables for consumption in urban areas. Catalonia places a strong focus on renewable energy, and in 2022 it produced 29,900 GWh of renewable energy (30.9% of total energy production) particularly cogeneration (8.2%), hydro (6.4%), wind (5.9%) and solar power (11.4%) and has set plans to increase its renewable energy capacity [23].

3.2.4 The Netherlands: North Brabant

Figure 4: Geographical position of North Brabant (source: Wikipedia)

North Brabant (Noord-Brabant) is a province in the south of the Netherlands with approximately 2.6 million people, a total area of 5,081 km^2 and a population density of about 536 inhabitants per square kilometer. The province has a GDP of around €143 billion and a per capita GDP of approximately €55,000 [24]. Although most Brabantians live in urban areas, a significant portion of economic activity is in the countryside, in livestock, farming and agriculture. North Brabant is the biggest agrifood region in the Netherlands, producing over 20% of all Dutch agrifood and exporting over 17% of total Dutch export. Over 13,000 companies participate in this record, representing an added value of €7,5 billion [25]. The predominant landscape features of North Brabant are rural areas, consisting of farmland, woodland, and rivers. In the sandy areas in the south-east are fens, moorland and woodland. At the national level, the production of electricity from renewable sources in the Netherlands increased significantly over the last 5 years and it reached 57 billion kWh in 2023 [26]. Renewable electricity is produced from solar energy (37%), offshore wind (31%), onshore wind (20%), biomass (12%) and water (0,12%). Solar electricity production increased by nearly a quarter from 2022 due mainly to the increased capacity of the installed solar panel. In North Brabant, the installed solar electricity capacity in 2022 was 3,323 MW and it is expected to grow over the next years due to newly installed solar modules [27]. Although renewable energy accounted for just over 10% of energy supplies in 2018 (19 TWh), there have been significant developments over the last 20 years to reach 23.5% by 2030.

3.3 RESULTS

This section presents the findings of the interviews conducted in each case-study. The results are organized according to the interview structure to allow a comparison among the four case-studies. The findings should be interpreted as the perceptions of the interviews rather than legislative or technical definitions, offering insights into the researched topic of environmental and energy justice in relation to Agri-PV.

3.3.1 Definitions of Agri-PV

This sub-section compares the definitions and underlying concepts provided by experts in the four regions. The definitions should not be understood as legislative definitions but aims to offer insights into the understanding of Agri-PV in each case study.

3.3.1.1 Free definitions

Belgium (Wallonia)

Walloon respondents defined Agri-PV as the combination and integration of agricultural and energy production on the same site, emphasizing the optimization of land use and the synergy between the two activities. Most interviewees recognize Agri-PV as an opportunity to blend both activities in a harmonious and balanced way. However, this approach requires a case-by-case analysis and the involvement of farmers to effectively implement the technology, emphasizing the importance of agriculture and livestock farming remaining the primary activity and being preserved.

Italy (South Tyrol)

South Tyrolean respondents defined Agri-PV as the combination of high-quality agricultural and renewable energy production on the same site, leading to combined use of land. This integration often results in a win-win situation where both sectors are mutually supportive. However, some confusion still exists between Agri-PV and the installation of PV modules on agricultural land.

Spain (Catalonia)

In Catalonia, interviewees characterized Agro-PV as the merging of agricultural and energy production on the same piece of land, allowing for combined purposes a particular emphasis on agriculture. “I believe the two key concepts here are coexistence [...] and complementarity, where photovoltaics enhances agricultural activity rather than taking its place”. One respondent highlighted the Spanish use of the terms “Agri-PV” and “Agro-PV”, referring with the first to agriculture (vegetal production) while with the second to farming (both agriculture and livestock).

The Netherlands (North Brabant)

Dutch respondents described Agri-PV as the integration of agriculture and energy production on the same land, enabling multiple land use and addressing land scarcity. This combination frequently creates a mutually beneficial scenario where both sectors support each other, by enhancing the profitability of the agricultural side.

Table 5: Free definitions of Agri-PV across the four case studies

	BELGIUM **Wallonia**	**ITALY** **South Tyrol**	**SPAIN** **Catalonia**	**THE NETHERLANDS** **North Brabant**
Free definitions of Agri-PV	• Optimization of land use • Synergy between agricultural and energy production • Requiring case-by-case analysis and involvement of farmers • Priority to agriculture	• Combined land use • Mutually supportive and beneficial scenario • Still some confusion	• Combined purposes • Coexistence and complementarity • Emphasis on agriculture	• Integration • Multiple land use • Mutually supportive and beneficial scenario • Addressing land scarcity

3.3.1.2 Difference between photovoltaic on agricultural land and Agri-PV, advantages and disadvantages of both / Importance of Agri-PV

Belgium (Wallonia)

According to the interviewees, solar fields offer greater convenience for energy companies, which can install more PV modules with a higher land cover ratio, ensuring efficiency and cost-effectiveness, albeit with the risks of unbalanced land use in favor of energy production and the subsequent risk of price speculation. PV fields implemented with cattle (or Agri-PV with forage), for instance, are negatively perceived as a justification for producing energy on agricultural land without adapting to local agricultural practices and prioritizing energy production over agricultural production. Conversely, Agri-PV is considered a more sustainable approach considering the impact on the landscape. This method permits the combined use of land and creates a synergy where both sectors benefit from each other, enhancing their profitability. “An analogy I like to use is comparing it by having PV modules on the roof of a house. Just as installing solar modules doesn't prevent you from living in your house, Agri-PV doesn't stop the agricultural use of the land”. Consequently, while traditional photovoltaics on land prioritizes energy interests, potentially overshadowing agriculture or livestock, Agri-PV is perceived to prioritize agricultural needs and benefits for farmers, adapting the design of the installation for the purpose of affecting least possible the farming activity. Another potential advantage for the farmer is the self-consumption of the energy produced and, aiming to foster community engagement, the promotion of local energy communities in case of energy in excess.

However, two interviewees expressed skepticism about Agri-PV, particularly concerning the system's design, which risks impeding agricultural activities (e.g., machinery passage, crop rotation, sunlight penetration), thereby disadvantaging food production. To address these issues, Agri-PV systems are suggested to be elevated to avoid disturbing agricultural activities and crop growth below.

On the other hand, Agri-PV was evaluated positively in terms of adaptation to climate change given its ability to shade crops and alleviate their exposure to high temperatures, decrease water transpiration and mitigate heavy rain and hailstorms (floods). It has been also pointed out that Agri-PV is crucial for energy transition and energy security in Europe: “Agri-PV is not just a solution but a key component of the energy transition in Europe. The challenge lies in determining where to start and where to end, in finding that equilibrium where both agriculture and solar energy production can coexist and complement each other effectively”.

Italy (South Tyrol)

Although PV modules on agricultural land are typically cheaper and therefore more convenient for energy companies, Agri-PV is seen as essential for a just energy transition, addressing issues of unbalanced land use. Priorities include using the produced energy for agricultural needs, generating multiple benefits such as local employment, and encouraging community participation in integrating energy infrastructure into the landscape. The perceived advantages of Agri-PV encompass reduced pesticide use and protection against climate change effects. This includes providing shade for crops, which is expected to decrease water transpiration, mitigate flooding, thereby enhancing crop quality. However, concerns remain about the potential negative effects on soil, agricultural production quality, and ecosystem preservation as well as the risk of industrial land exploitation.

Spain (Catalonia)

Catalan respondents emphasized that Agri-PV respects and considers agricultural needs, in contrast to traditional photovoltaics that prioritize energy production to the detriment of farming activities. The focus of Agri-PV is on ensuring that each operation remains profitable as an independent entity.

According to interviewees, Agri-PV might also be beneficial to the environment by helping adaptation of crops to problems connected with climate change and compared to traditional PV. However, the potential benefits were perceived to be dependent on the system layout and on the economic interests of energy companies in charge of the project.

The interviews revealed that farmers in Spain are facing a severe economic crisis due to low prices of agricultural products. Therefore, the positive economic impact of Agri-PV, which can promote local employment and generate additional and diversified income for farmers, is perceived to be particularly relevant. At the same time, interviewees preferred small-scale Agri-PV for self-consumption to enhance economic benefits for farmers and to ensure that existing agricultural activities are not overtaken by interests of energy companies.

The Netherlands (North Brabant)

In the Netherlands, Agri-PV was perceived by interviewees to enable land multifunctionality, with the primary objective of maximizing land productivity and optimizing land use to cope with soil scarcity and counteracting land waste of traditional PV systems.

Dutch experts claimed that since Agri-PV projects combine agricultural production and energy generation in a simple and effective way, they are more likely to receive subsidies compared to other projects (e.g. combining agrivoltaics with biodiversity conservation), which are much complicated to implement, making them attractive to farmers and investors. Additionally, the potential for installing PV modules on greenhouses, which have high electricity needs especially in cold and dark seasons, is expected to receive further interest by practitioners and researchers.

Table 6: Reported differences between PV panel on agricultural land and Agri-PV across the four case studies

	BELGIUM **Wallonia**	**ITALY** **South Tyrol**	**SPAIN** **Catalonia**	**THE NETHERLANDS** **North Brabant**
Differences between PV modules on agricultural land and Agri-PVs with advantages / disadvantages of both	• PV modules on agricultural land - AD: efficiency and cost-effectiveness; DISADs: inefficient land use, price speculation. • Agri-PV – ADs: combined use of land, synergy, benefits for farmers, creation of local energy communities, climate change adaptation; DISAD: obstacle to agricultural activities.	• PV modules on agricultural land - AD: cheaper; DISAD: unbalanced land use. • Agri-PV – ADs: social and environmental positive impacts (local employment, community engagement, climate change mitigation); DISADs: potential negative effects on crops, soil and biodiversity.	• PV modules on agricultural land – DISADs: prioritization of energy production over food production. • Agri-PV – ADs: consideration of agricultural needs, ensuring the profitability and independence of the two activities; multiple benefits (especially for farmers)	• PV modules on agricultural land - DISAD: unbalanced land use. • Agri-PV – ADs: multifunctionality, land use maximization, financially attractive; DISADs: social resistance, landscape impact.

3.3.1.4 Preferred system configuration and implications/limitations of each configuration

Belgium (Wallonia)

According to the majority of interviewees in Wallonia, type 1 configuration was the most favorable option, considering environmental and social impacts. It was perceived as the most respectful configuration for agricultural needs by allowing sunlight penetration, safeguarding crops from wind and soil erosion, and enhancing the microclimate. Nevertheless, concerns were expressed about the height of PV modules, which may face resistance in terms of social acceptability, installation costs—twice that of standard PV plants, feasibility for large-scale systems, compromised electricity production if wind impacts the modules, and potential insufficient spacing between rows to accommodate agricultural activities.

Interviewees agreed that type 2 configuration appears to be cheaper and lower in height compared to type 1, and therefore structurally more stable. It was perceived to have a lower landscape impact, potentially making it more acceptable for residents. However, it was regarded as less compatible with agriculture and livestock farming, resulting in inefficient land use.

Type 3 configuration with tracker appears to combine the positive aspects of type 1 and type 2. Interviewees suggested that this configuration allows space for agricultural machinery to move between the rows and it increases efficiency in energy production by adjusting modules to sunlight and agricultural routines (i.e. irrigation). From a landscape impact perspective, it was proposed that type 3 might substitute traditional fences, if placed at property borders, thus gaining acceptance from residents. One interviewee raised concerns over the gazing effect of type 3 since the reflection of sunlight off the modules might cause visual discomfort for the nearby residents.

A combination of type 1 and type 3 was valued positively by interviewees for the favorable environmental implications, as it respects agricultural production and maximizes food production. Without any specification on the configuration, it was mentioned that the promotion of Agri-PV systems that allow for crop diversification and are close to consumption sites (urban and industrial areas), might enable energy sharing, hence facilitating the energy transition, as well as mitigate climate risks related to monocultures. For example, monocultures such as potatoes in Belgium, currently reduces the resilience of the fields to flooding and raise the costs of climate risks.

Finally, the interviewees agreed that identifying the most suitable configuration depends on multiple complex factors that must be analyzed on a case-by-case basis. They also emphasized that an agroecological approach should be adopted to guide decisions in Agri-PV.

Italy (South Tyrol)

Experts in South Tyrol showed conflicting opinions regarding the perceived environmental and social impact of the three configurations of Agri-PV systems. There were opposite views concerning the impact of Agri-PV on biodiversity, ecosystem services, and agricultural productivity and quality due to potential changes in soil quality and solar irradiation.

From a sustainability perspective, type 1 configuration was preferred by most interviewees as it was perceived to allow full land exploitation and symbiosis. The high positioning of the modules was expected to not interfere with regular agricultural activities and to not endanger the environment, biodiversity, or workers.

In contrast, type 2 configuration was more debated. There was skepticism among experts about alternating rows of PV modules and crops due to crop rotation issues, particularly in horticulture. It was not seen as proper integration of agriculture and energy since the profitability was perceived to be in favor of energy production. Interviewees recommended type 2 for property edges and margins rather than for agriculture to maximize land use and tackle the problem of land waste.

Type 3 was rejected by the majority of respondents due to the landscape impact, which was perceived to be higher than in type 1 configuration. Furthermore, experts in the energy sectors suggested that in type 3, energy production was disadvantaged due to the vertical orientation of the modules, which allows for less solar radiation. Additionally, experts in the agricultural sectors pointed out that the vertical orientation of modules fails to provide protection of crops from solar radiation, as the shading of PV modules is limited, especially in the warmest hours of the day. On the positive side, the installation of type 3 is expected to be easier and more cost-effective than type 1, and the distance between rows of modules allows agricultural machinery to pass through.

Spain (Catalonia)

According to interviewees, the type 1 configuration exemplified the best integration of agricultural and energy aspects. The design was perceived to have positive environmental implications, enhancing microclimate under the PV modules while allowing sunlight and machinery to pass through the modules. However, one respondent noted that agricultural activities might be hindered, except in horticulture. Type 1 also offers crop protection from hail, wind and excessive solar radiation. One expert expressed concerns about the negative impact of type 1 configuration on biodiversity as high modules might obstruct wildlife movement, affecting especially bird flights and insects.

Type 2 configuration raised questions among interviewees over the definition of Agri-PV (most experts were unsure whether it can be classified as “Agri-PV”) and its adaptability and profitability, depending on factors such as row spacing, cultivation methods, and crop types. Concerns were expressed about the risk of reduced crop productivity under the modules and consequent income losses to farmers. It was noted that low-positioned modules, including terrestrial photovoltaics, could be well-suited for the edges and borders of farms, where there are no crops, maximizing space use without impacting agricultural or livestock activities. This configuration was considered compatible primarily with vegetable gardens and viable if economically feasible, resembling the concept of installing glass-like modules on greenhouses.

Type 3 was viewed critically by the majority of interviewees due to the vertical orientation of the modules, which was perceived to reduce solar radiation, negatively impacting energy production. From the agricultural point of view, although the structure provides space for machinery between the rows, further research is needed to understand whether food production could be affected in any way. It has been suggested that, to avoid affecting agricultural activities, modules could be placed on fences.

According to most experts, vertical and movable configurations hold great potential as they can adjust inclination and orientation to maximize energy production. Modular systems are expected to better distribute rainwater compared to horizontal or fixed modules, and to provide wind protection for crops. Experts were uncertain on whether they pose a barrier that could negatively affect biodiversity and called for further studies on this topic.

The Netherlands (North Brabant)

Experts in the Netherlands suggested that type 1 configuration seems to be more respectful of agriculture, allowing freedom of cultivation, and maximizing land use. It is perceived to be the most efficient configuration in terms of integration with the crop, preserving soil moisture and allowing sunlight to pass through, hence facilitating photosynthesis across the crop. However, type 1 is expected to face resistance from residents due to its visual impact, which contrasts with the traditional Dutch landscape.

Consequently, type 2 was appreciated by experts for its lower visual impact and is more acceptable to locals, though type 1 remains suitable for horticulture and orchards that already have covering structures, despite 60% of Dutch agriculture is dairy farming so less applicable.

The type 3 configuration was also valued for its low visual impact, as it does not rise high off the ground and is suitable for grasslands and livestock farms. While type 3 was appreciated for not affecting agricultural activities and providing a wind barrier for crops, it was considered inefficient for energy production due to the vertical orientation of the modules and the reduced amount of light they capture throughout the day. It could also compromise the agricultural part by keeping crops in the shade most of the time. However, there's a consensus that the best configuration depends on various contextual factors, such as the type of crop, community acceptance, environmental impact, agricultural practices, the complexity of the solar panel systems. The suggested approach consists in finding a balance between positive and negative impacts; hence it is fundamental to experiment with several design configurations. An important feature that has been emphasized is the freedom of movement of the modules (tracking systems), which is essential for their adaptability.

Table 7: Characteristics, implications & limitations of different Agri-PV configurations across the four case studies

	BELGIUM Wallonia	**ITALY South Tyrol**	**SPAIN Catalonia**	**THE NETHERLANDS North Brabant**
Different configurations (implications and limitations)	• Type 1 – IMPs: respectful of agricultural needs, crop and soil protection, sunlight penetration, microclimate enhancement; LIMs: height, installation costs, feasibility for large-scale systems, wind impacting energy production. • Type 2 – IMPs: cheaper, lower, more stable, minimal landscape impact, more acceptable for locals; LIMs: incompatibility with agriculture and livestock farming. • Type 3 – IMPs: combination of positive aspects of type 1 and type 2 (if movable), good for fences; LIM: sunlight reflection. • A mix of type 1 and type 3 is valued for its positive environmental implication.	• Type 1 - IMPs: full land exploitation and symbiosis (preferred). • Type 2 - IMPs: suitable for edges and margins of properties; LIMs: crop rotation issues, production disparity in favor of energy, no/less government subsidies. • Type 3 – IMPs: cost-effective, no disturbance to agricultural activities; LIMs: high visibility/landscape impact, less solar radiation, lack of crop protection.	• Type 1 – IMPs: enhancing microclimate, allowing sunlight and agricultural activities, climate change mitigation and adaptation; LIMs: obstruction to wildlife movement. • Type 2 – IMPs: adaptability and profitability to be further studied, suitable for edges and margins of properties, vegetable gardens, similar to glass-like modules on greenhouses; LIMs: under cropping, losses for farmers. • Type 3 - IMPs: no disturbance to agricultural activities, crop protection from wind, maximization of energy production (if movable), good for fences, better rainwater distribution; LIMs: less solar radiation, barrier for biodiversity.	• Type 1 - IMPs: freedom of cultivation, maximization of land use, best integration with the crop; LIMs: high visual impact. • Type 2 - IMPs: lower visual impact. • Type 3 - IMPs: lower visual impact, suitable for grassland and livestock farms, no disturbance to agricultural activities, wind barrier for crops; good option if movable (tracker); LIMs: inefficient energy production, shade for crops.

3.3.2 Agri-PV and landscape

3.3.2 1 Value of landscape

Most of the interviewees in the four countries agreed in defining landscape as a fundamental value to be respected and preserved.

Belgium (Wallonia)

In Belgium, interviewees conveyed that there's a growing sensitivity towards the landscape, especially when it relates to renewable energy projects. In the countryside, the rapid growth of new potential development of PV projects has met resistance by local communities who value the traditional landscape. Traditional landscapes include trees and hedges, community facilities, areas of biological interests and architectural heritage. There are attempts to quantify the value of landscape through tools that score the different dimensions of the landscape.

Italy (South Tyrol)

All the interviewees in South Tyrol agreed on defining landscape an important value, connected to aesthetics, and to the uniqueness and cultural identity of the region. Landscape permeates human life and defines the relationship between people and the earth, influencing their living conditions, health, and wellbeing. Some experts recognize the productive function of agricultural landscapes, emphasizing the importance of explicitly addressing landscape in the clean energy transition and in the process of innovation and transformation of the agricultural sector.

Spain (Catalonia)

The interviewees in Catalonia placed great value on landscape and on agricultural landscape, which needs to be respected and preserved. According to two interviewees, the landscape has a deep connection with human feelings and wellbeing, providing a connection with nature and an escape from urbanized landscapes.

The Netherlands (North Brabant)

In the Netherlands, the landscape is very important due to the limited availability of space. The landscape was perceived by most interviewees as changing rather than static, and it holds a different value for people living in urban areas compared to those in rural areas: "*people from the city value the landscape as nature and for them is about recreation. People from outside of the city see the landscape as a production landscape*".

Table 8: Perceptions of the value of the landscape across the four case studies

	BELGIUM **Wallonia**	**ITALY** **South Tyrol**	**SPAIN** **Catalonia**	**THE NETHERLANDS** **North Brabant**
Value of landscape	• High value of traditional landscapes • Landscape change due to PV projects currently meets resistance and opposition from local authorities and communities • Innovative tools to quantify the landscape impact of new development projects	• High value connected to aesthetics, uniqueness, and cultural identity of a region • Defines relationships between people and the earth • Agricultural landscape is a productive landscape	• High value due to influence on human wellbeing and feelings • Agricultural landscape providing a sense of tidiness and naturalness	• High value due to limited space availability • Dynamic rather than static • Romantic view of urban citizens vs functional view of rural citizens

3.3.2.2 Untouchable, inviolable, and unchangeable aspects of landscape

Most experts conveyed that landscape changes should occur in harmony between natural and built environments, leaving some spaces untouched and "open for the human eyes".

Belgium (Wallonia)

In Wallonia, most experts pointed out that traditional landscape in the countryside needs to be protected from a massive installation of photovoltaic energy projects, together with natural areas and historical centers. Elements of traditional landscape includes trees and hedges, agricultural buildings, community facilities, heritage sites, biodiversity habitats. According to one expert in Wallonia, development projects should prioritize urban areas and connecting with already existing energy infrastructure. Interviewees representing famer associations stated that decisions over landscape changes should be taken collectively through public consultation and it should be ensured that natural spaces are preserved as a duty towards future generations.

Italy (South Tyrol)

Experts in South Tyrol agreed that not all types of landscapes and crops are suitable for the installation of photovoltaic modules. Although it is recognized that pristine “natural landscapes” in Europe are rare due to human interventions occurring through centuries, there are several types of distinctive agricultural landscapes that needs to be preserved. The experts point, for example, to the legume fields in Castelluccio di Norcia, to the lemon terraces on the Amalfi Coast and to the vineyards in South Tyrol as agricultural landscapes to leave untouched. Additionally for South Tyrol, high-mountain valleys and haymaking landscapes are untouchable since they have a high value for the local community and the visual impact of Agri-PV would be extreme.

Spain (Catalonia)

In Catalonia interviewees pointed out the necessity of preserving soil of high agronomic value and landscapes that are very characteristics of the region such as gardens, greenhouses, and crop fields within natural areas. Special attention should be paid by the government in defining and regulating the permitting process for the installation of Agri-PV to mitigate the visual impact of those systems. Otherwise, the experts agree that Agri-PV should be preferred over land abandonment, which is occurring in the mountain part of Catalonia.

The Netherlands (North Brabant)

Experts in the Netherlands point out that the landscape is not static, but it is changing over time. Yet, changes should be done with care and priority should be given to areas that are more adaptable or already undergoing change. There are some landscapes that need to be considered with special care such as Nature 2000 sites, cultural heritage sites, peri-urban areas used for recreational activities by citizens.

Table 9: Untouchable, inviolable, and unchangeable aspects of landscape across the four case studies

	BELGIUM Wallonia	**ITALY South Tyrol**	**SPAIN Catalonia**	**THE NETHERLANDS North Brabant**
Untouchable, inviolable, and unchangeable aspects of landscape	• Traditional landscape (trees, hedges, community buildings) • Natural areas and historical centers • Preservation of landscape as a duty towards future generations	• High-mountain valleys and haymaking landscapes • Vineyards as distinctive agricultural landscape of the region	• Landscape with soil of high agronomic value • Landscape characterizing the region (gardens, crops...) • Landscape change preferred over land abandonment	• Protected areas as Natura 2000 sites • Per-urban areas used for recreational purposes by citizens • Cultural heritage sites

3.3.2.3 Impact of Agri-PV on landscape

Most interviewees affirmed that landscape transformation is a necessary condition for the clean energy transition. Agri-PV is perceived to be less impactful than other types of renewable energy sources such as wind turbines, hydropower plants or photovoltaic on land.

Belgium (Wallonia)

Experts in Wallonia recognized the positive aspect of Agri-PV in attempting to integrate energy production, yet the integration should carefully consider sustainability and minimize ecological disruption. Agri-PV was said to risk making landscapes appear uniform, losing the unique characteristics that distinguish Wallonia from other regions. Like the visual impacts of nets on orchards, Agri-PV can alter the landscape, though vertical placement of modules (Type 3 Agri-PV) is perceived to have the least impact. Integrating Agri-PV with greenhouses is even better since greenhouses are already present in the landscape. Despite these efforts, the visual impact of Agri-PV may affect residents' acceptance, especially with taller structures like Type 1 systems being less socially acceptable. The impact is reduced if Agri-PV systems are installed near existing infrastructure and artificialized zones. Compared to wind turbines and hydropower plants, Agri-PV is perceived to be more respectful of the landscape and ecosystem. However, concerns about their landscape impact are higher than for other renewable energy infrastructures that have become accepted over time by residents and local communities. This raises questions about whether society can get used to the sight of renewable energy infrastructure over time. Making renewable energy infrastructure visible can increase awareness of electricity consumption and commitment to renewable energy production. Integrating renewable energy infrastructure into the landscape as land art, as seen in China, can enhance the cultural and aesthetic value of the landscape. On the other side, to mitigate the visual impact of Agri-PV systems, especially in flat landscapes, planting hedges or vegetation to obstruct the view of PV modules can be an effective solution.

Italy (South Tyrol)

In Italy, experts had opposing views on the visual and environmental impact of Agri-PV impact. On the one hand, experts with a business and technical background stated that Agri-PV does not change the skyline of the landscape but rather innovates it. To reduce the visual impact of Agri-PV, some experts stated that in Italy some companies are experimenting the use of different materials such as wood poles or weathering steel to mimic traditional construction in the crops, reducing the perceived visual impact. One expert in Italy suggested that the visual impact of Agri-PV is positive since it defines a productive function for land. Other experts highlighted that Agri-PV can have a positive impact on biodiversity in agricultural fields if they bring a reduction in the use of pesticides and create habitats for animals. Unlike wind turbines, Agri-PV were not expected to affect the bird flights. On the other hand, experts representing local authorities and the civil society expressed their concerns because PV modules were perceived as alien to the surrounding environment. Additionally, experts in South Tyrol were worried about the impact of Agri-PV on tourism since the tourism industry is closely related to the traditional agricultural landscapes of the region.

Spain (Catalonia)

According to experts in Catalonia, Agri-PV, while beneficial for renewable energy generation, can create tecno-industrial landscapes and may not be suitable for small territories like agricultural parks. However, Agri-PV was seen by all experts as a necessary measure to support the clean energy transition and move away from fossil fuels. As any infrastructure development, Agri-PV is required to support human progress and combine food production with energy security. Yet, the experts stressed the importance of designing new plants in ways that favor the installations but at the same time minimize the landscape impact. Integrating renewable energy initiatives, such as Agri-PV, can provide economic benefits for local farmers while preserving the environment and the use of land. Although larger projects have greater impacts, Agri-PV is expected to offer more feasible integration with lesser visual impacts compared to other renewable energy sources such as wind turbines.

The Netherlands (North Brabant)

According to experts in the Netherlands, open Agri-PV positively impacts the soil by allowing for diverse uses and protecting biodiversity by promoting less intensive farming practices. Closed Agri-PV need further investigation to assess the impact of reduced sunlight on crop productivity. However, the perceived risk of Agri-PV by experts is that it may create an excessively industrialized landscape.

Table 10: Impacts of Agri-PV on landscape across the four case studies

	BELGIUM **Wallonia**	**ITALY** **South Tyrol**	**SPAIN** **Catalonia**	**THE NETHERLANDS** **North Brabant**
Impact of Agri-PV on landscape	• Negative impact on traditional landscape, although lower than other RES • Risk of transformation of agricultural land and productivity • Mitigate impact through green corridors, trees and hedges • Use Agri-PV as a form of art to mitigate impact and improve social acceptance	• Positive impact as agricultural landscape is productive • Positive impact on biodiversity (less use of pesticide, lower impact on bird flight) • Negative impact since PV is alien to agricultural/natural landscapes • Negative impact on tourism	• Risk of creating industrial landscapes • High impact on small agricultural parks • Necessary measure to move aways from fossil fuels • Less impact than other renewable energy project	• Positive impact on soil due to less intensive farming practices • TBD impact on agricultural productivity in greenhouses • Negative impact on landscape industrialization

3.3.2.4 Preferred areas for Agri-PV

Belgium (Wallonia)

The interviewees agreed that small scale systems are preferable over larger ones for two main reasons. Small agricultural lands were expected to not need machinery that might encounter difficulties in operating within Agri-PV fields. Furthermore, Agri-PV should be a localized energy source rather than a primary energy production method for countries. Vegetable, small fruits and fruit orchards were stressed as more suitable crops as they benefit more from the coverage effect of the PV modules against climate change effects and because there are already coverage infrastructures that can be used for installation, and which are already impacting the landscape. All interviewees agreed that Agri-PV should be in agricultural areas close to the built environment (cities, villages, industries, closes to agricultural buildings) rather than in open fields. One interview suggested that Agri-PV might help experimenting alternative models of agricultural production other than monoculture while contributing to the energy security of cities especially during extreme climatic events (floods risk reduced). Other interviewees declared that priority for PV installation should be given to rooftops, areas closed to the roads, motorways, railways, abandoned areas.

Italy (South Tyrol)

South Tyrol is a mountain region and has few open fields available for Agri-PV. Most agricultural lands are fragmented, small and dispersed across the different mountain valleys. The majority of experts conveyed that fragmentation and dispersion of agricultural lands also poses technical issues, for example, in connecting the PV plants to the grid. Experts agreed in saying that priority for PV installation should be given to other surfaces such as rooftops, parking lots, industrial areas, and only eventually agricultural lands in flatlands close to the motorway. When considering the crop types, apple orchards in flatlands that are already covered by hail nets, small fruits and potatoes were considered most suitable. Viticulture was excluded due to the changing morphology of the vineyards on mountains and to the extremely high landscape impact.

Spain (Catalonia)

In Catalonia, experts hold different opinions both on the size of agricultural areas and on the crop type more suitable for installation. Some experts stated that large monocultures should be the ideal location for Agri-PV since the agricultural landscape is already compromised. Others preferred small size agricultural land, linked to self-consumption and more manageable from a cultivation perspective since there are no large machinery. Concerning the crop types, some prioritized horticulture and lower crops since it overcomes the problem of machinery, and it minimizes the visual impact due to lower panel height. Others point to apple orchards with hail nets.

The Netherlands (North Brabant)

In the Netherlands, height rather than size was considered by all experts as the most important characteristic determining perceived landscape impact. Since the country is a flatland, the visual impact of Agri-PV system of 4 or 5 meters was perceived to be high. For this reason, the vertical configuration was considered more suitable for installation, particularly for dairy fields or above greenhouses. Concerning the most preferable crop types, dairy farms, small fruits, and fruit orchards were considered appropriate as they already make use of hail nets which generate a landscape impact. Other experts suggest concentrating Agri-PV in dedicated landscapes of poor aesthetic and productive value. Yet, particular attention should be paid to the design of Agri-PV systems, to tailor them to the characteristics of the area.

Table 11: Preferred areas for the implementation of Agri-PV across the four case studies

	BELGIUM **Wallonia**	**ITALY** **South Tyrol**	**SPAIN** **Catalonia**	**THE NETHERLANDS** **North Brabant**
Suitable areas for Agri-PV	• Small scale systems • Vegetable cultivation, small fruits, and fruit orchards with already existing infrastructures (hail protection nets, etc.)	• Few areas available due to fragmentation and dispersion of agricultural land in mountains • Apple orchards in flatlands (already covered by net hails), small fruits and potatoes	• Large monocultures vs small agricultural land for self-consumption • Apple orchards and horticulture, lower crops with no need of large machinery	• Dairy farms, small fruits, and fruit orchards • Greenhouses • Large plant concentrated into one Agri-PV district

	• Agricultural areas closed to the built environment • Closed to cities, to experiment new approaches for agricultural production and energy resilience to climate change			• System design tailored to the morphology of the installation area

3.3.2.5 Impacts of landscape change on people

The impact of Agri-PV on landscape was expected to meet the opposition and resistance of residents in all case studies.

Belgium (Wallonia)

In Wallonia, experts stressed the negative impact of Agri-PV on residents and local communities which were already impacted by rapid landscape transformations over the last twenty years. According to most experts, familiar landscapes are highly valued by the local population, especially in the countryside, regardless of the objective value of those landscapes. Changing or adding artificial elements without any consideration of the visual impact to local populations might lead to resistance and strong opposition. Yet, some experts suggested to consider green design solutions that can minimize landscape change while allowing the installation of Agri-PV on fields.

Italy (South Tyrol)

In South Tyrol, there was a shared view among experts that Agri-PV impoverishes agricultural landscapes and thus it has a severe negative impact on local population which identify with those landscapes. Yet, the use of participatory approaches to identify suitable areas and to exploit the benefits of Agri-PV systems was suggested as a solution to mitigate the negative landscape impact.

Spain (Catalonia)

In Catalonia, there were opposite views concerning the impact of Agri-PV on people. On the one hand, Agri-PV was said to offer an additional source of income for farmers who are suffering from low agricultural prices. This might allow them to keep land cultivated and avoid land abandonment. Yet, there were concerns about the financial resources and capabilities of small farmers to install, operate, and maintain the Agri-PV systems. The public sector might play a role in providing financial support and capacity-building programs through, for example, public-private partnerships. On the other hand, experts were concerned that local populations may not accept the installation of Agri-PV in their landscapes and could oppose Agri-PV projects (NIMBY not-in-my-backyard syndrome).

The Netherlands (North Brabant)

Experts in North Brabant agreed that landscape changes have various impacts on people, including intergenerational differences where elderly generations perceive these changes more negatively than younger ones. The distortion of the "romantic" agrarian landscape was expected to have psychological impacts, as the loss of traditional scenery affects emotional and cultural connections to the land. Additionally, the shift to an industrial landscape was said to negatively impact the health and wellbeing of local communities, contributing to broader concerns about the quality of life in these areas.

Table 12: Impacts of landscape change on people across the four case studies

	BELGIUM **Wallonia**	**ITALY** **South Tyrol**	**SPAIN** **Catalonia**	**THE NETHERLANDS** **North Brabant**
Impacts of landscape change on people	• Negative impact due to rapid landscape changes in the last 20 years • Opposition and resistance of RES projects by local population • Use of natural elements in the design can	• Negative impact due to impoverishment of agricultural landscape, which is an identity value. • Need of participatory approaches to select suitable areas and distribute benefits of	• Potential positive impact on farmers income, although concerns about financial resources and capabilities to operate the plants. • NIMBY by local populations	• Intergenerational effect: elderly generations perceive higher negative impact higher than younger generations. • Psychological impact due to distortion of the “romantic” agrarian landscape

	minimize landscape impact perceived by local communities	Agri-PV among residents		• Industrialized landscape negatively affects the health and wellbeing of local communities

3.3.2.6 Possible compensation for landscape change

Belgium (Wallonia)

According to experts in Wallonia, monetary compensation alone was not considered to represent a comprehensive solution for addressing the impact of Agri-PV on local landscapes. While planting trees may alter the landscape further, it can also help compensate for changes caused by introducing Agri-PV systems. Engaging local communities, such as through the creation of energy communities, was suggested as a strategy to mitigate the need for traditional economic compensation. Additionally, clear communication of the benefits of Agri-PV systems, both environmental and economic, was stressed as crucial to increasing resident acceptance and understanding.

Italy (South Tyrol)

In South Tyrol, experts agreed that compensation mechanisms should be designed to offset the negative landscape impact of Agri-PV for residents, local communities, and tourists. Some suggested that a form of "environmental compensation" might be in the form of Nature-based Solutions (NbS) as, for example, involving the creation of small habitats for bees and insect, of pile stones for lizards or the plantation of trees, hedgerows, and flowers. Others pointed out that energy infrastructure development projects that impact local territories already include economic compensations for municipalities where the plants are installed. These economic compensations are expected to be spent by municipalities for the advantage of the whole community.

Spain (Catalonia)

In Catalonia, some interviewees declared that compensation mechanisms should not be necessary if Agri-PV systems are designed in a way that does not significantly affect the landscape. This means that the economic benefits of Agri-PV should primarily go to local farmers rather than large multinational companies, and these installations should be placed in areas where the impact on the landscape is minimal. Alternatively, Agri-PV might be linked to energy communities where the energy and/or the income derived from renewable energy production is distributed in a fair way to the members of the community.

The Netherlands (North Brabant)

In North Brabant, experts stated that the main compensation for people will be to "*keep Agri-PV out of sight*". The use of participatory approaches to open the conversation on Agri-PV is aimed at including residents and local communities in renewable energy projects both as part of the decision process and as owners of the projects. Participation was also suggested to make local communities aware and informed about new renewable energy project in the area. Establishing energy cooperatives where residents are members or co-investors was suggested as a solution to ensure acceptability of Agri-PV.

Table 13: Possible compensations for landscape change across the four case studies

	BELGIUM Wallonia	**ITALY South Tyrol**	**SPAIN Catalonia**	**THE NETHERLANDS North Brabant**
Possible compensation for landscape change	• Energy communities • Involvement of residents to understand what Agri-PV is • Explain the environmental and economic benefits of those systems	• Environmental compensation through NbS to hide Agri-PV systems • Economic compensation for municipalities to invest in community projects	• Compensation is not necessary if Agri-PV is installed consciously, with minimal landscape impact • Income of Agri-PV should go to local farmers • Agri-PV as part of EC where benefits are distributed among members	• Minimize the visual impact of Agri-PV for local population • Use participatory approaches to raise awareness and to include local populations in decisions on Agri-PV • Energy cooperatives to make residents co-owners of Agri-PV

3.3.3 Justice implications of Agri-PV

Belgium (Wallonia)

According to Belgian experts, Agri-PV contributes to environmental justice by protecting the soil and by locally producing and consuming renewable energy sources (RES). Moreover, from an environmental justice point of view, Agri-PV is expected to provide equal access to RES' benefits while ensuring a fair distribution of costs of its production. Finally, experts suggested that it ensures equity and inclusivity by considering everyone's needs and interests and respecting different opinions and helps addressing the historical power imbalance between cities and rural areas.

In Wallonia, according to experts, Agri-PV systems may benefit fauna by supporting and enhancing local ecosystems and biodiversity through providing shade and benefiting wildlife such as birds and bats. They could also positively impact flora and crops by offering additional shadow, reducing exposure to excessive irradiation and high temperatures, preventing thus soil dryness and improving water retention, and finally enhancing the microclimate by offering wind protection. Additionally, Agri-PV systems were expected to help prevent or mitigate floods if under the PV modules polyculture or orchards are farmed and contribute to energy transition targets and climate change mitigation by producing renewable energy. Experts reported different kinds of negative environmental impacts of Agri-PV in Wallonia, among which there were those on fauna, as modules may produce the mirror effect that can cause disturbances for birds which might mistake them for the surface of water, those on flora and crops, as there is the risk that overshadow negatively impacts agricultural production, those on land, modules in fact may prevent water percolation on the beneath soil and, finally, from a life cycle sustainability point of view, the disposal of Agri-PV' modules.

Walloon experts reported several positive social impacts of Agri-PV, including economic benefits such as increased profitability of agricultural production due to synergy with energy production and the production of electricity with controllable costs for municipalities. Agri-PV could also foster community engagement by promoting the creation of local energy communities. However, experts noted also negative impacts such the risk of creating new power imbalances if Agri-PV projects are owned by external investors and the risk of exploitation of young and precarious labor.

Italy (South Tyrol)

According to Italian experts, environmental justice entails the protection of the environment as a common good, considering the consequences of any environmental degradations on society. Justice goes beyond mere social acceptance; it must be actively perceived as just. Concerning social justice, it involves creating win-win situations in the distribution of costs and benefits for all parties involved, including both the environment and society. From this point of view, Agri-PV helps reduce inequalities in the access to renewable energies by consenting self-consumption. However, the development of Agri-PV could lead to increased land prices, posing a risk of speculation, which might require ad hoc policy interventions.

In Italy, experts reported that Agri-PV could positively impact fauna by supporting and enhancing local ecosystems and biodiversity by providing shade. Additionally, Agri-PV systems could benefit flora and crops by reducing exposure to excessive irradiation and high temperatures, offering additional shadow, and contributing to energy transition targets and climate change mitigation by producing renewable energy. Among the negative environmental impacts of Agri-PV, Italian experts mentioned only a risk that overshadowing negatively impacts agricultural production.

No social impacts, either positive or negative, of Agri-PV were explicitly reported by Italian experts.

Spain (Catalonia)

Spanish experts emphasize the need of everyone's contribution to realize a just energy transition. From this perspective, smaller participatory models are ideal to fulfill social justice, such as energy communities, that consent a fair access to the benefits of Agri-PV. In Spain, the positive impacts of Agri-PV on flora and crops include reduced exposure to excessive irradiation and high temperatures due to the additional shade provided by Agri-PV systems. These systems could also improve water retention in the soil and protect it from hail. The only negative environmental impacts of Agri-PV reported for Spain is the risk that Agri-PV installations may hinder the movement of animals.

No social impacts, either positive or negative, of Agri-PV were explicitly reported for Spain.

The Netherlands (North Brabant)

According to Dutch experts, it is a political responsibility to protect the environment. Renewable energy production should happen in balance with the environment, and those who benefit economically from solar energy production should compensate for any negative environmental impacts. Social justice involves transparency and inclusivity in the decision-making process that concerns Agri-PV. In the Netherlands, Agri-PV systems could positively impact flora and crops by preventing soil dryness, while the only negative environmental impact reported by experts has a life cycle sustainability focus and considers the extraction of critical material to produce PV modules.

No social impacts, either positive or negative, of Agri-PV were explicitly reported for the Dutch case study.

Table 14: The meaning of justice, environmental and social impacts of Agri-PV across the four case studies

	BELGIUM **Wallonia**	**ITALY** **South Tyrol**	**SPAIN** **Catalonia**	**THE NETHERLANDS** **North Brabant**
Meaning of justice	***Environmental*** • Protection of the soil • Local production and consumption of RE ***Social*** • Equal access to the benefits while ensuring a fair distribution of costs • Inclusivity of different needs and interests • Answer to rural-urban power unbalance	***Environmental*** • Protection of the environment as a common good ***Social*** • Justice must go beyond mere social acceptance • Creation of win-win situations for both the environment and society • Reduction of inequalities in access to RE • Risk of land price speculation	***Environmental*** • Everyone must contribute to the energy transition ***Social*** • Smaller participatory models as energy communities • Equal access to Agri-PV' benefits	***Environmental*** • The environmental protection is a political responsibility • Environmental restorative justice ***Social*** • Transparent and inclusive decision-making process
Environmental impacts	***Positive***: • Support and improvement of biodiversity, both flora and wildlife • Reduced exposure of crops to excessive irradiation and high temperatures • Prevention of soil dryness thanks to improved water retention • Improved microclimate thanks to wind protection • Prevention and mitigation of floods • Contribution to energy transition targets ***Negative***: • Disturbance for birds • Overshadowing of crops • Impediment water percolation into the soil • end-of-life disposal of PV modules	***Positive***: • Reduced exposure of crops to excessive irradiation and high temperatures • Support and improvement of biodiversity • Contribution to energy transition targets ***Negative***: • Overshadowing of crops	***Positive***: • Reduced exposure of crops to excessive irradiation and high temperatures • Improved water retention of soil • Protection from hail ***Negative***: • Impediment to the movement of animals	***Positive***: • Prevention of soil dryness ***Negative***: • PV modules life cycle sustainability concerns
Social impacts	***Positive:*** • Economic: Increased profitability of agricultural production due to synergy with energy production, and production of electricity	No social impacts, either positive or negative, reported	No social impacts, either positive or negative, reported	No social impacts, either positive or negative, reported

	with controllable costs for municipalities. • Social: Promotion of community engagement through the creation of local energy communities ***Negative:*** • Risk of creating new power imbalances • Risk of exploitation of young and precarious labor			

As explained in the paragraph concerning the results of the literature review, environmental/climate/energy justice theoretical frameworks consider the concept of justice in all its different dimensions: a distributional one, that involves the distribution of costs and benefits, and the identification of those who are advantaged and disadvantaged by such distribution. The recognitional aspects of considering neglected and vulnerable individuals and their needs, and finally the procedural effects, concerning all features of involvement. The experts covered all dimensions of justice in their interviews.

3.3.2.1 Distributional effects

Belgium (Wallonia)

In Belgium, experts reckoned that the economic benefit that Agri-PV primarily entails is the additional revenue that farmers could gain from selling the energy produced by the Agri-PV systems. Moreover, farmers may benefit from the savings that electricity self-consumption produces, while energy sharing practices, which can be shaped as energy community, permit the local community to benefit of electricity at cheaper prices. Residents could also gain by participating as shareholders in Agri-PV projects, together with other investors, i.e. energy providers. Finally, the introduction of Agri-PV systems could benefit the local development, by supporting local and rural communities. Experts underlined the potential inequality in the distribution of such economic benefits: who invests in Agri-PV may not be who receives the returns on investment. Experts mentioned also other benefits, beyond the economic one, such as the universal benefit of contributing to climate change mitigation by supporting the energy transition and the improvement of environmental conditions of the land, by offering shade and improving water retention of the soil. Belgian experts also reported the costs of Agri-PV. There are the economic costs of management and maintenance of the system which are higher than installing and using modules not in synergy with agricultural production, which must be surely planned. Furthermore, there are some other costs that are uncertain but potential, as for the land price for sale or rent that may increase, due to the enhanced land pressure.

The distribution of benefits and costs leads to the identification of who is advantaged and who disadvantaged. Among the most advantaged groups Belgian experts identified Agri-PV farmers, more specifically large farmers, and the subcategory of landowners, all those individuals that are investors of Agri-PV projects, and the local community of residents, who, as already mentioned, may gain from the involvement in an energy community and energy sharing practices. On the contrary, traditional/conventional farmers who do not receive additional economic subsidies for Agri-PV and in general do not benefit from the additional economic revenues of Agri-PV, as well as those farmers who rent the land they cultivate, who cannot decide to implement Agri-PV, or small farmers who do not have the initial capital to convert to Agri-PV. Additionally, residents could be disadvantaged by the implementation of Agri-PV systems if their properties lose value due to the proximity to Agri-PV fields, or if they are impacted by landscape change. Finally, big energy suppliers could be disadvantaged from local energy production from Agri-PV.

Belgian experts consider young farmers a specific vulnerable category, due to the issue of land access and the strenuous activity of farming in general. Agri-PV could foster the motivation of such young farmers to go on farming, by giving them the economic incentive of gaining an extra income.

Italy (South Tyrol)

Italian experts did not explicitly report economic benefits of Agri-PV but mentioned some environmental benefit and cost: Agri-PV could help reduce the use of pesticides, an issue to be further investigated, but also negatively impact agricultural productivity, which would eventually lead to an economic loss for farmers. Moreover, farmers could be affected by a potential increase of land price for sale or rent. However, when Italian experts where asked who is advantaged and who disadvantaged from the distribution of benefit and costs, they reported also economic benefit and costs. In fact, they mentioned as advantaged category Agri-PV farmers, which gain from an additional revenue, both landowners and large farmers due to scale economies and small farmers benefitting from lighter authorization procedures. Finally, they also included among the advantaged categories of stakeholder's investors of Agri-PV projects. On the opposite, Italian experts identified two disadvantaged categories: farmers, who rent the land they cultivate (particularly small farmers), and residents who could be disadvantaged if they work in tourism as traditional landscape, their main asset, might be compromised. These two categories have been identified as most vulnerable groups by Italian experts.

Spain (Catalonia)

Spanish experts extensively mentioned as economic benefit of Agri-PV the additional revenue coming from the sale of surplus electricity for farmers, or the savings gained by electricity self-consumption. Also, Spanish experts mentioned the potential positive externalities of Agri-PV on local rural development and local communities, benefitting from energy sharing practices. According to Spanish experts Agri-PV also enhances the land value. Among the costs of Agri-PV, there are some social costs, such as the costs related to landscape change, and some environmental costs that must be considered, like those of biodiversity loss.

Spanish experts reported only one category of stakeholders who are advantaged by Agri-PV, i.e. investors or shareholders of Agri-PV projects, and just one category of disadvantaged stakeholders: traditional and small farmers. This category has been identified as most vulnerable group by Spanish experts.

The Netherlands (North Brabant)

Dutch experts reported only one typology of economic benefit that Agri-PV might entail, the additional revenue that farmers could gain from selling the energy produced by the Agri-PV systems, but they extensively listed the costs of Agri-PV. Among those, they reported the economic costs of management and maintenance of the system, some social costs, such as the cost of subsidies paid by the society in general, the risk of social conflict among neighbours that may hinder social cohesion and the potential ownership of Agri-PV systems by foreign investors. Finally, they also reported some environmental costs that must be considered, like the potential negative impact on soil, and the cost of extraction of critical materials needed for the manufacturing of PV modules.

Dutch experts reported only one category of stakeholders who is advantaged by Agri-PV: farmers, as they may benefit from an additional income, as previously explained. They did not indicate any category of stakeholder who may be disadvantaged by Agri-PV, but identified young families as most vulnerable group, as they do not have the time to participate in the discussion and must bear the decisions of others concerning the implementation of Agri-PV projects in their neighborhood.

Table 15: Benefits and costs of Agri-PV, and advantaged and disadvantaged individual or groups in their distribution across the four case studies.

	BELGIUM Wallonia	**ITALY South Tyrol**	**SPAIN Catalonia**	**THE NETHERLANDS North Brabant**
Benefits	• Additional revenue from selling the energy produced • Savings coming from electricity self-consumption • Support of local development and communities • Energy sharing • Climate change mitigation • Improvement of environmental conditions	• Reduced use of pesticides	• Additional revenue from selling the energy produced • Savings coming from electricity self-consumption • Support of local development and communities • Energy sharing practices • Improved land value	• Additional revenue from selling the energy produced

Costs	• Costs of management and maintenance of the system • Increase of land price	• Lower agricultural productivity • Increase of land price	• Costs of landscape change • Biodiversity loss	• Costs of management and maintenance of the system • Cost of subsidies • Risk of social conflict among neighbors • Foreign ownership of Agri-PV systems • Soil degradation • Cost of extraction of critical materials
Advantaged groups or individuals	• Farmers, large farmers, and landowners • Investors • Local energy community	• Farmers, large and small farmers, and landowners • Investors	• Investors	• Farmers
Disadvantaged groups or individuals	• Traditional farmers, farmers who rent the land, small farmers • Residents • Big energy suppliers	• Farmers who rent the land, small farmers • Residents who work in tourism	• Traditional farmers, small farmers	
Most vulnerable groups or individuals	• Young farmers	• Farmers • Residents	• Farmers	• Young families

3.3.2.2 Recognition effects

Concerning the recognition effects of Agri-PV, the experts identified people or groups of individuals whose needs are more recognized or on the contrary more neglected in the development of Agri-PV systems and the reasons for that.

Belgium (Wallonia)

Walloon experts identified landowners, agricultural organizations that defend the farmers stakes, and local authorities as powerful stakeholders, as they can influence in general the decision making concerning Agri-PV and the use of the agricultural surface. They play role respectively in allowing to install modules on their land, the communication with farmers and hence can influence them and the approval of Agri-PV projects.

On the other hand, Belgian experts recognized neglected categories, such as farmers in general, whose needs and interests are neglected or even oppressed by national governments that prioritize renewable energy production over agriculture, and some kind of breeders are overlooked in Wallonia. Moreover, citizens are often excluded from decisions concerning renewable energy projects even if their houses may be depreciated. Finally, there are other neglected subjects, such as future generations that have the right to a protected environment, and thus ecosystems and biodiversity themselves that have the right to be preserved against intensive farming and monoculture, and whose interests are defended by ecologists.

Italy (South Tyrol)

Italian experts identified agricultural organizations and local authorities as stakeholders whose needs and voices are more recognized, while among the neglected subjects they listed citizens, who up to now have never been involved in discussions and decisions concerning Agri-PV, and local fauna that may be negatively impacted by Agri-PV infrastructure.

Spain (Catalonia)

According to Spanish experts, big investors and agricultural organizations are the most influential stakeholder in Agri-PV decision making since they hold economic power. On the contrary, farmers in general are the least recognized category of stakeholders, and another vulnerable category is nature, whose interests are defended by ecologists.

The Netherlands (North Brabant)

Dutch experts mentioned 3 categories of stakeholders whose voices and needs are considered when it comes to Agri-PV decision-making. Firstly, some categories of farmers such as older farmers, secondly big investors and thirdly residents, who are involved and heard in Agri-PV decision-making processes. The drivers of such recognition are the power to influence the authorization of Agri-PV projects, economic power, land ownership, and the time to dedicate to participate in local decision-making. They also listed categories of neglected stakeholders, such as farmers in general, oppressed by governments and their land policies, and some categories in the specific, like young entrepreneurs and residents, and in general broader societal concerns are neglected. Finally, ecosystems and biodiversity are overlooked by farmers who focus on efficiency.

Table 16: Recognitional implications of Agri-PV across the four case studies

	BELGIUM Wallonia	**ITALY South Tyrol**	**SPAIN Catalonia**	**THE NETHERLANDS North Brabant**
Groups or individuals whose needs are more recognized	• Landowners • Agricultural organizations • Local authorities	• Agricultural organizations • Local authorities	• Agricultural organizations • Big investors	• Big investors • Farmers, older farmers • Residents
Drivers of recognition	• Power to influence the Agri-PV decision making • Land ownership		• Economic power	• Power to influence the Agri-PV decision making • Economic power • Land ownership • Time to participate
Groups or individuals whose needs are neglected	• Farmers • Breeders • Citizens • Future generations • Ecosystems and biodiversity	• Citizens • Ecosystems and biodiversity	• Farmers • Ecosystems and biodiversity	• Farmers • Young entrepreneurs • Citizens • Ecosystems and biodiversity
Drivers of negligence	• Negligence by government and policy • Exclusion from decision-making • Own needs protection delegated	• Exclusion from decision-making	• Negligence by government and policy	• Negligence by government and policy • Own needs protection delegated

3.3.2.3 Procedural effects

Belgium (Wallonia)

According to Belgian experts the involvement of local communities is crucial for the successful implementation of Agri-PV projects. As the support of residents is indeed necessary, it can be fostered through various forms of public engagement, such as the creation of local energy communities which can effectively overcome potential opposition and actively engage citizens in Agri-PV projects. Furthermore, community involvement can be encouraged through weekly markets where vegetables are sold, providing a space for communication, and sharing. Another possibility is the establishment of shared gardens where residents can engage in agricultural production. Collaborative approaches, such as involving local community organizations to share both energy and agricultural products, also help to foster a sense of community. In Wallonia, a mixed support from farmers indicates the need for a continuous informational process to communicate the benefits of Agri-PV and ensure public support. Additionally, involving residents as shareholders can further increase their support for Agri-PV projects.

Belgian experts listed stakeholders of all possible categories, to be involved in Agri-PV decision making processes. From the civil society need to be involved residents, as part of energy communities, civil society organizations such as organizations working with people affected by energy poverty. Among stakeholders of the agricultural sector to be involved, Belgian experts mentioned: farmers, local small-scale farmers, all categories of breeders, and their umbrella agricultural associations and cooperatives. Moreover, the policy sector needs to be represented in decision making by local authorities, who need to be involved also as mediators and warrantors of public goods and needs, environmental authorities, such as forest authorities and natural sites managers, to find suitable locations for Agri-PV and to avoid negative environmental impacts, those responsible for landscape urbanism, and even archaeology. Additionally, regional and authorities, as well as European institutions must be included in discussions. For the energy sector, energy providers and DSOs must be involved. Finally, representing the private sector, investment cooperatives might be entailed.

Concerning the desired timing of stakeholder involvement, Belgian experts agree it should happen from the very beginning, while they reported different modalities of involvement, like informative campaigns to disseminate knowledge about implications of Agri-PV for farmers and citizens and answer to their possible concerns. Moreover, to realize collective decision-making in Agri-PV, different stakeholders should enrich the discussion, co-creating the system through a collaborative approach that ensures shared responsibility, and the definition of untouchable areas should result from a public decision-making process. Public tenders would be needed for large-scale Agri-PV projects, with public offers from different kinds of potential investors. Additionally, a thorough analysis of the location of the Agri-PV project based on different criteria, along with the identification of stakeholders' roles, is pivotal for the success of each project.

Italy (South Tyrol)

In Italy there are no existing forms of civil society involvement in Agri-PV projects, to Italian experts' knowledge. The only reference to possible forms of public involvement is through the establishment of energy communities or of community gardens. According to Italian experts, when planning a decision-making process about Agri-PV projects, local communities have to be involved, as they may create an energy community and benefit from local energy sharing, as well as civil society and environmental organization. Farmers and their associations should be involved to represent the agricultural stakes, while the touristic sector needs also to be part of the discussion. For the policy side, local authorities and specifically the department of tourism must be involved, and also national and European institutions should step in. At this stage, a stronger stance from national authorities and a European policy are needed to spread the Agri-PV experience throughout Europe.

Italian experts did not mention a desired timeline for stakeholder involvement but reported different modalities to ensure comprehensive participation and awareness. Firstly, dissemination of knowledge and information, and training is crucial, not only for general awareness but also for educational purposes involving schools and communities. In Italy there is still too little knowledge about Agri-PV and photovoltaics in general, and to be part of the change, people must be aware of both the positive and negative implications. Replicating successful experiences and showcasing data from case studies can help people understand the potential for similar implementations in their territory. Moreover, citizen involvement in the decision-making process for Agri-PV should be carried out at the local level, through focus groups or climate councils for example citizens can be asked to identify suitable areas for Agri-PV, they can discuss the number of installations etc. Additionally, interviews with citizens and hoteliers can provide valuable insights.

Spain (Catalonia)

In Spain, at the level of civil society, no ecological organizations have yet emerged, but municipalities have received funds to implement photovoltaics and other renewable energy production infrastructures in public buildings, showing a public significant support for the creation of energy communities. In fact, energy communities are gaining strength in the field of photovoltaics, but regarding Agri-PV, there is still limited deployment at the collective community level. In general, although there are signs of progress concerning the development of Agri-PV, the discussion is hindered by a lack of information, specific regulations, and clear definitions of Agri-PV, leaving the debate on hold.

Spanish experts believe that first and foremost agricultural organizations must be involved, as they have the needed knowledge and are representative of the sector. Secondly, local administrations need to be part of the discussion, and specifically the department of Agriculture and the urban planning one. Finally, the private sector should get involved, represented by multinationals and entrepreneurs, and the citizens organized in energy communities.

Finally, Spanish experts did not report anything regarding the desired timing and possible modalities of stakeholder involvement.

The Netherlands (North Brabant)

In the Netherlands, there is the experience of an energy cooperative owner of the system having a cooperation with the farmer on the exploitation and the use of this Agri-PV systems. Dutch experts consider that environmental organizations urge to be involved, to represent the natural environment's stakes and ensure their protection. Secondly, experts and enterprising farmers can contribute with their expertise, as well as landscape architects to gain a long-term vision of the project. Finally, the local community must be involved and the local authorities, specifically someone committed to the topic.

According to Dutch experts, stakeholder involvement should happen already in the early stages, to facilitate their ability to have a voice, making the process easier and quicker. During the initial exploration phase, gathering input from people on how they would shape the landscape among different options is important. This can be achieved through co-creation activities, where stakeholders can actively contribute to the design and planning of Agri-PV systems.

Table 17: Procedural implications of Agri-PV across the four case studies.

	BELGIUM **Wallonia**	**ITALY** **South Tyrol**	**SPAIN** **Catalonia**	**THE NETHERLANDS** **North Brabant**
Forms of civil society involvement	***Potential:*** • energy communities • local markets or community gardens • informational process • citizens as shareholders	***Potential:*** • energy communities • community gardens	***Potential:*** • energy communities	***Existing:*** • energy communities
Stakeholders to be involved in discussion	***Civil society:*** • individual citizens • local communities • energy communities • civil society organizations ***Agriculture:*** • farmers • small farmers • breeders • agricultural associations and cooperatives ***Energy:*** • energy providers • DSOs ***Policy:*** • local authorities • environmental authorities • urban and landscape planning • archaeology • regional authorities • national and European institutions ***Private sector:*** • investment cooperatives	***Civil society:*** • individual citizens • local communities • energy communities • civil society organizations • environmental organizations ***Agriculture:*** • farmers • agricultural associations and cooperatives ***Policy:*** • local authorities • department of tourism • national and European institutions ***Private sector:*** • tourism organizations	***Civil society:*** • individual citizens • energy communities ***Agriculture:*** • agricultural associations and cooperatives ***Policy:*** • local authorities • urban and landscape planning • agricultural department ***Private sector:*** • multinationals • entrepreneurs	***Civil society:*** • local communities • environmental organizations ***Agriculture:*** • farmers ***Policy:*** • local authorities • urban and landscape planning
Timing of stakeholder involvement	• from the outset			• from the outset
Modalities of stakeholder involvement	• Informative campaigns • Focus groups • Co-design participatory activities • Public tenders	• Informative campaigns • Focus groups • Interviews • Co-design participatory activities • Demo cases		• Apps and digital tools • Focus groups • Co-design participatory activities

3.4 DISCUSSION

3.4.1 Definitions and system configurations

While responses varied based on individual backgrounds and regional contexts, there was a consensus that Agri-PV lacks a clear commonly agreed definition, leading to confusion with traditional photovoltaics. Moreover, implementing this technology requires detailed, case-specific analyses. A commonly accepted definition described Agri-PV as the combined use of land for both agriculture and energy production, creating a synergistic relationship between the two functions. This setup should prioritize agricultural production, with energy generation playing a supportive role that does not interfere with farming activities.

Experts underlined the main difference between PV modules on agricultural land, and Agri-PV in their benefits and drawbacks. PV modules on agricultural land tend to be preferred by energy companies for their efficiency and lower cost. Agri-PV, however, integrates solar energy production with agriculture without sacrificing fruit and vegetable production, and provides multiple benefits, such as additional income for farmers.

Most interviewees in the four regions agreed that Agri-PV can contribute to the clean energy transition. It promotes land multifunctionality, business diversification, and local employment. Despite its benefits, there is skepticism regarding Agri-PV' energy profitability overshadowing agriculture, potential design issues hindering farming, and the risk of industrial exploitation of land by large companies.

Concerning the system configurations, there was disagreement among experts in the four regions. Type 1 configuration was the preferred choice for meeting agricultural needs while promoting sustainability. It was suggested to be adopted in fruticulture and orchards as it can optimize sunlight for photosynthesis and protect crops from adverse weather conditions. Concerns were raised in relation to high installation costs and social acceptance due to visual impact both in flatlands and in mountains.

Type 2 configuration was less clearly defined and understood, varying with factors like row spacing, cultivation methods, and crop types, necessitating further investigation. Concerns were raised include potential under-cropping and land inefficiency, which could result in farmer losses. Some experts suggested placing low-mounted modules at farm edges to avoid interference with agricultural or livestock activities, optimizing land use. Type 2 systems were favored for their minimal visual impact, proximity to the ground, and lower cost, but doubts remain about the integration of the modules with crop rotation needs.

Type 3 Agri-PV systems faced criticism for being less effective at producing energy because the PV modules stand upright and capture less solar radiation. On the positive side, they are easier and cheaper to set up, protect crops from wind, and allow agricultural machinery to move freely. However, opinions vary on their agricultural benefits: some say they don't shield crops enough from the sunlight, leaving them exposed, while others think they create shade too often. Having a tracking system that adjusts to follow the sun and farming routines would greatly improve their efficiency, combining benefits from Type 1 and Type 2 setups. Vertical and movable systems also help distribute rainwater better than flat modules, but they may reflect sunlight uncomfortably. Putting modules on fences has been suggested to avoid disrupting farming and gain acceptance from communities, especially in grasslands and livestock areas.

Combining Type 1 and Type 3 configurations was regarded as more supportive of farming activities. Italy terms this blend 'advanced Agri-PV,' which qualifies for increased government support. Incorporating Type 1, Type 2, and Type 3 configurations diversifies agricultural output and optimizes energy generation throughout the day. Experts suggested that this approach also brings power production nearer to consumption points, promotes energy sharing, and aids in the transition to sustainable energy sources.

3.3.2 Landscape impact

Agri-PV systems were described as largely affecting the landscape. Yet, the impact was considered to vary based on the height, design, structure, and integration of the plants with the agricultural landscape. The value of landscape was high in all case studies, with traditional agricultural landscape being perceived as closely linked to cultural identity, sense of belonging and characterization of European regions. Landscape value rates as especially high for regions with limited space availability such as mountain areas (South Tyrol) and densely populated regions (North Brabant). The value of landscape was also related to human well-being (Catalonia), and to the relationships between people and the planet. In some countries, landscape is regarded as a dynamic rather than static value that is related to the history and technological development of humankind.

Yet, landscape transformations should occur gradually and in harmony between natural and built environments, leaving some areas untouched and “open to the human eyes”. “Untouchable” agricultural landscapes include natural areas (e.g., Natura 2000 sites), cultural heritage sites and historical centers, high-mountain valleys, landscapes with high agronomic value and distinctive features for regions (e.g., vineyards in South Tyrol; olive crops in Spain; trees, hedges, and community buildings in Wallonia), peri-urban areas used for recreational purposed by citizens.

Although Agri-PV changes the landscape, its impact was perceived to be smaller compared to other renewable energy sources such as wind turbines or hydropower plants. According to some experts, Agri-PV is necessary to move away from fossil fuels. However, there is a risk of transforming agricultural landscapes into technological landscapes, with negative impacts on other sectors such as tourism.

Differences in perceived impacts were also reflected in disagreement among experts concerning the most suitable areas for Agri-PV installation. From one side, Agri-PV was expected to be more suitable for small-scale farming since it does not require large machinery (Wallonia) and it integrates better into the landscape (South Tyrol). On the other side, large-scale plants were said to benefit from economies of scale and from fields already compromised by monocultures (Catalonia, North Brabant). Small fruit and fruit cultivation were preferred over other types of crops for Agri-PV installation since they can exploit already existing infrastructure to install PV modules while minimizing landscape impact. Horticulture also is well suited to Agri-PV systems.

Given the landscape impact, experts suggested that Agri-PV is going to meet resistance and opposition by residents and local communities. In regions such as Wallonia, South Tyrol and North Brabant, local communities are suffering the wounds of intensive and rapid landscape changes occurred in the past due to the artificialization of their territory (RES, infrastructures, intensive agricultural activities). The transformation of traditional agricultural landscapes was also expected to have a psychological impact on urban citizens due to the “de-romanticization” of those areas. Potential impact mitigation measures include the use of camouflage and natural elements in the design of Agri-PV plants and the use of NbS or participatory design approaches. The active involvement of local populations through participation in plant ownership or energy community is also suggested as a mitigation measure.

3.3.3 Environmental and energy justice

In examining the experts’ perspectives on justice regarding Agri-PV, several common key themes emerge. From an environmental justice perspective, the importance of environmental protection as integral to justice emerged from the interviews, while from a procedural and energy justice standpoint the experts recognize the need for fair and inclusive decision-making processes, and the insurance that the benefits and costs of renewable energy production from Agri-PV are equitably shared among residents and local communities. Nonetheless, some peculiarities among countries emerged. Dutch experts for example mentioned the principle of restorative environmental justice, which is the responsibility of those who profit from solar energy production to be held accountable for any negative impacts they cause, ensuring that they contribute to restore the ecological balance or to compensate for the negative externalities produce. Moreover, one of the Belgium experts highlighted the fact that agrivoltaics could represent an opportunity to solve the structural rural-urban power imbalance.

Experts then listed the environmental and social impacts that Agri-PV systems have, both positive and negative. A common positive environmental impact recognized by experts in all case studies is the reduced exposure of crops to excessive irradiation and high temperatures, preventing soil dryness and improving water retention. Belgian and Italian experts also highlight the support and improvement of biodiversity that Agri-PV systems offer, demonstrating a shared recognition of the ecological benefits of Agri-PV. Additionally, both Belgium and Italy underscore the contribution of agrivoltaics to energy transition targets, supporting the mitigation of climate change. On the negative side, overshadowing of crops is a shared concern for both Belgian and Italian experts, indicating potential conflicts between energy production and agricultural productivity in Agri-PV systems. Ecological disturbances are also noted, as Belgian and Spanish experts reported concerns about the impediment to the movement of wildlife in Agri-PV fields. Finally, Dutch and Belgian experts highlighted the issue of lifecycle sustainability of PV modules, from the extraction of critical material to the end-of-life disposal, reflecting a broader environmental consideration of the entire lifecycle impact of Agri-PV infrastructure.

Among the positive social implications of Agri-PV, experts cited economic benefits such as increased profitability of agricultural production due to synergy with energy production for farmers and the production of electricity with controllable costs for municipalities. Agri-PV could also foster community engagement by promoting the creation of local energy communities. Nonetheless, among negative social impacts experts noted the risk of creating new power imbalances if Agri-PV projects are owned by external investors and the risk of exploitation of young and precarious labor. To be noted that just the Belgian experts explicitly reported possible social impacts of Agri-PV.

Among the distributional effects of Agri-PV the most mentioned by the experts was the economic benefit, with all its complex facets. It includes additional revenue from selling the produced energy, savings from electricity self-consumption, as well as the support of local development and communities, also through energy sharing practices, as emphasized by Belgian and Spanish experts. Italian and Belgian experts also reported environmental benefits such as climate change mitigation and improvement of environmental conditions, which can increase the land value, as pointed out by Spanish experts.

The costs associated with agrivoltaics vary significantly across the experts' opinions. Common costs include the management and maintenance of Agri-PV systems, recognized by both Belgian and Dutch experts, and the increase in land price for both buying and leasing, and the consequent risk of speculation on price, noted by Belgian and Italian ones. Experts also reported the risk of environmental degradation and the resulting lower agricultural productivity.

In the trade-off of benefits and costs, experts agreed that large farmers, landowners and financial investors are more advantaged. Conversely, small farmers and those who rent the land tend to be disadvantaged, as well as traditional farmers who might not receive subsidies compared to farmers who have financial resources to invest in Agri-PV. To be noted that Italian experts mentioned residents who work in the touristic sector as group that may be disadvantaged by the implementation of Agri-PV systems, due to the negative impact on the landscape that Agri-PV could have.

Experts mentioned that the stakeholders who succeed in getting their needs and interests recognized in the Agri-PV decision-making process include agricultural organizations, local authorities, and large investors, as they hold economic power, or can influence the approval of Agri-PV projects. Conversely, ecosystems and biodiversity, farmers and citizens were perceived as neglected or excluded from discussion. Ecosystems and biodiversity rely on ecological activists to advocate for their protection. Farmers are overlooked by national governments and policies, while citizens are generally not involved in decision-making processes.

Only the Dutch experts reported existing forms of involvement of civil society in Agri-PV systems, i.e. through the creation of energy communities. Experts from other countries mentioned other possible forms of involvement, such as local markets or community gardens. Belgian experts added the possibility for citizens to participate as shareholder in Agri-PV projects.

In Agri-PV decision making processes the involvement should happen from the outset, through informative campaigns and co-design participatory activities. Experts identify a broad variety of stakeholders to be involved in Agri-PV decisional processes. Common stakeholders across all countries include civil society members such as local communities and energy communities, as well as local authorities, highlighting the importance of public participation. Farmers and their umbrella organizations have been named by all country's experts. Italian experts uniquely mention the need to include the tourism sector, highlighting the importance of tourism on the local economy. Both Italian and Dutch experts include environmental organizations as crucial stakeholders to be involved, indicating a shared focus on environmental advocacy and sustainability. Belgian experts are the only one to cite stakeholders of the energy sector, i.e. energy providers and DSOs, to be involved.

4. FORESIGHT WORKSHOP 1: VISIONS FOR AGRI-PV IN EUROPE

4.1 PURPOSE OF THE WORKSHOP

The workshop aimed at encouraging a discussion on potential pathways for the future adoption of Agri-PV in Europe by explicitly addressing the concept of justice. As reported in Chapter 2, there are still limited studies on the justice implications of Agri-PV as socio-economic analysis tends to focus on social acceptance rather than on distributional, recognitional and procedural factors characterizing justice.

The workshop took place on January 24th, 2024, at Parc UPC – Agròpolis in Barcellona, during the second Project Meeting of Symbiosyst. The workshop lasted two hours and involved 22 participants representing the partners of the Symbiosyst's consortium. The workshop was designed with the goal of discussing the concept of justice among professionals and academics with a technical background, and to provide alternative conceptual frameworks and perspectives to consider in relation to Agri-PV.

The workshop involved partners to debate around political, environmental, social, technological, legal and economic (PESTLE) factors influencing the uptake of Agri-PV across Europe so as to ensure environmental and social justice. Building upon the identified factors, participants collaborated to envision future scenarios for Agri-PV in the EU. Belgium, Italy, Spain, and the Netherlands were selected as case studies since they are the locations of the project's demo-sites. To summarize, the purposes of the workshop were multiple:

a) to fuel a debate on Agri-PV considering the concept of justice;
b) to collect insights from experts on the influencing factors of Agri-PV in the EU;
c) to grasp differences and similarities across the four countries and in Europe on known and unknown PESTLE factors related to Agri-PV;
d) to generate visions for the future pathways of Agri-PV in the EU;
e) to validate the foresight method and workshop format for future replication with other stakeholders.

4.2 METHODS

4.2.1 Foresight methods

The workshop used foresight methods to guide the participants in identifying influencing factors and generating future scenarios for Agri-PV. Foresight is the discipline of exploring and anticipating the future in a structured and systematic way [28]. It helps form a shared understanding of the future, considering it as something that can be shaped and created rather than something fixed and given. It is neither prophecy nor prediction: it helps building the future rather than "unveiling" it [29]. Foresight methods usually considered three principles (Figure 5):

- **Open**: many possible alternative futures can be considered to think about the future
- **Participatory**: multiple stakeholders can be involved to debate the future, not just academics.
- **Action-oriented**: centered around the concrete steps that organizations can take to shape envisioned future.

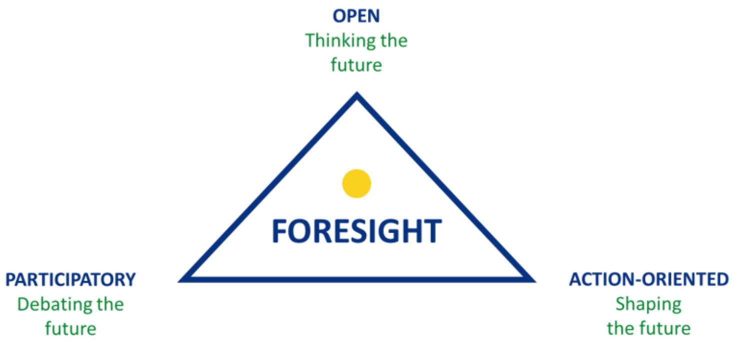


Figure 5: Three principles of foresight methods. Adapted from JRC-IST accessed through http://foresight-platform.eu/community/forlearn/what-is-foresight/

There are several foresight methods that can adopt qualitative or quantitative approaches or take a short-term or long-term perspective. Most methodologies combine qualitative and quantitative data so the boundaries between the different methodologies are quite blurred. For example, business organizations use forecasting as a method to make linear projections or estimations of future events whose outcomes are uncertain. They also use trend analysis to collect data and information to identify patterns that can help framing the impact or expected outcomes of business activities over time. Scenario planning helps organizations anticipate change and prepare strategies for responding effectively to those changes. The process entails combining known factors about past and present operational environments, and uncertain factors about the future context to identify plausible paths of development. Given the potential of combining known and unknow factors related to the future of Agri-PV in Europe, scenario generation was selected as foresight method during the Symbiosyst workshop.

4.2.2 Scenario planning

Scenarios are stories that describe alternative ways the external environment might look in the future. Each scenario explores how different conditions might support or constrain the deployment of Agri-PV in Europe by 2050. Scenarios are not predictions. They are not meant to be 'right' or 'wrong', 'good' or 'bad', but to offer interesting (and in some cases challenging, stretching or controversial) pictures or insights of the future based both on present factors and trends, and on unknown path that can be determined by the expertise and experience of the participants.
Scenarios developed in a workshop are brief but provide insight into the specific challenges and opportunities each future presents. Narrative structures can be used to develop and research more detailed stories or do further forecasting or back casting exercise. The foresight workshop in Barcelona focused on brainstorming of known and unknown factors, and on the creation of scenarios deriving from those factors.

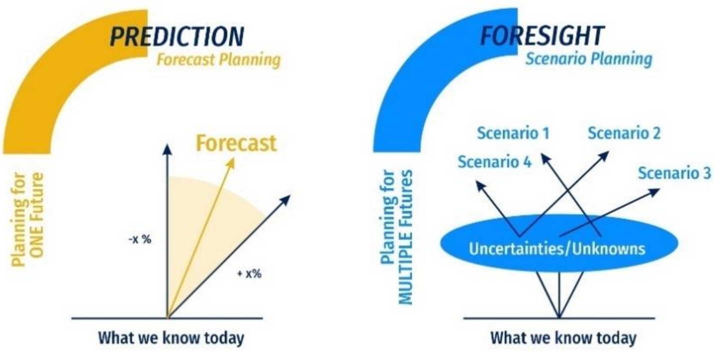


Figure 6: Predictions vs Foresights: how to create scenarios.
Source : www.futuresplatform.com/blog/9-foresight-methodologies-successful-companies-use-stay-ahead

4.2.3 PEST(L)E analysis

The discussion on the factors was based on a PESTLE analysis, which stands for Political, Economic, Social, Technological, Legal, and Environmental factors. Due to time constraints and lack of expertise on legal aspects, the workshop focused on five factors rather than six, leaving the discussion on legal factors to the next editions of the foresight workshop. The factors addressed during the workshop were:

- **Political Factors**: include government policies, regulations, and political direction of national and regional governments. In the case of Agri-PV, political factors might involve incentives and subsidies for agricultural innovation and/or renewable energy, land use regulations, renewable energy regulations but also prohibition on the installation of Agri-PV systems and conflicts between energy and agricultural policies.
- **Economic Factors**: entail aspects such as economic growth, inflation rates, foreign investment, and industry and market trends. For Agri-PV, economic factors might include the cost for installation and maintenance of solar modules, market demand for renewable energy, commodity prices affecting agriculture, and funding availability for the integration of Agri-PV as part of sustainable farming practices.
- **Social Factors**: relate to cultural norms and values, lifestyle changes, and consumer behavior. In Agri-PV, social factors could involve community acceptance and perceptions of the technology, public awareness of renewable energy, farmer attitudes towards innovation, and the impact of Agri-PV on landscape and local communities.

- **Technological Factors**: relate to advancements in technology that can influence operations and competitiveness in the market for renewable energy and agriculture. In Agri-PV, technological factors might include improvements in solar panel efficiency, developments in agricultural automation, PV design fitting agricultural and farming practices, and emerging innovations in renewable energy storage.
- **Environmental Factors**: focus on ecological issues, climate change, sustainability concerns, and natural resource availability in local territories. In Agri-PV, environmental factors include the impact on soil health, water usage, biodiversity conservation, and resilience of crops to climate change effects.

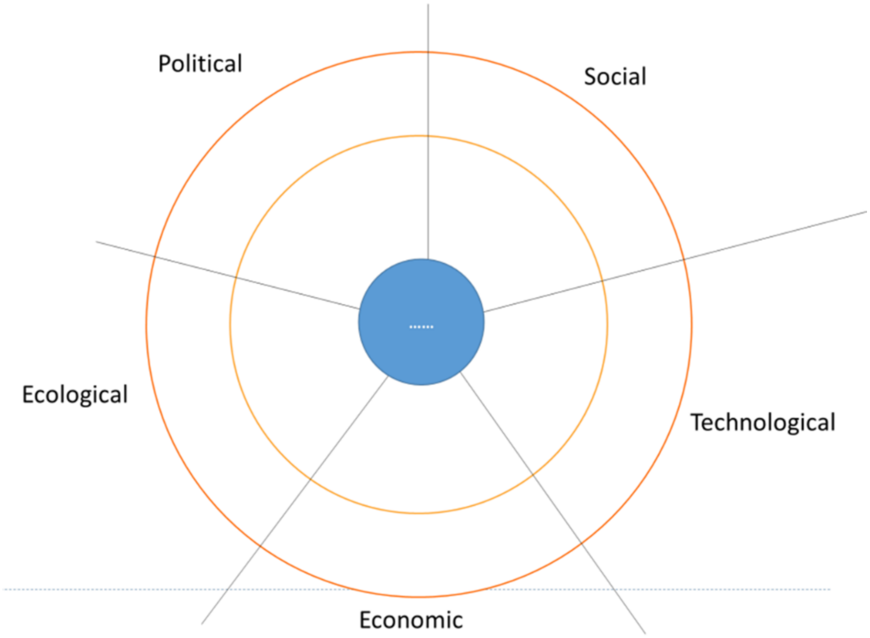


Figure 7: Template used to guide PEST(L)E analysis during the workshop.

Figure 7 represents the template that was used by the workshop moderatos to guide the group discussion during the PEST(L)E analysis. In a first step, participants were asked to individually brainstorm known and unknow factors for each category, and to write them down on post its. In a second step, participants were asked to discuss on the brainstormed factors and to identify common and most relevant ones.

The use of the PEST(L)E methodology at the start of the workshop helped participants to think comprehensively about the external factors influencing the development pathways of Agri-PV. By addressing holistically multiple perspective, participants were forced to widen their point of view, and to proactively consider aspects other than technological ones in the elaboration of future scenarios.

The scenario resulted as narratives deriving from the systemic consideration of the identified PEST(L)E factors.

4.2.4 Workshop format

The workshop was structured in three parts:

- Individual brainstorming of known and unknown factors influencing Agri-PV in Europe and discussion in four groups.
- Creation of “official” and “alternative” scenarios for the future of Agri-PV by 2050. Participant were distributed in four groups representing Belgium and the Netherlands, Spain, Italy, and the EU.
- Plenary presentation of the scenarios and group discussion.

The participants were divided into four groups according to the country of their organization (Figure 8), and each group was managed by a moderator following a standard set of questions (ANNEX 1).

Spain

Moderator: Universitat Politècnica de Catalunya (UPC)

1. UPC: Participant 1
2. UPC: Participant 2
3. UPC: Participant 3
4. UPC: Participant 4
5. UPC: Participant 5
6. UPC: Participant 6

Italy

Moderator: EURAC Research

1. EF Solare: Participant 7
2. ENEA: Participant 8
3. ETA Florence: Participant 9
4. SBB: Participant 10
5. CONVERT: Participant 11

The Netherlands and Belgium

Moderator: EURAC Research

1. TUD: Participant 12
2. PHYSEE: Participant 13
3. KUBO: Participant 14
4. KUL : Participant 15
5. LUCISUN: Participant 16
6. IMEC: Participant 17

Europe

Moderator: EURAC Research

1. ABOVE: Participant 18
2. ALEO: Participant 19
3. ENGIE-LAB: Participant 20
4. KUL: Participant 21
5. UPC: Participant 22

Figure 8: Four groups of the workshop.

4.3 RESULTS

4.3.1 Key drivers

The workshop started with participants being invited to discuss the key drivers that will support the future deployment of agrivoltaics in their geographical contexts. The conversations at the four tables identified key political, economic, social, technological, and environmental drivers that will help or hinder agrivoltaics in the EU (Table 18).

Political drivers

All four tables identified the key role of EU policies in defining and providing a clear regulatory framework for the implementation of Agri-PV across the 27 member states. In the “Spain” table, while Agri-PV is expected to be favoured but not prioritized over food production, ensuring that agricultural output remains a primary focus of national agricultural policies. In Italy and across Europe, a significant driver is the integration of energy and agriculture policies within the EU's Common Agricultural Policy (CAP) to promote a synergic approach to sustainable agriculture and renewable energy production. The CAP is expected to provide policy support and subsidies at the national level to encourage Agri-PV implementation. In Belgium and the Netherlands, EU policies are expected to provide extra support to local photovoltaic (PV) production, aligning with broader climate change objectives that necessitate the expansion of renewable energy sources.

Economic drivers

According to the “Spain” table, the key economic drivers for Agri-PV is the growing multinational control of land due to low value of agricultural land and products which will push local farmers to search alternative revenue sources. Although farmers will have to accept the leasing of their land to multinationals for Agri-PV, they will benefit from additional revenue that will offset the decrease in the value of agricultural production. The “Italy” table suggests that Agri-PV will be driven by national incentives for renewable energy production that will favour this technology. According to the “Netherlands and Belgium” table, the decreasing costs of Agri-PV systems due to the industrialization of PV production in Europe and the increasing industrialization of agriculture will lead to the large-scale deployment of these systems. The “EU” table suggests that EU carbon labels for agricultural products grown under Agri-PV, and tax reductions for farmers producing with Agri-PV might be key economic drivers.

Social drivers

According to the "Spain" table, farmers' decision-making power over their land will be the primary social driver bringing to the adoption of Agri-PV in the country. However, this decision is likely to meet resistance and low acceptance by residents and local communities due to is perceived negative impact on agricultural landscape and the unfair distribution of the benefits related to energy productions across the country (i.e. cities being the main energy consumers and rural areas being the main energy producers). The "Italy" table suggests that demonstrating the advantages of Agri-PV to residents and local communities and providing learning opportunities to agronomists and farmers will be a key social driver. Social acceptance will be related to stakeholder participation to Agri-PV projects such as by becoming members of energy communities. In the "Belgium and the Netherlands table" increasing population density and reducing space availability will be key social drivers for Agri-PV. Social awareness on the impacts of climate change by local communities and the need to find resilient solutions for agriculture productions are also perceived as important drivers. The "EU" table suggests that producing a balanced yield between agricultural and energy production to the benefit of local societies will drive social acceptance.

Technological drivers

According to the "Spain" table, crops will be increasingly dependent on the shadow and climatic benefits provided by Agri-PV modules. The PV modules will become more transparent and sustainable. However, Agri-PV will be one minor source for clean energy production since alternative clean energy sources will emerge. According to the "Italy" table, Agri-PV will be promoted by technological improvements in their efficiency, space-saving qualities, and strong synergy with agricultural land. The "Netherlands and Belgium" table points out technological advancements such as increased PV efficiency and the development of lighter PV modules and structures will be key technological drivers. According to the "EU table", there will be significant investment in transparent PV back sheets and the establishment of data collection platforms to monitor Agri-PV performance across the EU. Additionally, new materials, which offer higher efficiency at lower costs compared to traditional silicon modules, will be key technological drivers.

Ecological drivers

The future of agrivoltaics in Europe will be shaped by a range of ecological drivers, as outlined by workshop participants. The "Spain" table emphasizes the ecological impact of photovoltaic (PV) systems will be limited to PV production, while the installation and use of PV technology will have no impact on ecosystems, i.e. it will not destroy or damage ecosystems as other energy projects, such as marine gas and oil pipelines. The "Italy" and "Belgium and the Netherlands" tables highlight that key ecological drivers will be the increasing biodiversity loss occurring in all Europe due to monocultures and extractive land use, the increasing soil deterioration and desertification due to massive use of fertilizers and the exacerbation of water shortages. According to the "EU" table, key ecological drivers will be related to the identification of crop types best suited for Agri-PV to optimize agricultural productivity while integrating biodiversity conservation efforts. The concept of Agri-ecovoltaics is proposed as an innovation that explicitly addresses biodiversity enhancement, sustainable agricultural production, and renewable energy production.

Table 18: Key PESTE (L) drivers of Agri-PV in Spain, Italy, Belgium and the Netherlands, and Europe

	Spain	Italy	The Netherlands & Belgium	Europe
Political	• EU policies are well defined for Agri-PV • Agri-PV is favoured but not prioritized over food production	• Integration of energy and agriculture policies in the EU CAP (Common Agricultural Policy)	• Policy support local Agri-PV production in Europe • Climate change policies require additional renewables	• EU CAP integrates Agri-PV • EU policy defines Agri-PV and provide subsidies at national level
Economic	• Multinationals control Agri-PV • Lower value of agricultural products • Farmers have additional income from energy production	• Incentives for renewable energy production	• Costs of materials decrease • Industrialization of PV technology, that is produced in Europe • Economized use of land	• Agri-PV food has an EU carbon label, and a tax rebate is applied to Agri-PV producers

Social	• Farmers use decision power over their fields • Low acceptance of Agri-PV among local populations due to landscape impact and delocalised energy consumption	• Agri-PV learning programs for agronomists • Demonstrated advantages of Agri-PV for the whole community • Social acceptance by stakeholders • Energy communities	• Population density increases • Space availability is scare • Social awareness of climate change impacts	• Balanced yield between food and energy gain for the benefit of local societies
Technological	• Dependency of crops on PV shadow and benefits • PV modules are transparent and sustainable • Alternative clean energy sources are available besides Agri-PV	• Electrification of agricultural machinery • Agri-PV systems are more efficient, use less space and highly synergic with agricultural lend	• PV efficiency increased • Light PV modules and structure	• Investment in transparent PV backsheet • Data collection platform for data on performances of Agri-PV • New materials besides silicon for PV modules, with lower costs and higher efficiency
Ecological	• Ecological impact related to PV production, not implementation or use	• Integration of Agri-PV systems in the ecological systems • More attention on biodiversity • Fertilisers created desert fields • Climate change impact • Water shortages	• Biodiversity loss • Climate change • Pesticides used only for flowers	• Crop type limitation, clear indication about the types that are most suitable for Agri-PV • Concept of Agri-ecovoltaics integrate biodiversity

4.3.2 Official and alternative futures

The discussion about the key drivers resulted into eight scenarios for the future of Agri-PV in 2050. The "official" scenarios represent the "most likely future" considering the present drivers and barriers to Agri-PV in the four countries and in Europe more in general. The "alternative" scenarios consist of a wider perspective of the potential future of Agri-PV, considering factors and drivers that might be less likely to happen from the present. The exercise was an opportunity to stimulate imagination and to lead participants in suggesting innovative perspectives on the deployment of Agri-PV that go beyond the current developments. Although the results are biased by the academic and professional background of participants, they provide interesting and different perspectives on how the future of Agri-PV is perceived in the different countries (Table 19).

Spain: the "investors driven" and "local farmers" scenarios

In Spain, the "official future" is characterized as "investment driven". In this scenario, multinational companies dominate the Agri-PV sector, which is expected to account 15%-30% of the renewable energy produced in the country and cover 5% - 10% of agricultural areas. Foreign investors will purchase low-value agricultural land for Agri-PV installations, while local farmers will be excluded due to high capital costs associated with purchasing and maintaining these systems.

In contrast, the "alternative future" is "local farmer driven". Agri-PV is purchased and managed by local farmers, who benefit from additional income and thus can value and re-invest in agricultural landscapes. This scenario makes rural living more attractive to urban residents by creating new income and businesses opportunities.

Italy: the "technology driven" scenarios

In Italy, the official and alternative futures are based on the large-scale deployment of Agri-PV across the country. Under the "official" scenario, Agri-PV is projected to achieve an installed capacity of 100 GW by 2050. In the "alternative scenario", the goal is an ambitious 500 GW of installed capacity by 2050.

Belgium and the Netherlands: the "agriculture driven" and "local communities driven" scenarios

In Belgium and the Netherlands, the official scenario is "agriculture driven". Under this scenario, Agri-PV installations are primarily deployed in open fields rather than in greenhouses. This approach makes field management more efficient and integrates better with traditional farming practices.

The alternative scenario is "Local Communities-driven." Here, Agri-PV is developed sustainably, based on mutualism among farmers and residents. Local communities take the lead in managing Agri-PV systems, ensuring that the benefits are shared locally and promoting a cooperative approach to renewable energy and agricultural productivity.

The EU: "scale-economy driven" and "extinction driven" scenarios

In the EU, the official future of agrivoltaics is expected to follow a "scale-economy driven" scenario. This approach involves the deployment of customized, large-scale Agri-PV plants across the continent, tailored to align with individual national policies and morphologies. The focus is on maximizing efficiency and integrating Agri-PV with existing agricultural practices, promoting widespread adoption and significant contributions to renewable energy production.

The alternative scenario has been called an "extinction driven" scenario. It presents a more speculative future where agrivoltaics are utilized on spacecraft as humanity seeks to sustain life beyond Earth. In this vision, Agri-PV becomes a critical technology for supporting agriculture in space, providing essential resources for human survival in extraterrestrial environments.

Table 19: Official and Alternative Scenarios for Agri-PV in Spain, Italy, Belgium and the Netherlands, and the EU

	Spain	Italy	Belgium & the Netherlands	European Union
Scenario 1 "Official Future"	**Investors driven** 25%-30% of the energy produced is from Agri-PV which means 5-10% of agricultural surface. Agri-PV mostly controlled by multinational companies. Foreign capital invested to buy low-value agricultural land	**Technology driven** 100 GW of installed Agri-PV in Italy by 2050	**Agriculture driven** Agri-PV installed more in the fields than in greenhouses. Fields more manageable	**Scale-economy driven** Customized* and large Agri-PV plants across Europe *depending on national policy
Scenario 2 "Alternative Future"	**Local farmers driven** Agri-PV is managed by local farmers Local farmers become rich Living in the country becomes "sexy"	**Technology driven** 500 GW of installed Agri-PV in Italy by 2050	**Local communities driven** Agri-PV is sustainable and based on mutualism among farmers and residents	**Extinction driven** Agri-PV will be used on spacecrafts where humanity will live

4.4 DISCUSSION

The workshop in Barcelona highlighted a multitude of drivers that could lead to different future scenarios for the implementation of Agri-PV across Europe. The creation of a European policy on Agri-PV is a key political driver to establish a clear regulatory framework across Europe for the sustainable integration of agricultural and energy production. Such regulatory framework could be integrated in the Common Agricultural Policy (CAP) of the European Commission to establish a system of Agri-PV subsidies and programs to ensure support to local farmers and sustainable rural development. National subsidies, incentives and tax reductions are suggested as key economic drivers to encourage the installation of Agri-PV. The creation of EU carbon labels for agricultural products could be associated with tax reduction programmes for farmers adopting Agri-PV.

Technological innovation in the materials, lighter design and structures of PV modules are expected to improve synergy with agricultural productivity while improving efficiency and lowering the costs of Agri-PV plant installation and maintenance. Affordability of purchasing Agri-PV and decision-making power over agricultural land by proprietary local farmers are key social drivers. Supporting local ownership of Agri-PV plants is encouraged to limit the power of multinational companies which, nevertheless, are expected to rapidly penetrate the market. By offering an alternative revenue source to farmers through land leasing, they are likely to lead the market of Agri-PV. However, large-scale installations of Agri-PV are expected to encounter resistance and oppositions from residents and local populations due to both perceived landscape impact and unfair distribution of benefits related to renewable energy production. In particular, the polarization between urban and rural residents is expected to exacerbate consumer-producer relationships in relation to energy and food, leading to justice implications over space and landscape claims. Ecological drivers are expected to be crucial for Agri-PV since increasing biodiversity loss, water scarcity, soil deterioration due to both climate change and monocultures will require careful consideration for the survival of future generation. Finally, the concept of “Agri-ecovoltaics” is suggested as a functional “integration by design” of agriculture, biodiversity and renewable energy.

At the European level, the combination and prevalence of one driver over the other are expected to promote different scenarios for the future of Agri-PV by 2050. “Official” scenarios tend to envision Agri-PV as the extreme industrialization of agriculture led by multinational companies with scarce consideration for sustainability and justice implications. On the contrary, “alternative” scenarios are human-centric, actively involving small farmers and residents in the ownership of Agri-PV plants. This inclusive approach ensures that local community collectively benefit from Agri-PV, which becomes a significant source of renewable energy for rural areas.

5. FORESIGHT WORKSHOP 2: VISIONS FOR AGRI-PV IN SOUTH TYROL

5.1 PURPOSE OF THE WORKSHOP

The second foresight workshop has been organized as an internal event at Eurac Research, and took place on 6 May 2024, with the title "What future for a symbiosis of agriculture and energy production from Agri-PV in South Tyrol?". It aimed at bringing together colleagues from different Institutes of Eurac Research (Alpine Space, Climate Change Transformation, Renewable Energy) with different academic backgrounds to identify and discuss political, socio-economic, environmental, and technological factors that can promote or hinder Agri-PV in South Tyrol. Moreover, based on the identified key drivers, participants have been asked to generate visions for the future development of Agri-PV in South Tyrol for 2040.

The workshop had the additional objective of validating the foresight methodology that will be used in the next stakeholder engagement activities that will be organized in South Tyrol and in Italy during 2024/2025 to further explore justice implications and future visions for Agri-PV.

5.2 METHODS

The workshop started with an introductory presentation of the concept of Agri-PV and its implementation in the EU and in South Tyrol, its current barriers, and future opportunities. A second presentation followed introducing the concept of justice applied to Agri-PV and giving some insights from the literature review, presenting the foresight methodology, and the preliminary results from expert interviews and the survey administered to farmers in South Tyrol.

The workshop consisted then of 2 different participatory activities: 1. Defining Agri-PV key drivers, 2. Defining a vision for Agri-PV in South Tyrol in 2040. The first activity aimed at identifying and prioritizing the key drivers of Agri-PV, pivotal to later define future visions of Agri-PV. Based on the number of participants, 2 tables with 8 participants each were formed. Each table discussed a set of driver categories: table 1 discussed political and socio-economic factors, table 2 discussed technological and environmental factors. The participants at each table had similar expertise according to the factors' categories to be discussed at the table (e.g. experts in energy worked on technological factors).

The activity was structured as follows: first participants were asked to individually brainstorm on drivers, those that in their opinion were the most relevant and specific drivers that will have an impact on Agri-PV in the future in South Tyrol, and to write them down on sticky notes. They were then asked to map and select the drivers on a matrix, according to their level of uncertainty and impact, discuss them in group, and select the most uncertain and that will have the most impacts on the future of Agri-PV in South Tyrol. Finally, each group reported back in plenary the results.

The methodology of this first activity is Based on the Driver Mapping Tool developed by the UN Global Pulse[1], adapted to the aims of the Symbiosyst project.

The second activity has as objective to develop images of the future (scenarios) for Agri-PV in South Tyrol in 2040. Based on the number of participants, 2 tables with 8 participants each were formed. The participants at the 2 tables differed from the previous activity, thus at each table all different types of expertise were represented. In fact, to develop future scenarios participants were asked to consider all drivers' categories (political, socio-economic, technological, and environmental factors).

The second activity followed the following steps: first we asked participants to select one driver for each category, among those identified in the previous activity. For each driver, they were then asked to think of two opposite outcomes for each driver, i.e. how each driver would play out in a worst case and in an ideal scenario. This would enable participants to imagine two extreme scenarios for Agri-PV. Then, starting from the two extreme scenarios, participants had to draft their own scenario, that could be either one of the two extremes, or a nuanced version. They had to note the four key drivers, to identify key things, sentiments and feelings for their scenario and brainstorm on the initial scenario narrative, by discussing how the scenario would work out. Participants were provided with a template to be filled out (ANNEX 2).

[1] https://foresight.unglobalpulse.net/blog/tools/driver-mapping/

5.3 RESULTS

Concerning the first activity, the two groups agreed on the key drivers. Provincial regulation of Agri-PV will be needed to ensure a clear definition of suitable installation areas, ownership, and controls of the combined use of land. Beneficiaries of Agri-PV will be identified to ensure fair distribution of benefits in local communities, where Agri-PV can be an additional RES for local energy communities. Technology development will be done in synergy with agriculture productivity and agricultural diversification. Landscape harmony, environmental quality and biodiversity preservation will be key environmental drivers. An additional pivotal driver will be the definition of clear decarbonization targets for South Tyrol, that are missing today.

The outcome of the second activity were two different images of the future of Agri-PV in South Tyrol: the "Community and nature-based Agri-PV according to needs" scenario envisions smaller areas of intensive agricultural production integrated with Agri-PV systems alternated by areas set aside for biodiversity. Agri-PV systems will be designed for multi-functionality and reduced landscape impact (for example, using diverse and light patterns of PV modules). Agri-PV will play a role in local renewable energy community production and in nature-building communities. Benefits will be shared across communities and there will be a social contract between downhill and up-hill farmers to share the benefits arising from the implementation. The social contracts will be strategically framed within the local RE plan, integrated in local climate plans to be provided by municipalities linked to provincial regulations.

The "Leibniz" scenario envisions a balanced regulation of Agri-PV to reach feasible and clear renewable energy targets according to EU directives and considering constraints like landscape conservation, social inequalities, biodiversity, justice implications, etc. There will be the possibility of sharing the energy and economic benefits of Agri-PV installations by creating local energy communities across the region. There will be incentives for small farmers to install the technology and drive the transition. If big farmers will be involved in the implementation of Agri-PV systems, the governance of energy communities will ensure a fair distribution of benefits among its members. Elevated Agri-PV with tracking systems would be the preferred technical configuration allowing to maximize the combined production, though other Agri-PV typologies could be considered depending on the crop underneath. Agri-PV systems will be functional to increase the rate of restorative areas for biodiversity preservation on agricultural land, in fact Agri-PV installations will give an additional source of income to farmers which will allow them to turn away from monoculture and experiment alternative models of agricultural production that will be more biodiversity friendly.

6. CONCLUSIONS

This document reported the results of qualitative research on the environmental and energy justice implications of Agri-PV development across four regions in the EU, moving beyond the concept of social acceptance. The research is part of the Symbiosyst project that will design, install and test innovative and sustainable Agri-PV systems in Belgium, Italy, Spain, and the Netherlands. By adopting multiple qualitative methods, this research used interpretative literature review, semi-structured interviews, and foresight workshops to explore the justice implications of Agri-PV deployment in the present and in the next future.

There is a recent growing literature on Agri-PV, focusing mainly on technical aspects. Research on the social implications of Agri-PV is limited to the concept of social acceptance and focuses mostly on case studies in the USA and Germany. Agri-PV is traditionally presented as a solution to land use conflicts between agriculture and energy production. Key factors influencing social acceptance of Agri-PV include local externalities and lack of public involvement, with major concerns being the impacts of agrivoltaics installations on landscapes, infrastructure interference with agricultural practices, and current regulatory uncertainties. To the best knowledge of the authors, Agri-PV has so far not been addressed using environmental and energy justice frameworks in the existing literature. Yet, as preparatory activity for the design of the protocol of the experts' interviews, the justice lens has been applied to scrutinize and categorize described social implications of Agri-PV. Thus, environmental and energy justice in Agri-PV would involve equitable distribution of benefits and costs, recognizing marginalized voices, and ensuring inclusive decision-making that address environmental and social impacts. Tenant farmers, residents and local communities often face disadvantages, missing potential economic benefits and suffering visual impacts, and at the same time having their needs and interests neglected. Environmental concerns of Agri-PV would include negative impacts on flora and fauna. Finally, procedural justice would call for inclusive stakeholder engagement to establish legitimate planning frameworks for Agri-PV.

The results of the literature review were then confirmed and extended by this study. Experts' interviews suggest that a common definition of Agri-PV is currently missing, causing misunderstandings with traditional PV systems on land, while Agri-PV is characterized by real combination of land use where renewable energy production is symbiotic and complementary to agricultural production. Agri-PV has a landscape impact, which however can be mitigated through the design, use of light structures and camouflage materials. Configuring Agri-PV system according to the morphology of the landscape emerged as a key strategy to mitigate landscape impact. However, some landscapes are perceived to be "untouchable" for Agri-PV systems. These include mountain agricultural landscapes, traditional high-value agricultural landscapes, historical and cultural heritage site, protected areas such as Natura 2000 sites and agricultural landscapes highly valued by local populations in defining their cultural identity. Areas that were suggested as suitable for Agri-PV are agricultural fields closed to already existing infrastructures such as roads, railways, buildings, or crops with hail protection nets or other agricultural infrastructure. Engaging stakeholders in the co-design of the Agri-PV systems through multiple participatory approaches and using compensation mechanisms either as economic deposits to municipalities to be used for community projects or as nature-based solutions or other restoration projects to camouflage Agri-PV systems are additional approaches to mitigate landscape impact.

According to the experts, justice in Agri-PV means environmental protection, fair decision-making, and equitable sharing of its benefits and costs, highlighting Agri-PV's potential to address rural-urban power imbalances and to apply restorative justice principles. Among environmental benefits of Agri-PV, experts identified reduced crop exposure to extreme weather conditions related to climate changes, while also noting the risk of crop overshadowing, and impacts of fauna such as improved biodiversity but also wildlife movement disruption. Moreover, Agri-PV is expected to lead to increased profitability in the agriculture sector, due to additional revenue from selling the produced energy, although potentially creating new power imbalances among farmers. Agricultural organizations, local authorities and large investors hold economic power and can influence the design and approval of Agri-PV projects, while ecosystems, farmers and residents are often excluded from the decision-making process. To overcome this situation and pursue inclusivity in Agri-PV decision making, the involvement should happen from the outset, through informative campaigns and co-design participatory activities, involving all kind of stakeholders, especially local communities, residents, farmers, local authorities.

In line with the results of the interviews, the drivers that will affect the future of Agri-PV in Europe, identified during the two workshops, are first the creation of an EU policy, preparatory also for the establishment of national clear regulatory framework across Europe. Such regulatory framework could entail subsidies, incentives, and tax reductions, which may encourage the installation of Agri-PV. To achieve a fair distribution of the economic benefits of Agri-PV, it is pivotal that the purchase, installation, and maintenance of Agri-PV systems become affordable, and the decision over the use of agricultural land lies in the hands of the farmers and local administrations granting a fair development of the innovation. Moreover, the benefits should be shared with local communities, as Agri-PV could become the RES for local energy communities, where necessary adapting the grid infrastructure, or cooperatives. Agri-PV projects should not operate effectively in isolation; they require integration with wind projects and biogas systems to address the intermittency inherent to RES. Research efforts needs to be focused on the integration of solar, wind, and biogas technologies to achieve consistent energy production throughout the year. Additionally, the deployment of collective battery storage solutions should be investigated to store surplus energy generated during daylight hours for use during peak consumption periods in the evening. As emerged in one interview in Belgium, communal battery system should be designed as an energy storage solution capable of ensuring that surplus energy generated during the day can be utilized during peak demand when individuals return home at night. Furthermore, managing grid stability is recognized as essential, despite the inherent challenge On the agricultural side, Agri-PV technology should respect agricultural productivity and diversification while improving sustainability and efficiency. Finally, Agri-PV should enable landscape and biodiversity preservation and improvement to resolve the problems of biodiversity loss, water scarcity, soil deterioration due to both climate change and monocultures.

During the two workshops, the “official” scenarios envision Agri-PV as the extreme industrialization of agriculture led by multinational companies focusing on technology and economies of scale, with scarce consideration for sustainability and justice. In contrast the “alternative” scenarios offer more optimistic visions of Agri-PV, proposing a balanced regulation that mandates restorative areas for biodiversity preservation and landscape protection. These positive scenarios also emphasize the active involvement of farmers and local communities in the ownership of Agri-PV systems, potentially through the creation of local energy communities or social contracts to share the economic benefits.

To conclude, the future deployment of Agri-PV across the EU will benefit from stakeholder co-creation and engagement while creating genuine synergies between the agricultural and energy sectors. Agriculture must remain the priority of agricultural land use, but it might be enhanced by the installation of PV systems in ways that are in line with the need of residents, local communities, and ecosystems. Merging techno-economic considerations with socio-environmental ones is the key challenge for local, national, and European policy makers to ensure sustainability and justice of Agri-PV deployment. Successfully integrating these four aspects could offer new opportunities to transform both the agriculture and energy sectors in ways that align with the EU Green Deal and clean energy transition goals. Conversely, neglecting socio-environmental justice could result in the extreme industrialization of agriculture and agricultural lands, to the detriment of younger and future generations.

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ANNEX 1

Instruction for moderators

Hi Moderator,

Your role in this workshop will be:

1) **Time keeping** try to keep the discussion as follow
   a. Identification of key trends and drivers in scenario 1 (10 min)
   b. Writing of the "official future" in scenario 1 (5 min)
   c. Brainstorming of "alternative future" in scenario 2 (10 min)
   d. Brainstorming of changing key trends and drivers in relation to "alternative future" (5 min)

2) **Stimulate the discussion**: ask questions to the participants during the session
   a. What are the key trends and drivers in your country today concerning the development of Agri-PV? Please, consider PESTLE trends and drivers in the following fields (10 min):
      i. *Policy* (e.g., new regulations, policies, measures that support Agri-PV)
      ii. *Environmental (*e.g., energy transition needs that respect biodiversity, landscape value, etc.)
      iii. *Social* (e.g., social attitudes towards Agri-PV and social benefits from the technology)
      iv. *Technical (*e.g., technology development of Agri-PV)
      v. *Economic* (e.g., business model innovation to produce and distribute energy produced from Agri-PV)

   b. Based on the key trends and drivers, what will be the "official future" of Agri-PV that will be most likely to result in 2050? (5 min)

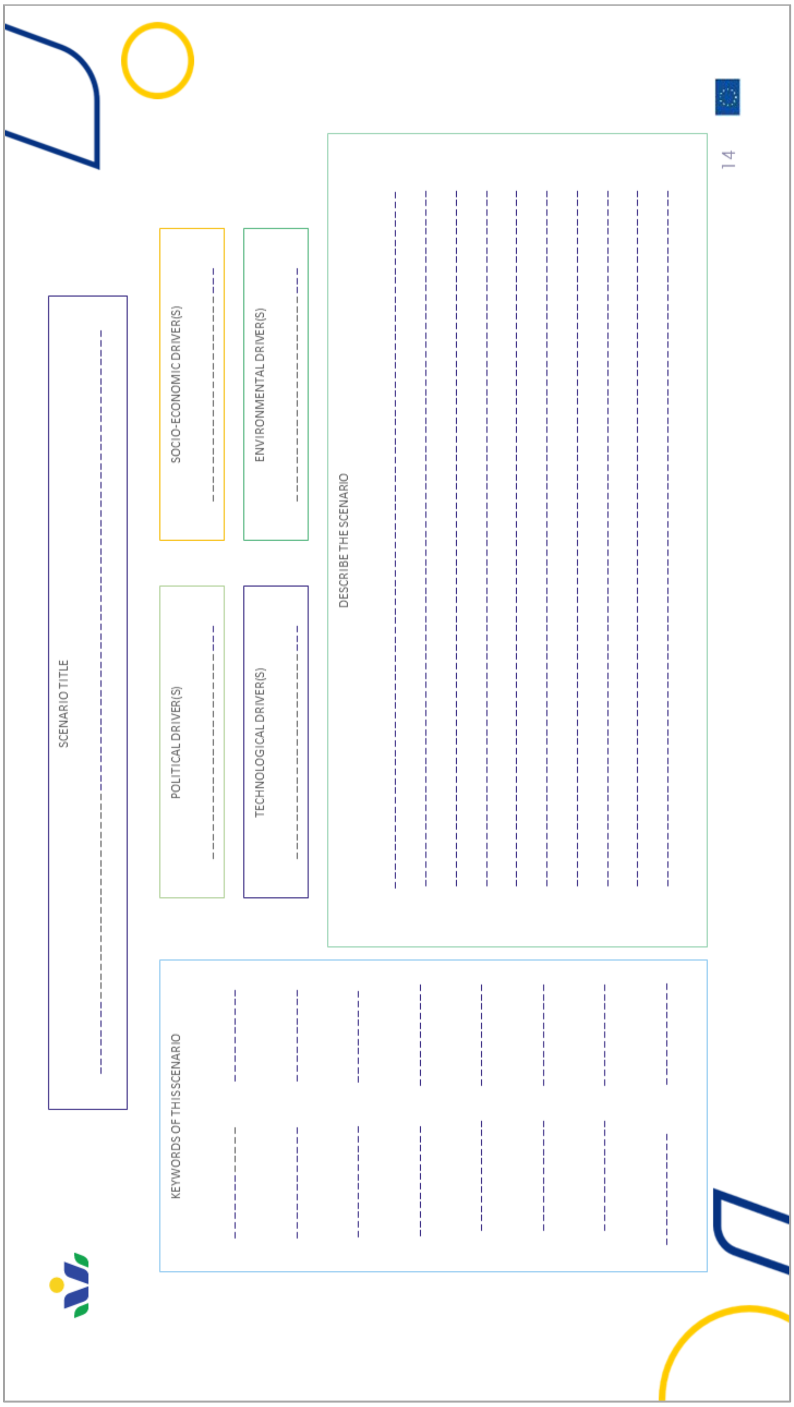
   c. Widen your perspective: can you imagine "alternative futures" of Agri-PV that might happen in 2050? Be creative and discuss **plausible** alternatives: choose one! (10 min)

   d. What PESTLE trends and drivers would be needed to support the happening of your "alternative future" on Agri-PV in 2050? (5 min)

3) **Write down post its** and ask participants to write their ideas on post-its and put it on the drawing on the table

4) **Nominate one representative** that will present the results during the plenary session

ANNEX 2


SCENARIO TITLE
SOCIO-ECONOMIC DRIVER(S)
ENVIRONMENTAL DRIVER(S)
POLITICAL DRIVER(S)
TECHNOLOGICAL DRIVER(S)
DESCRIBE THE SCENARIO
KEYWORDS OF THIS SCENARIO
14