REGACE – Crop Responsive Greenhouse Agrivoltaics System with CO2 Enrichment for Higher Yields

Project Deliverable Report

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Executive Summary

This deliverable is reporting the activities consistently with the objective of participation and involvement of farmers from the five countries (Italy, Germany, Austria, Greece and Israel) involved in the implementation of the project with particular attention to:

- knowledge of project activities;
- awareness of the possible impacts of the project results;
- involvement in project development, communication and dissemination activities;

In particular, it espouses the activities made according to:

1. Researcher training (M1-6), with two researchers trained for each country involved who will accompany the entire participatory process on analytical and participatory methodologies: non-standard interviews, focus groups, sentiment analysis, world café

2. Analysis of farmers' mental and social representations of technology and photovoltaics through:

    - Analysis of the mental and social representations of farmers in general on technologies applied to agriculture and specifically on photovoltaics through for each partner country: 10 non-standard qualitative interviews, 3 focus group

    - Sentiment analysis on a body of text identified in the groups present on farmers' social media (Twitter and Facebook) and any online thematic forums on photovoltaics in agriculture

3. Participation through the means of the World café technique with: presentation of the project; Requests, doubts and aspirations of the participant farmers with respect to the agrivoltaics

4. Discussion, communication and dissemination of results

5. Evaluation of change in mental and social representations through the analysis of the collected material

All the activities have been conducted according to the Regace Innovation Action Project as planned.

In conclusion, REGACE demonstrates that integrating PV into greenhouses can deliver meaningful renewable energy production and climate benefits. The impacts on agricultural yields vary across crops, regions, and seasons, and can be partially mitigated through CO_2 enrichment. The findings highlight the importance of crop-specific strategies, technological innovation, and farmer engagement to optimize the synergies between food and energy production.

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Chapter 1 - Researcher training on citizen science as the theoretical context and on research techniques

Description of contest analysis based on the framework of citizen science and citizen participation to scientific programmes.

1. Citizen science as a transformative epistemic paradigm

Citizen science has emerged as a transformative epistemic paradigm within environmental and sustainability research, reshaping the relationship between scientific knowledge, public participation, and the democratic legitimacy of innovation. Since the 1990s (Irwin, 1995; Bonney, 1996), it has marked a profound shift in how knowledge is conceived, produced, and validated in societies characterized by complexity, uncertainty, and interdependence between science and society. As Finke (2014) observed, citizen science is not merely voluntary data collection but a reconfiguration of knowledge governance, enabling citizens to define research priorities, interpret findings, and assess their broader implications. It challenges the hierarchical model of scientific expertise, promoting a dialogical and pluralistic understanding of inquiry that recognizes the epistemic value of lay experience and situated know-how.

In environmental and ecological sciences, citizen science—scientific activity conducted by the public in collaboration with professional researchers—has become crucial for studying complex adaptive systems such as ecosystems, climate, and energy transitions that transcend disciplinary and territorial boundaries. By mobilizing distributed observers and communities of practice, it enhances the temporal and spatial resolution of data while embedding science in social contexts of meaning and care. The Nature Reviews Methods Primers (2022) article shows that such participation improves data granularity and representativeness, and strengthens transparency, accountability, and co-ownership. When communities see their contributions reflected in research outcomes and decision processes, science regains legitimacy as a collective good rather than a professional monopoly.

The link between citizen science and public understanding of science has also become central. Bonney et al. (2016) suggest that participation can increase knowledge of scientific principles, broaden awareness, and enhance the relevance of research for individuals. It offers communities a voice in local environmental decisions and helps bridge the science–society gap through four factors: project (co-)design, measurable outcomes, engagement of new audiences, and the pursuit of new inquiry directions. Thus, citizen science acts not only as a data-gathering method but as a medium of science communication and education that fosters epistemic agency among participants.

From contributory models—where citizens collect data—to collaborative and co-creative ones—where they co-design protocols and interpret results—citizen science

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transforms research into a collective learning ecosystem and living laboratory. This epistemic turn connects empirical investigation with civic engagement, linking the pursuit of knowledge to practices of citizenship and stewardship. The convergence of scientific and civic rationalities resonates with the principles of open science and responsible research and innovation (RRI), both calling for transparency, inclusivity, and reflexivity in knowledge production and use. Within this framework, citizen science appears as both a methodological innovation—expanding the scope, reproducibility, and resilience of environmental research—and a political instrument that democratizes expertise, redistributes epistemic authority, and fosters social trust.

Recent theoretical contributions have refined this view by situating participation within broader "ecologies of engagement." Pallett et al. (2021) describe these as dynamic configurations of actors, institutions, and technologies through which citizens interact with environmental and energy systems. Participation thus emerges as a continuum of practices—from consultation to co-design and co-creation—through which publics negotiate their roles in collective problem-solving. Similarly, Radtke and Renn (2024) argue that sustainable energy transitions depend on inclusive and reflexive participation capable of bridging institutional, technical, and civic rationalities. Their typology—autocratic, adversarial, collaborative, and inclusive—shows that only the latter two foster socially robust and cognitively transparent transitions. Together, these perspectives frame citizen science as both a theoretical foundation and methodological approach for the REGACE Project, especially within this work package on sustainability, which focuses on designing democratic, participatory processes for sustainability innovation.

2. Agrivoltaics as a socio-technical arena for citizen science

In light of the prevailing view of citizen science, we explore how agrivoltaics (agri-PV) exemplifies the intersection of scientific and social participation in sustainability innovation, combining technological experimentation, agricultural practice, and civic engagement. Designed to enable the dual use of land for cultivation and photovoltaic generation (Jamil & Pearce, 2025), agrivoltaics responds to competing land-use pressures and advances the systemic integration of energy and food systems. It promises synergies between food security, renewable energy, and rural development, yet its significance transcends technical optimization. Agrivoltaics redefines land not as a mere productive resource but as a socio-technical landscape where ownership, benefit distribution, and ecological and aesthetic integration are decisive for legitimacy and public acceptance (Sareen, Shokrgozar, McCarthy & Wolf, 2025).

As a hybrid infrastructure at the crossroads of technology and culture, agrivoltaics highlights the politics of scale and visibility that mark contemporary energy transitions and the notion of a just transition (Haiven, 2024). The deployment of photovoltaic modules reshapes both the material and symbolic dimensions of rural space,

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challenging established imaginaries of agriculture. The installation of panels, supports, and sensors transforms the field into an experimental surface where agronomy, engineering, and environmental design converge. In this sense, agrivoltaics materializes the Anthropocene condition (Ruddiman, 2013): productive landscapes become sites of ecological monitoring, energy production, and socio-economic negotiation.

Empirical studies, such as Pascaris et al. (2021), show that community support for agrivoltaics varies according to control distribution, benefit fairness, and alignment with local values. Small-scale, cooperative, or farmer-led projects gain greater endorsement, preserving agency and territorial attachment. Conversely, externally imposed or opaque initiatives generate opposition, often framed in terms of landscape degradation or procedural injustice. These dynamics mirror wider debates on energy justice and socio-technical legitimacy, emphasizing local ownership and participation as central to sustainable governance. They also inform the theoretical and methodological framework of this REGACE work, focused on co-design and co-creation between scientists and farmers.

Within this perspective, citizen science emerges as a mediating epistemic and social practice linking technological design to local knowledge systems. Through participatory data collection and collaborative experimentation, citizen science enables farming communities to generate empirical insights on microclimate, crop performance, biodiversity, or shading effects. Farmers involved in agrivoltaics often develop informal observation networks and adaptive management strategies, producing practical knowledge that complements scientific research and supports future optimization. Some become hybrid actors—both practitioners and co-researchers—testing configurations, monitoring yields, and assessing co-benefits such as water retention or livestock shelter.

In this light, agrivoltaics constitutes a co-produced knowledge infrastructure that balances technical efficiency with social and environmental values. Participatory approaches foster reciprocal exchange between scientists and farmers, building trust through co-creation and adaptation. Early stakeholder involvement in design and evaluation enhances resilience and legitimacy, making agrivoltaics a platform for participatory governance rather than mere energy technology.

Farmer engagement in co-design embeds innovation within existing social and economic networks, enabling continuous calibration of technologies to local conditions and promoting community-based diffusion. Experienced operators act as intermediaries, translating performance metrics into practice and demonstrating the feasibility of dual-use systems. This "peer-to-peer epistemology" broadens agrivoltaics' knowledge base beyond academic and industrial circles, strengthening cultural acceptance of renewable energy in agriculture.

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Finally, when citizen science practices integrate into these networks, agrivoltaics becomes a shared process of rural innovation. Applied within farmer communities, it embodies a collective experiment reconciling productivity with sustainability, technological advancement with ecological continuity, and individual livelihoods with collective energy futures. Through the active participation of farmers, scientists, and technicians, agrivoltaics evolves into a living lab—open, adaptive, and reflective of how rural societies engage with the green transition.

3. Deliberative engagement and participatory governance in agrivoltaics

Deliberative engagement has become a key factor in shaping how communities perceive and negotiate the implementation of agrivoltaics systems. Participation is not an accessory to technical design but a foundation of socio-technical legitimacy. The processes through which local actors — farmers, cooperatives, energy developers, and institutions — define priorities, expectations, and acceptable trade-offs are decisive for the viability and longevity of projects. When these actors engage in early and continuous dialogue, system configurations tend to balance efficiency, environmental compatibility, and social equity. Inclusivity transforms project development from a technocratic exercise into a deliberative process grounded in shared responsibility and collective learning.

Participation in agrivoltaics design carries both political and epistemic functions. Through consultation, participatory modeling, and scenario-building, communities learn to visualize energy transitions as part of their own social and ecological landscapes. These practices help articulate trade-offs between productivity and land conservation, aesthetic coherence and technological visibility, local autonomy and national goals. In doing so, they create a discursive arena where justice, heritage, and sustainability are debated and aligned with engineering rationalities. This leads to forms of co-production in which knowledge, values, and institutions evolve together, producing infrastructures co-authored by the territories they inhabit.

This shift toward participatory co-design parallels the broader evolution of citizen science. Beyond data collection or outreach, citizen science in agrivoltaics becomes a framework for collective design and governance. Stakeholders collaborate in shaping research questions, testing prototypes, and evaluating social outcomes. Farmers act as both observers and innovators, using their situated expertise to inform decisions on panel configuration, shading, crop selection, and soil management. Their experiential knowledge, once marginalized, becomes crucial for calibrating technological performance and ecological resilience. Likewise, communities engaged in monitoring and participatory mapping gain tools to interpret and communicate the broader implications of agrivoltaics adoption, from diversification of food systems to regional energy autonomy.

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When embedded in long-term participatory structures, these processes generate governance ecosystems linking citizen science, policy innovation, and capacity building. Such ecosystems function as iterative arenas where technical and social feedback loops continuously interact. Collaborative learning becomes an instrument of adaptive management: stakeholders refine institutional norms, recalibrate incentives, and negotiate outcomes based on collectively generated evidence. The establishment of participatory infrastructures at multiple scales—from local cooperatives to regional planning—demonstrates how agrivoltaics can operate simultaneously as technological innovation and as a social contract for sustainable transformation.

At the transnational level, the convergence of participatory governance and agrivoltaics innovation is fostering a paradigm of inclusive green transition. International initiatives now integrate co-design principles into renewable energy and rural development policies, promoting replicable methodologies that respect contextual diversity. The emphasis on transparency, inclusivity, and reflexivity acknowledges that sustainability cannot rely solely on technical optimization but must emerge from democratic processes of negotiation, learning, and accountability. Agrivoltaics thus evolves beyond a tool for optimizing land use into a laboratory of deliberative democracy, where citizens, institutions, and technologies co-evolve toward shared ecological futures.

4. From theoretical perspective to an operational approach

Once the theoretical framework of citizen science had been consolidated and agrivoltaics had been identified as the experimental domain within which to operationalize it, the team moved to address the complex methodological challenge of selecting the most appropriate participatory techniques and engagement formats to both investigate and actively involve farming communities in the innovation process tested by the REGACE project. The central aim was to create a methodological architecture capable of combining social inquiry with co-production of knowledge, ensuring that farmers were not merely respondents but co-interpreters of agrivoltaics innovation.

To this end, a comprehensive questionnaire was designed and disseminated through local working groups—whose members had been adequately trained during the Spring School held in May 2023—to the farming communities showing interest in agrivoltaics development across Italy, Greece, Israel, Austria, and Germany. The questionnaire represented an essential baseline instrument for capturing initial perceptions, expectations, and reservations regarding the integration of solar technologies into agricultural settings. It served as a diagnostic tool for identifying socio-technical readiness, degrees of awareness, and the perceived trade-offs between agricultural productivity and renewable energy generation.

Following this preliminary quantitative stage, a second, qualitative phase was implemented to deepen the understanding of these dynamics. The reference team conducted a set of ten semi-structured interviews per partner country, targeting selected

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members of the farming communities previously involved in the survey. These interviews explored the participants' narratives, attitudes, and imaginaries concerning the evolving relationship between environmental stewardship and energy transition, and their interpretation of photovoltaics and agrivoltaics as instruments for achieving dual objectives—enhancing agricultural sustainability while contributing to clean energy production. This phase provided rich interpretive material, allowing the team to map not only opinions but also the symbolic and practical dimensions of farmers' engagement with technological change.

Both the questionnaire data and the interview findings were carefully analyzed before initiating the third tier of social inquiry, which focused on participatory activities designed to stimulate deliberation, mutual learning, and collective sense-making around agrivoltaics innovation. This final methodological step enabled researchers to work closely with small, purposively selected groups of farmers, creating an immersive environment for dialogue, experimentation, and evaluation. The participatory format—developed specifically within the REGACE framework—was structured around four interconnected stages:

1. Exposure to innovation, both in the field and within technical-scientific venues, guided by REGACE scientists and accompanied by explanatory sessions and Q&A interactions.
2. Reflective phase employing Open Space Technology (Owen, 2008), fostering both individual and collective visualization of insights and reactions to the innovation to which participants had been exposed.
3. Collective discussion and deliberation, organized through the World Café model (Fouché, & Light, 2011) enabling participants to exchange and negotiate viewpoints in a dynamic, dialogical setting.
4. Final debriefing and synthesis, facilitated through the Fishbowl technique, allowing the group to consolidate shared reflections, highlight divergences, and co-construct conclusions.

Overall, a total of two participatory sessions were organized in Italy (both at the Fattoria Solidale del Circeo in Pontinia in 2024 and 2025), two in Germany (in BIO-Gärtnerei Watzkendorf in 2024 and at the Humboldt-Universität zu Berlin in January 2025), two in Greece (both at the Thessaly University in Volos in February and October 2025), and one in Austria (at the BOKU University of Natural Resources and Life Sciences the 2025). No sessions could be carried out in Israel, due to the prolonged state of war from October 2023 to October 2025. Each session was thoroughly documented through systematic notetaking, photographic records, and thematic reporting, focusing on emergent themes, patterns of consensus, and areas of divergence.

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The analytical synthesis presented in the remainder of this deliverable draws upon the triangulation of insights derived from these three complementary methodological components:

1. the questionnaire phase, establishing baseline attitudes and expectations.
2. then in depth-interview phase, generating interpretive depth and contextual understanding.
3. the sentiment analysis on social network.
4. the participatory sessions, revealing collective reasoning processes and the emergence of shared socio-technical imaginaries.

Collectively, these interconnected phases demonstrate how farmers across diverse European contexts interact with agrivoltaics innovation as a multifaceted process that transcends the mere adoption of technology. Through shared experimentation, exchange of practical knowledge, and participation in regional and transnational networks, agrivoltaics becomes not only a technical solution but also a space of collaborative learning and co-production. This process transforms innovation from an isolated act of implementation into a socially embedded practice, shaped by collective reasoning, territorial cooperation, and mutual adaptation. Consequently, the process of technological modernisation assumes a relational character, founded on community engagement and inter-farm dialogue. In this context, agrivoltaics emerges as a unifying field of practice, redefining the interaction between agriculture, energy, and social cohesion throughout Europe.

5. Activities of Spring School on Citizen Science and Qualitative Research Methods

A three-day residential Spring School was organized in Pontinia, hosted in the Training Hall of the Fattoria Solidale del Circeo, with the participation of two researchers from each partner country of the project from 3 to 5 may 2023 (programme in annexes). The initiative was conceived as a key capacity-building action aimed at strengthening the theoretical understanding and practical skills of early- and mid-career researchers in the fields of citizen science, qualitative research, and participatory methodologies.

The Spring School represented an important step in the project's broader strategy to promote a culture of collaborative research, where citizens, communities, and researchers actively contribute to knowledge co-production. The training was designed not only as a technical upskilling opportunity but also as an immersive environment fostering reflection on the social and practical dimensions of engaging citizens as partners in scientific and social inquiry. In this training session lectures, seminars, onsite experimental activities were carried out by REGACE participants Andrea Volterrani, Cristina Cornaro, Stella Iezzi, Marco Serra, Maria Cristina Antonucci.

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Objectives and Rationale

The main objective of the Spring School was to enable participants to develop a shared methodological and conceptual framework for implementing citizen science initiatives and qualitative research activities within their respective local contexts. The course placed particular emphasis on the integration of qualitative research tools with participatory and community-based approaches, recognizing that meaningful citizen involvement depends on the ability to listen, interpret, and co-create knowledge with non-academic actors. Quantitative approaches related to social media sentiment analysis were also presented.

To achieve this, the training combined theoretical lectures, interactive workshops, group discussions, and simulation exercises. Each session was designed to provide participants with both conceptual grounding and hands-on experience in methods that facilitate active participation, dialogue, and co-interpretation of research data.

Core Themes and Training Content

The Spring School was structured around a coherent sequence of thematic modules, each exploring a different dimension of citizen science and qualitative research practice.

1. **Introduction to Citizen Science and Co-Creation in Research**
   The opening module provided a comprehensive overview of citizen science, tracing its evolution from early volunteer-based initiatives to contemporary models of co-designed and community-led research. Participants explored key concepts such as co-creation, open science, and collaborative innovation. Discussions focused on the challenges of inclusivity, data quality, and sustainability of citizen science projects, emphasizing how researchers can facilitate equitable partnerships with citizens and local stakeholders.

2. **Principles of Qualitative Inquiry and Reflexivity in Research**
   This module introduced the philosophical underpinnings and methodological principles of qualitative research, with attention to the interpretivist paradigm, reflexivity, and the importance of the researcher's positionality. Participants learned strategies for maintaining transparency, analytical rigor, and critical awareness throughout the research process.

3. **In-depth Qualitative Interviews**
   One of the core skills addressed was the design and facilitation of **in-depth interviews**. The session combined theoretical input on interview typologies—semi-structured, narrative, and life-story approaches—with practical exercises in question design, active listening, and probing techniques. Role-play sessions allowed participants to practice conducting and analyzing interviews, with peer

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feedback and collective reflection on issues such as interviewer bias, trust-building, and managing sensitive topics.

4. **Focus Groups as Spaces for Collective Sense-Making** A second methodological block centered on **focus groups**, emphasizing their value as arenas for shared meaning-making and social interaction. The session covered key steps in focus group design, including participant selection, facilitation techniques, and strategies for documenting and analyzing group dynamics. Through simulation exercises, participants experimented with facilitation styles that balance structure and spontaneity, ensuring that all voices can emerge within a respectful and inclusive discussion space.

5. **Sentiment Analysis on Social Media** is the systematic study of data produced on digital platforms such as X Facebook and other online communities. It focuses on user-generated content—posts, comments, hashtags, images, and interactions—to identify patterns and discourses that reveal how people think, feel, and communicate about specific topics or events. The approach combines quantitative and qualitative methods. Quantitative analysis examines measurable aspects like post frequency, engagement rates, and network structures, while qualitative approaches explore meanings and narratives through discourse, thematic, or sentiment analysis. Together, these methods offer a nuanced understanding of how online communities shape opinions and collective identities. The main goal of social media analysis is to understand how information, opinions, and emotions circulate online, influencing collective perceptions and behaviors. Social media functions as a vast arena of public debate where individuals exchange views and co-construct meanings. By analyzing these dynamics, researchers can trace emerging trends, public attitudes, and collective representations of social, environmental, and technological issues.

6. **Participatory Methodologies: From Open Space Technology to World Café** The participatory dimension of the Spring School was further expanded through a full-day workshop devoted to participatory research and facilitation methodologies. Participants experienced first-hand the Open Space Technology (OST) format, a method that allows large and diverse groups to self-organize around topics of shared interest. Guided by the principle that "the people who come are the right people," OST encouraged participants to explore the dynamics of self-managed dialogue, spontaneous agenda setting, and emergent learning.

   Building on this, the World Café methodology was introduced as a complementary approach designed to foster cross-pollination of ideas in smaller, rotating discussion groups. Participants engaged in successive rounds of dialogue, each table focusing on a specific question related to citizen science

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practices and community engagement. The use of Talking Canvas - large visual boards that capture and synthesize key insights - helped participants visualize and connect the multiple threads emerging from the discussions.

7. **Participatory Restitution and the Fishbowl Method**
The final training segment focused on methods for **participatory restitution** of findings, ensuring that knowledge generated through participatory research is collaboratively validated and shared. The **Fishbowl technique** was used as a live simulation of participatory reflection: an inner circle of discussants engaged in dialogue while outer-circle participants observed, took notes, and later rotated into the discussion. This approach demonstrated how to democratize reflection and synthesis processes, making space for multiple perspectives and emergent insights.

Pedagogical Approach and Learning Dynamics

The educational design of the Spring School combined experiential learning, peer-to-peer exchange, and collective reflection. Rather than merely transmitting knowledge, trainers acted as facilitators, creating an environment conducive to mutual learning and co-exploration. Each session alternated between conceptual introductions, small-group practice, and plenary debriefings where participants collectively analyzed their experiences and identified lessons for application in their future research contexts.

The residential format played a crucial role in fostering informal interactions and cross-cultural exchange. Evenings were devoted to collective reflection sessions and informal networking activities that deepened the sense of community among participants. The setting of the Fattoria Solidale del Circeo, surrounded by nature and designed as a multifunctional learning space, offered an ideal atmosphere for concentration, creativity, and collaboration.

Reflections and Key Outcomes

By the end of the three days, participants had not only acquired new methodological competencies but also developed a shared vocabulary and strategic understanding of participatory research. They reported an enhanced awareness of how to balance academic rigor with inclusivity, how to translate community insights into valid research outputs, and how to design projects that empower citizens as co-researchers rather than passive data providers.

The Spring School also served as a Living Lab of interdisciplinary and intercultural collaboration. Participants from different disciplinary backgrounds—social sciences, environmental studies, urban planning, education, and digital humanities—discovered the value of methodological pluralism and reflective practice. Many highlighted the

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transformative impact of engaging with peers from other national and institutional contexts, recognizing that citizen science is inherently a transnational and context-sensitive practice.

In addition to the technical content, the training stimulated reflection on participatory processes as drivers for sharing innovation in an open context for citizens science. Participants discussed issues of representation, co-production, and knowledge translation, exploring how participatory approaches can generate more inclusive and relevant outcomes for communities. The sessions encouraged researchers to see citizens as holders of situated knowledge, capable of shaping research agendas and interpretations.

Follow-Up

As a concrete output of the Spring School, participants co-developed a set of practical recommendations for implementing, in each one the countries where the REGACE activities had to be carried on qualitative and participatory methods within the broader framework of the project. These guidelines include templates for interview protocols, focus group moderation guides, and visual facilitation materials for World Café and Fishbowl sessions. Each partner institution committed to adapting and testing these tools in upcoming project activities, ensuring the sustainability and long-term impact of the training.

The feedback collected through a closing evaluation session was positive. Participants appreciated the balance between theory and practice, the openness of the learning environment, and the emphasis on co-creation and reflexivity. Many expressed the intention to replicate the methodologies within their institutions, both for research and for community engagement initiatives.

Conclusions

The Spring School in Pontinia proved to be a pivotal experience within the project's capacity-building framework. By blending methodological training, participatory experimentation, and intercultural dialogue, it created a fertile ground for rethinking the role of researchers in contemporary society. The skills and attitudes cultivated during the training—listening, empathy, collaboration, and co-creation—are now being carried forward into the next phases of the project, shaping a more inclusive, dialogical, and socially responsive research practice.

One of the most significant outcomes of the Spring School was the richness of knowledge exchange and learning among participants. Coming from different countries, disciplinary backgrounds, and professional experiences, participants shared their diverse perspectives on participatory research and citizen science, building a

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collective understanding that transcended local contexts. This dynamic interchange of experiences, best practices, and methodological approaches created an open and generative environment where learning occurred not only through formal instruction but also through the informal, spontaneous interactions that characterized the residential format. Participants learned from each other's successes and challenges, discovering new ways of applying participatory tools in different social, cultural, and environmental contexts.

The Spring School also served as an effective platform for capacity building. Through a balance of theoretical input and hands-on experimentation, participants strengthened their skills in designing, implementing, and evaluating participatory methods. The training allowed them to explore and practice a range of qualitative and participatory techniques—such as in-depth interviews, focus groups, Open Space Technology, World Café, and Fishbowl discussions—thereby enhancing their methodological repertoire. The immersive, practice-oriented approach of the Spring School gave participants the confidence to translate these techniques into their professional contexts, adapting them to the specific needs and dynamics of their research environments.

The experience further contributed to the creation of a strong network of collaboration among participants. The bonds developed during the three days in Pontinia laid the groundwork for ongoing cooperation within the Social Work Package of the REGACE Project, which will continue over the next two years. This network of researchers and practitioners now functions as a living community of practice, committed to mutual support, the sharing of resources, and the joint advancement of participatory approaches in research. Many participants have already initiated collaborative dialogues and planning for joint activities and future projects inspired by the methodologies explored during the training.

Importantly, the training materials and methodologies developed and tested during the Spring School were rapidly put into practice in the weeks that followed. Participants began applying the acquired tools in their respective research contexts, conducting in-depth qualitative interviews, organizing World Café sessions, and performing sentiment analyses as part of their ongoing project activities. The immediate implementation of these techniques demonstrated both the practical relevance and the transferability of the training content. This early adoption also ensured that the knowledge gained through the Spring School was not confined to the training environment but became a tangible resource for advancing participatory research within the project and beyond.

In addition to individual skill enhancement, the collective learning dynamic that emerged during the Spring School played a key role in creating an enduring learning environment. Participants collectively contributed to the dissemination and adaptation of participatory techniques within their own institutions and networks, especially in the field of environmental research. The exchanges and collaborative exercises undertaken

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during the training inspired participants to act as multipliers, transferring knowledge to colleagues, students, and community partners. This has fostered the growth of a broader community committed to participatory and citizen science approaches for environmental monitoring, sustainability transitions, and the co-production of knowledge about ecological challenges.

The overall impact of the Spring School extends beyond methodological training. It reinforced the value of collaborative learning and demonstrated how participatory approaches can act as drivers of social and scientific innovation. By bringing together researchers from diverse disciplines and cultural contexts, the event fostered a spirit of openness, curiosity, and shared purpose. Participants left the training equipped not only with new competencies and practical tools but also with a renewed sense of motivation to apply participatory methods in their future work, to engage communities more effectively, and to foster research processes that contribute to social change and sustainable technological innovation.

In this sense, the Spring School in Pontinia did not simply conclude with the end of its three-day program. Rather, it marked the beginning of a continuing process of collaboration, learning, and experimentation among the participants and partner institutions. The community of practice that emerged from this experience now acts as a catalyst for the diffusion of participatory research approaches, ensuring that the methodologies, insights, and relationships developed in Pontinia continue to generate impact throughout the REGACE Project and in the broader field of citizen science and environmental research.

Chapter 2 - Analysis of farmers' mental and social representations of technology and photovoltaics

A. REGACE in depth interview analysis

In-depth qualitative interviews with prospective end users of agrivoltaics technologies constitute a central methodological component of the REGACE project, designed to elucidate how innovation is interpreted, evaluated, and potentially integrated across diverse agricultural contexts. This analytical report synthesizes the findings from in-depth interviews (see box 1) conducted in the five national settings—Italy, Greece, Austria, Germany, and Israel— of the State partners in REGACE and covering a wide spectrum of production systems, organizational scales, and ecological conditions. The shared semi-structured protocol adopted by all research teams ensured methodological coherence and cross-country comparability, allowing for a systematic analysis of how farmers involved in this section of the Project understand technological change, assess risks and opportunities, and position themselves toward agrivoltaics adoption. By examining how technological imaginaries intersect ecological conditions, production logics, and institutional environments, this section of analysis of the interviews

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provides a comprehensive perspective on the socio-technical pathways shaping innovation in contemporary agriculture. The cross-national synthesis highlights converging tendencies—such as the emphasis on empirical validation, ethical responsibility, and pragmatic adaptation—alongside diverging trajectories influenced by scale, governance structures, and generational outlooks. Taken together, the interviews delineate a model of reflective modernization in which technological progress is approached as a collective, evidence-based, and ethically accountable process rather than a purely technical or market-driven transformation.

Box 1 – In depth interviews

In-depth interviews are a core qualitative method within the REGACE project, designed to access the experiential and reflective dimensions of those directly engaged with agricultural production and innovation. By targeting specific groups—farmers, cooperative representatives, agronomists, and enterprise managers—the method captures situated perspectives that cannot be elicited through standardized surveys or purely quantitative tools.

This approach is particularly suitable for describing attitudes toward emerging technologies such as agrivoltaics, where perceptions are shaped by experience, local conditions, and professional identities. Through open, semi-structured dialogue, interviewees articulate not only their opinions but also the reasoning, emotions, and contextual factors that inform their choices. The resulting narratives offer a "thick description" of how innovation is interpreted, evaluated, and domesticated within concrete practices.

Rather than aiming for statistical representativeness, in-depth interviews seek *analytical generalization*: they reveal the underlying logic, tension, and interpretative frames that characterize a sector's broader orientation toward change. When conducted with methodologically diverse samples—covering variation in scale, geography, and generation—they provide a reliable sketch of how a given community perceives and negotiates a phenomenon. Within REGACE, this method thus enables the reconstruction of a nuanced map of expectations, reservations, and adaptive strategies surrounding agrivoltaics innovation across different socio-ecological contexts.

Methodology

The activity of in-depth interviews was designed as a qualitative research component aimed at capturing farmers' perceptions, experiences, and expectations regarding technological innovation, photovoltaic integration, and agrivoltaics systems across the five REGACE partner countries—Italy, Austria, Germany, Greece, and Israel. The interviews followed a common semi-structured protocol developed collaboratively by the research teams during the preparatory phase of the project. This shared framework ensured conceptual alignment and methodological coherence while allowing each national partner to tailor participant selection to the specific characteristics of its agricultural and socio-economic context.

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Interviews Implementation

Each research group autonomously defined its target group, identifying relevant actors within the horticultural and agricultural sectors based on representativeness, technological engagement, and farm typology. Researchers contacted prospective participants directly, presenting the objectives of the REGACE project and the specific goals of the interview activity. The process was designed to encourage open, reflective dialogue, ensuring that interviewees could articulate both practical experiences and broader reflections on innovation processes in their sector.
All in-depth interviews were conducted in the local language by trained national researchers and were audio-recorded, with several also video-recorded to capture non-verbal dimensions of communication and contextual details. Following data collection, the interviews were fully transcribed and subsequently translated into English, enabling comparative analysis across linguistic and national boundaries. This translation process was double-checked to preserve semantic accuracy and cultural nuances, ensuring that key terms and contextual references were rendered consistently across the corpus. The research dimensions investigated by the semi-structured questions, posed in all the 5 national environments in order to have comparison are presented in Table 1.

Research dimension	Analytical focus	Corresponding questions	Description
1. Professional and organizational respondent background	Structure, scale, and evolution of the farm enterprise	Q1	Explores the interviewee's professional trajectory, enterprise organization, and the historical evolution of the agricultural model, establishing context for subsequent analysis.
2. Perceptions on technological innovation	Conceptual attitudes toward innovation and technology in society	Q2	Investigates the respondent's general understanding of innovation, perceived benefits and limitations, and its social and economic implications beyond agriculture.
3. Technological innovation in agriculture	Application and perception of technology in farming and environmental management	Q3	Examines how farmers conceptualize innovation within agricultural practice, focusing on efficiency, competitiveness, and environmental adaptation.
4. implementation of technological innovations	Concrete examples of technologies adopted in production and processing	Q4	Identifies actual instances of technological adoption, assessing motivations, investment logic, and operational impact.
5. Perception on energy transition and sustainability	Views on energy conservation, renewables, and environmental responsibility	Q5	Evaluates farmers' awareness of the energy transition and the perceived relationship between energy use, sustainability, and agricultural productivity.
6. Land use and photovoltaics	Opinions on the use of farmland for renewable energy installations	Q6–Q7	Analyses farmers' attitudes toward land-use conversion for photovoltaic panels, considering economic, regulatory, and aesthetic implications.

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Research dimension	Analytical focus	Corresponding questions	Description
7. Perceptions on Agrivoltaics	Evaluation of agrivoltaics systems as dual-use technological innovations	Q8	Investigates familiarity with and perceptions of agrivoltaics, focusing on feasibility, productivity, and willingness to adopt the technology within existing farm operations.

Table 1 Dimensions of research in the in-depth interviews

The analytical phase proceeded in two complementary stages. First, each national team carried out a country-specific analysis, focusing on local patterns of perception, technological adoption, and policy influence within the agricultural innovation ecosystem. Second, the Italian research team, acting as the coordinating body for this task, performed a cross-national comparative analysis. This stage involved the systematic coding of the translated transcripts, the identification of shared thematic dimensions, and the synthesis of converging and diverging tendencies across contexts. The comparative interpretation thus integrated national findings into a coherent transnational framework, elucidating both common epistemic orientations and structural differences shaping innovation attitudes across partner states. The activities of interviews implementation are presented in Table 2.

National Context	Number of Interviews	Period of Data Collection
Italy	10	Jun – Dec. 2023
Austria	6	Jun – Oct. 2023
Germany	8	Jun – Oct. 2023
Greece	10	Jun – Nov. 2023
Israel	10	Jun – Oct. 2023

Table 2 Interview implementation plan

The results of this methodological process—comprising national analyses and the overall comparative synthesis—are presented in the following sections of this deliverable, in accordance with the objectives defined for this work.

Data Processing and Analysis

The analysis of the interview corpus followed a qualitative and interpretative approach, combining thematic coding, comparative synthesis, and cross-case triangulation to identify recurrent patterns and country-specific variations. The analytical process was structured in several sequential stages designed to ensure methodological rigor, transparency, and internal coherence across the five national datasets.

a. Data preparation

After transcription and translation, all interviews were reviewed for accuracy, completeness, and consistency. The transcripts were anonymized to protect the identity of the participants, with all personal and identifying information replaced by standardized codes indicating the country and interview sequence (e.g., IT1, AT2,

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DE3). The translated materials were then compiled into a shared repository accessible to the international research consortium, facilitating collaborative examination and cross-verification of key excerpts.

b. Coding and thematic categorization

The analytical process was based on thematic coding, following a combined deductive–inductive logic.

- Deductive coding drew on the conceptual framework developed during the project's preparatory phase, particularly the analytical categories linked to innovation, energy transition, and agrivoltaics adoption.
- Inductive coding emerged from the empirical material itself, allowing for the identification of new themes, contextual nuances, and locally specific interpretations.

The coding procedure was carried out using both manual annotation and qualitative data analysis software (*NVivo*), which enabled the systematic organization of statements under thematic nodes such as *perceptions of innovation*, *energy efficiency*, *bureaucratic constraints*, *technological experimentation*, and *collaboration networks*.

c. National-Level Analysis

Each national research team conducted a within-case analysis, synthesizing the results of their interviews in relation to the broader national context of agricultural modernization. This stage involved the identification of key themes, illustrative quotations, and interpretative insights reflecting local specificities in farm structure, policy environment, and innovation culture. The outputs were presented as national reports, structured according to a harmonized template to facilitate later comparison.

d. Cross-National Comparison

The Italian research team coordinated the cross-national synthesis, applying a comparative framework aimed at identifying both converging trends (shared perceptions, common challenges, recurring strategies) and diverging trajectories (institutional asymmetries, scale-dependent innovation logics, and regionalized adaptation processes). This comparative procedure was guided by the principles of *analytical triangulation* and *epistemic coherence*, ensuring that interpretations remained grounded in empirical evidence while allowing conceptual generalization.

The comparative matrix developed through this process included dimensions such as:

- Epistemic orientation toward innovation
- Scale and institutional positioning
- Agrivoltaics awareness and adoption logic
- Regulatory and policy environment
- Generational perspectives and knowledge exchange

Synthesis and Interpretation

The final interpretative phase integrated the findings into a transnational framework of agricultural modernization. This synthesis captured how innovation processes are shaped by combinations of technical rationality, economic pragmatism, and institutional adaptation. The results were expressed through thematic tables,

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comparative charts, and narrative syntheses illustrating how different farming systems and governance structures influence the acceptance and operationalization of agrivoltaics technologies.

Through this multi-stage analysis, the study ensured both depth and comparability: depth, through close engagement with qualitative material and contextual insight; and comparability, through the consistent use of shared analytical dimensions across all five national interviews corpora.

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ANALYTICAL REPORT OF THE INTERVIEWS IN GREECE

General Overview

Within the REGACE project framework, ten in-depth qualitative interviews were conducted with Greek agricultural producers, cooperative representatives, and agronomists to investigate the epistemic and socio-technical dimensions of innovation in agriculture. The empirical corpus contributes to the project's comparative exploration of how agrivoltaics technologies are perceived, evaluated, and potentially integrated by end users across European contexts. The Greek case provides a particularly rich field for analyzing how technological imaginaries intersect with economies, energy dependencies, and agrarian traditions.

The interviews were undertaken between June and July 2023 across multiple agro-ecological zones—Attica, Thessaly, Pelion, and Central Greece—covering a representative range of production systems: from small-scale family farms and multifunctional agro-touristic enterprises to advanced greenhouses and cooperatively managed estates. This heterogeneity was methodologically deliberate, enabling the analysis to capture diverse epistemic orientations and institutional configurations shaping innovation practices.

The Greek research team, trained during the 2023 Spring School, adopted a shared semi-structured protocol aimed at eliciting reflective narratives rather than mere opinions, always sticking to the general interview pattern developed for all the five partners of the Project. Through these narratives, producers articulated how they understand technological change, interpret risk, and reconcile innovation with ecological and moral imperatives. Transcription and translation followed a double-verification process ensuring semantic precision and comparability across the REGACE national datasets. All identifiers were removed in accordance with the project's ethical standards. The presentation of the socio-demographic features of the interviewees is presented in Table 3.

Interviewee	Age	Gender	Location	Cultivation	Greenhouse
Int. 1	>65	F	Attica	Tropical fruits, vegetables, olives	Yes
Int. 2	35–65	M	Thessaly	Apricots, peaches, almonds	No
Int. 3	<35	M	Thessaly	Almonds, permaculture	No
Int. 4	>65	F	Larisa	Cotton, legumes, aromatic plants	No
Int. 5	35–65	M	Magnisia	Tomatoes, cucumbers	Yes
Int. 6	35–65	M	Pelion	Gardenias	Yes
Int. 7	<35	M	Pelion	Beekeeping, olives	No
Int. 8	35–65	M	Pelion	Ornamentals	Yes
Int. 9	<35	M	Agia, Thessaly	Apples, cherries	No
Int. 10	35–65	M	Central Greece	Mixed horticulture	Yes

Table 3 Socio-professional characteristics of the Greek interviewees

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Despite their structural and generational heterogeneity, all participants display a high degree of experiential literacy in production and energy management. This cumulative reservoir of embodied expertise functions as an epistemic infrastructure, mediating the translation of emerging technologies, most notably agrivoltaics—from abstract innovation into contextually legitimate and operationally actionable practice.

Tendencies Emerging from the Interviews in the Greek Context

The Greek corpus of ten interviews reveals a dynamic and multilayered configuration of pragmatic adaptation, empirical reasoning, and operational negotiation. Innovation is not conceived as a linear trajectory of technological substitution but as a situated process of deliberation, embedded in practical experience and local adaptation. Producers consistently describe modernization as a conditional necessity—an imperative driven by mounting energy dependency, climatic volatility, and demographic decline—yet one that must remain compatible with the material conditions and rhythms of agricultural practice. As one Attican farmer observed, *"Technology is very good, if it is used the way it is supposed to. Because this is not always the case"* (Interview 1). Such statements reveal a cautious but proactive attitude: innovation is welcomed when it complements existing practices and proves its reliability in real-world conditions.

A first analytical finding concerns the empirical rationalization of innovation, a theme that cuts across generational and structural lines. Senior producers, such as those in Interview 1 and Interview 4, emphasize experience-based learning and the calibration of new technologies to established cultivation logics. Their discourse distinguishes between technologies that enhance control and efficiency and those perceived as intrusive or disproportionate. In contrast, younger producers, including Interview 9 and Interview 7, express a more entrepreneurial outlook, linking modernization to digitalization, data monitoring, and diversification. As one younger greenhouse producer stated, *"I couldn't do it without drones and smart systems; they save time and make monitoring more precise"* (Interview 10). Despite differences in emphasis, both generations converge on the principle that technological change must demonstrate empirical efficacy and economic coherence before being integrated into daily operations.

A second major theme emerging from the corpus is energetic pragmatism, which operates simultaneously as a material constraint and a strategic orientation. High energy costs, infrastructure fragility, and fossil dependency are universally acknowledged as structural pressures that influence innovation priorities. The near-universal interest in renewable energy—ranging from biomass and rooftop photovoltaics to cooperative initiatives—reveals not ideological enthusiasm but a pragmatic search for autonomy and cost control. As the head of a cooperative in Thessaly explained, *"Better choices for photovoltaics would be barren hillsides, rooftops, or water canals—places that do not affect cultivable land. Fertile soil must remain for food"* (Interview 2). Such

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perspectives illustrate a spatially and economically rational approach to energy transition, where technological integration must not compromise agricultural productivity.

Agrivoltaics, introduced during the interviews as a conceptual and technical prospect, elicited a consistent tone of cautious optimism. Farmers recognized its potential for dual land use—simultaneous energy and crop production—but insisted on the need for concrete validation before adoption. A young permaculture farmer articulated this position clearly: *"If used correctly, agrivoltaics can do less harm than simple photovoltaics. But we must see real results first"* (Interview 3). For more technologically advanced producers, such as those in Interview 6, agrivoltaics represents a logical extension of precision horticulture—a system that could synchronize crop optimization with renewable energy generation. For others, particularly among small-scale operators, the technology remains an object of observation rather than immediate adoption, pending evidence on light diffusion, yield stability, and financial viability.

A scheme of the trends emerging from the ten interviews is presented in Table 4.

Analytical dimension	**Empirical tendencies**	**Interpretative pattern**
Innovation and moral economy	Innovation linked to moral and ecological values; accepted when seen as responsible and balanced.	Innovation as a search for balance between efficiency and care for the environment.
Energy transition and autonomy	Renewable energy is used mainly to reduce costs and increase independence.	Sustainability is understood as practical autonomy, not ideology.
Agrivoltaics perception	Interest combined with caution; accepted if it proves reliable and does not reduce productivity.	Innovation is viewed as a gradual process of testing and learning.
Generational dynamics	Younger farmers experiment more; older ones focus on stability and experience.	Dialogue between generations keeps changing steady and grounded.

Table 4 Analytical synthesis of emerging tendencies in the Greek corpus

The Greek interviews therefore depict a measured and reflective model of modernization, grounded in observation, empirical validation, and gradual adaptation. Innovation is neither uncritically embraced nor ideologically resisted but advances through incremental experimentation and collective learning. Across the corpus, producers associate new technologies with efficiency, cost-effectiveness, and environmental compatibility. Adoption depends on demonstrable reliability and integration within existing agro-ecological and economic frameworks. Energy transition, in this light, is valued primarily for its capacity to reduce dependency and enhance resilience, while agrivoltaics exemplifies a broader culture of testing before scaling.

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Finally, generational dynamics introduce an important mediating layer. Younger producers act as vectors of diversification and experimentation, while older farmers safeguard continuity and operational stability. Their interaction fosters a balanced modernization process, where change is continuous yet controlled, innovative yet rooted in practice. As one participant summarized, *"We learn from each other; the older ones trust results, the younger ones try new things, and together we move forward"* (Interview 7).

The tendencies emerging from these in-depth interviews describe Greek agriculture as evolving through incremental, evidence-based adaptation, where innovation is validated through performance, adjusted to context, and disseminated through cooperation and shared experience.

Converging and Diverging Tendencies Emerging from the Interviews

A comparative analysis of the Greek interviews reveals a balance between shared ways of thinking and structural differences within the sector. Farmers and producers operate within a shared understanding of innovation that is rooted in observation, experience and agronomic reasoning. They evaluate new technologies across regions and production types through direct engagement with land, light, and crops, ensuring that every change remains consistent with practical knowledge and ecological logic. As one greenhouse operator explained, 'You cannot apply technology blindly. You need to see what impact it has on your plants and land before deciding whether to keep it" (Interview 6). This shared way of reasoning fosters a sense of cohesion, connecting quite different farming realities through a collective process of observation, testing, and adjustment.

However, differences arise from the institutional and economic context in which producers work. Cooperatives and research-linked enterprises function as experimental hubs, enabling them to test and adopt new technologies more quickly. In contrast, smaller or independent farmers tend to adopt new technologies more gradually, favouring reliability and low risk. These different speeds complement each other, forming a distributed innovation system in which experimentation, observation and imitation occur in parallel. In this way, innovation spreads less through formal programmes and more through everyday learning and local exchange. "If something works for one of us, it will soon reach everyone else. We just need to see it in practice first,' explained a farmer from Thessaly (Interview 2), capturing the informal and adaptive diffusion of innovation across the sector.

Light for crops plays a central role in this shared mindset. It is a physical condition of production and a measure of the balance between technology and nature. For most producers, innovation should not obscure or disrupt the natural equilibrium but rather make it more visible and manageable. Light thus becomes a practical indicator of

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technological compatibility, helping farmers to evaluate the suitability of agrivoltaics installations and greenhouse systems.

Institutional differences influence how this balance is achieved. Cooperative structures, which are often better connected and funded, provide spaces for practical experimentation where new ideas can be assessed and adapted. By contrast, smaller family farms follow a logic of careful pragmatism, focusing on continuity and minimising risks. Nevertheless, both groups contribute to an overall culture of innovation based on mutual observation and informal knowledge exchange.

In a trans-generational perspective, modernisation appears as a dialogue rather than a divide. Younger farmers bring curiosity, digital tools and an entrepreneurial spirit, while older farmers contribute experience, restraint and a long-term vision. Together, they strike a balance that ensures innovation remains reflective and adaptive rather than disruptive. Overall, the picture is one of gradual modernisation — steady, cautious, and rooted in practical reasoning — where change is continuously adjusted to fit the social and ecological realities of Greek agriculture.

A synthesis of the converging and diverging trends is presented in Table 5.

Analytical dimension	**Converging themes**	**Diverging themes**	**Interpretative analysis**
Epistemic orientation	Consensus on empirical validation and light as central heuristic.	Differences in sophistication and technological access.	Shared epistemic realism anchors innovation in agronomic observation.
Scale and institutional context	Universal recognition of innovation as structural necessity.	Larger enterprises pilot; smaller farms consolidate.	A polycentric innovation regime balancing experimentation and reliability.
Agrivoltaics adoption logic	Broad acceptance of dual-use land rationale.	Differentiated readiness tied to risk exposure and funding access.	Agrivoltaics as empirical testbed for reflective modernization.
Generational outlook	Common belief in modernization as continuity, not rupture.	Younger actors link it to entrepreneurship; elders to stewardship.	Temporal reflexivity harmonizes transformation with moral accountability.

Table 5 Comparative table of converging and diverging tendencies in the Greek corpus.

The Greek interviews present a model of modernisation based on practical experience, empirical discipline, and adaptive reasoning. For the interviewed producers, technological progress is not viewed as a linear process of substitution or acceleration, but rather as an ongoing cycle of experimentation, refinement, and validation. Change occurs through the gradual calibration of knowledge, practice, and context. This results in a pragmatic, experience-based approach to innovation, whereby new technologies are only adopted when they demonstrate reliability and compatibility with local

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conditions, as well as offering tangible benefits for production and resource management.

Within this framework, agrivoltaics emerges as a technological opportunity and an area of experimentation. It provides a practical test of the feasibility of combining energy production with agricultural activities, evaluating whether this can be achieved without compromising productivity or ecological balance. Farmers view agrivoltaics as more than just an energy solution; they see it as a means of reconsidering how agriculture interacts with natural resources and spatial constraints. This perspective turns agrivoltaics into a collaborative learning environment, where producers, researchers and policymakers work together to evaluate results, handle uncertainty, and foster confidence in technological innovation.

Greek agriculture, as reflected in these interviews, embodies a gradual and adaptive mode of sustainable transformation. It evolves through reflection rather than rupture, guided less by external pressure or technological momentum than by internal logics of balance, verification, and continuity. Progress is understood as a shared endeavour linking scientific insight with local expertise and integrating innovation into existing social and environmental frameworks. In this sense, modernisation is co-produced rather than imposed, advancing through collective experimentation and a sustained commitment to contextual adaptation.

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ANALYTICAL REPORT OF THE INTERVIEWS IN AUSTRIA

General overview

In-depth interviews with prospective end users of innovative technology represent one of the most effective qualitative tools for deepening the understanding of their expectations, experiences, and perceived scenarios of adoption. Within the REGACE project, this methodological choice served to capture how future end users—farmers, horticultural producers, and enterprise managers—interpret innovation processes, evaluate risks and benefits, and envisage the possible introduction of agrivoltaics systems in their operational contexts. By privileging the experiential and reflective dimension of actors directly involved in agricultural production, the interviews allowed the research team to trace how technological imaginaries intersect with professional practices, economic rationalities, and ecological ethics.

The interviews were conducted by the Austrian research team trained during the 2023 Spring School, where a shared methodological framework and a common semi-structured interview protocol were elaborated collectively. The Spring School provided both theoretical and practical training, enabling the team to harmonize criteria for case selection, question sequencing, and documentation standards. Each team member participated in the identification and recruitment of interviewees, the realization of the field interviews, and the subsequent phases of transcription and translation. This participatory approach ensured a consistent understanding of the research objectives and enhanced the reliability and internal coherence of the collected material.

All eight interviews were conducted in 2023/24 in accordance with a standardized qualitative framework designed to ensure comparability across cases and methodological rigor in data collection. Interviews were recorded, fully transcribed in the original language, and then carefully translated into English through a double-checking process that preserved the semantic nuances of the interviewees' discourse. To enable a collective and ethically sound analysis, all identifying elements were subsequently removed or replaced, resulting in an anonymized corpus suitable for cross-national comparison within the broader REGACE project.

Table 6 synthesizes key contextual and attitudinal information derived from eight in-depth interviews conducted with Austrian horticultural producers within the framework of the REGACE project.

The table below provides a concise overview of the main socio-professional characteristics of the interviewees—age, gender, role, cultivation type, and greenhouse configuration. As a result of the selection of the interviewees, the participants differ in location, scale, specialization, while all already experimented with greenhouses in their farming experience.

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Interviewee	Age	Gender	Role	Location	Cultivation	Greenhouse
Int. 1	38	M	Owner, farming enterprise	Vienna	Ornamental plants	Yes
Int. 2	37	F	Managing Director, agricultural enterprise	Hartl, Styria	Tomatoes, cucumbers, peppers, fruit trees	Yes
Int. 3	30	M	Manager, vegetable producer	Vienna (22nd district)	Tomatoes, cucumbers	Yes
Int. 4	33	M	CEO	Vienna	Mixed vegetables, mushrooms	Yes
Int. 5	65	M	Former owner, nursery	Großweikersdorf	Vegetables and ornamentals	Yes
Int. 6	32	M	Managing Director, nursery	Vienna	Oxheart tomatoes	Yes
Int. 7	56	M	Director, training nursery	Hollabrunn	Vegetables and ornamentals	Yes (unheated foil)
Int. 8	44	M	Managing Director, vegetable enterprise	Münchendorf	Tomatoes, cucumbers	Yes

Table 6 Synthesis of the socio-economic data of the interviewees in Austria

Table 6 provides a synthesized overview of the principal socio-professional characteristics of the 8 interviewed producers, including their age, gender, professional role, cultivation typology, and greenhouse configuration. The composition of the sample reflects deliberate heterogeneity, encompassing enterprises that differ in geographic location, organizational scale, production specialization, and degree of technological integration. This diversity was not incidental but instrumental to the research design, which aimed to capture a broad spectrum of perspectives within the Austrian horticultural sector. Despite these differences, all interviewees share a concrete familiarity with greenhouse-based production systems, whether in technologically advanced facilities or in more traditional, partially automated structures. Their collective experience with protected cultivation provides a robust empirical basis for examining how innovation, and particularly the potential integration of agrivoltaics technologies, is interpreted and operationalized across distinct organizational and regional contexts.

Table 7 presents a synthesized analysis of the interviewees' positions regarding the broader dynamics of technological development in agriculture (Column 1) and, more specifically, their assessments of agrivoltaics systems (Column 2). Prior to addressing the latter theme, interviewers provided all participants with a standardized briefing based on a shared reference sheet, which outlined the distinctive technical and operational characteristics of the agrivoltaics model promoted within the REGACE project. This methodological step ensured that the discussion proceeded from a common conceptual and informational baseline, thereby enhancing the internal

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comparability of responses and the analytical coherence of the resulting corpus. By aligning interviewees' understanding of the technological framework, the procedure enabled a more rigorous interpretation of their perceptions, expectations, and reservations concerning the prospective integration of agrivoltaics solutions within contemporary agricultural practice.

Interviewee	View on Innovation	Position on Agrivoltaics
Int. 1	Strongly positive; seeks efficiency and modernization	Positive if dual use without light loss; light in winter crucial
Int. 2	Essential for climate adaptation and efficiency	Interested but skeptical; feasible only if high-light transmission maintained
Int. 3	Very open; innovation vital for competitiveness	Opposed to PV on farmland; possible only if light unaffected
Int. 4	Supports innovation and resource cycles	Skeptical; prefers hybrid energy systems
Int. 5	Cautious; favors gradual innovation	Supports conceptually; notes structural and ethical concerns
Int. 6	Highly positive and experimental	Willing to evaluate; concerned about light loss and snow load
Int. 7	Open but cost-sensitive; favors efficiency	Positive in principle; constrained by cost and storage
Int. 8	Strongly pro-innovation; embraces modernization	Enthusiastic if light not reduced; supports testing

Table 7 Interviewees' positions on technological innovation and agrivoltaics adoption

The data presented in Table 7 reveal a broadly convergent orientation among the 8 Austrian farming producers, for whom technological innovation constitutes a structural imperative within contemporary agricultural development. Across the in-depth interviews' perspective, modernization is articulated through a pragmatic and instrumental rationality, grounded in notions of efficiency, competitiveness, and adaptive resilience to climatic and market variability. Yet, this openness to technological advancement is tempered by a pronounced epistemological caution: innovation is accepted as far as it can demonstrate empirical reliability, economic feasibility, and compatibility with established farming practices. With respect to agrivoltaics, positions oscillate between conditional endorsement and prudent skepticism, contingent upon assurances regarding light transmission, structural soundness, and long-term cost-effectiveness. Taken together, these findings delineate a model of reflective modernization in which technological progress is neither uncritically celebrated nor resisted, but continuously negotiated through the interplay of scientific evidence, professional expertise, and ecological responsibility.

Tendencies emerging from the interviews in the Austrian contexts

A first and overarching finding concerns the place of innovation within the cultural economy of Austrian farming. Across all interviews, technological modernization is described not as a discretionary option but as a necessary adaptation to shifting climatic, economic, and demographic conditions. Producers across scales identify innovation as the decisive factor that determines long-term survival in a sector increasingly exposed to global competition, volatile energy markets, and chronic labour scarcity. Yet rather

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than subscribing to an ideology of unrestrained progress, Austrian farmers articulate a distinctly reflective approach: innovation is acceptable only when it aligns with agronomic rationality and remains accountable to practice. As one grower noted, *"I am always very open to new technologies—interested to promote, use, and simply test them"* (Interview 5). Another added, *"New ideas are good, but they must fit into the production rhythm; you cannot risk a whole season for an experiment"* (Interview 4). Together, these views illustrate a pragmatic culture of technological realism in which innovation must demonstrate concrete improvements in efficiency or resilience before becoming routine.

The second key finding relates to the energy transition, widely recognised as both a strategic necessity and an operational opportunity. Renewable energy is viewed not as symbolic compliance with environmental goals but as a practical means to stabilise costs and strengthen autonomy. Many interviewees already rely on biomass heating, thermal water circuits, or rooftop photovoltaics. As one producer explained, *"Our heating system is completely based on renewable energy—we use hot thermal water, not fossil fuels"* (Interview 2). The general orientation is pragmatic: technologies are assessed through maintenance feasibility, reliability, and amortisation rather than ideology. Austrian farmers show a high level of technological literacy, aware that storage limits and climatic variability constrain full fossil substitution. Hence the preferred path is hybridisation, combining renewable sources to ensure year-round complementarity.

Within this framework, agrivoltaics represents both a promise and a test. Farmers express curiosity toward dual-use land systems capable of reconciling energy and food production, yet their enthusiasm is tempered by clear technical reservations. Light transmission stands out as the decisive parameter. *"Every shadow creates problems in spring; we need all the light we can get,"* stated one greenhouse operator (Interview 3). Agrivoltaics can therefore be accepted only if empirical trials confirm that yields and quality remain equivalent to conventional systems. Producers in mountainous regions also mention snow load, cleaning frequency, and cabling access as barriers. Their adoption logic follows a sequential pattern—pilot first, validate through data, and scale only once agronomic parity is proven—transforming innovation from a leap of faith into calibrated experimentation.

A further insight concerns the differentiated structure of innovation capacity across Austrian farming. Larger enterprises, often connected to research institutions, act as experimental nodes able to absorb financial and technical risks. Smaller holdings progress through incremental optimisation, focusing on precision irrigation, efficient heating, or improved logistics. Social and cooperative initiatives add another layer, interpreting innovation in social or educational terms rather than as mere technological expansion. This configuration forms a distributed innovation ecosystem where progress advances through asynchronous yet interconnected diffusion.

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Finally, the Austrian interviews underline a pervasive sense of responsibility and continuity. Farmers link economic viability with environmental stability and the endurance of local livelihoods. As one respondent concluded, *"You have to see it realistically—some crops will work, others will not; winter light is our real limit"* (Interview 4). Such pragmatism summarises the Austrian approach to modernization: change proceeds through verification, cooperation, and incremental adjustment, ensuring that innovation reinforces rather than disrupts the long-term equilibrium of agricultural production.

Table 8 summarises all the emerging trends.

Analytical Dimension	**Empirical Tendencies**	**Interpretative Patterns**
Innovation as structural adaptation	Innovation is perceived not as an optional choice but as a structural response to climatic, economic, and demographic pressures. Both small- and large-scale producers identify technological modernization as essential to long-term viability. Younger farmers associate it with experimentation and sustainability, while older producers emphasize the continuity of craft and experiential knowledge.	The Austrian farming context embodies technological realism: innovation acquires legitimacy only when it produces verifiable improvements in efficiency, quality, or resilience. Modernization is approached reflectively, aligning technical progress with moral and agronomic rationality.
Energy transition and technological pragmatism	Renewable energy is widely recognized as both an ethical commitment and a strategic necessity. Biomass heating, thermal water circuits, and rooftop photovoltaics are already integrated, though energy storage and seasonal intermittency remain constraints. Farmers favor hybrid energy configurations to ensure operational stability.	The energy transition is interpreted through a lens of pragmatic optimization rather than ideological compliance. Austrian producers display a high degree of technological literacy, conceptualizing innovation within a systemic understanding of energy, climatic dynamics, and biological productivity.
Agrivoltaics as experimental frontier	Agrivoltaics elicits strong curiosity but also critical reservations concerning light transmission, snow load, and maintenance logistics. Acceptance depends on empirical validation showing	Agrivoltaics functions as both a promise and a test case for reflective modernization. Adoption follows a sequential and data-driven logic—pilot, monitor, and scale—transforming innovation into a controlled process of empirical

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	equal or improved yields relative to conventional systems.	verification rather than speculative experimentation.

Table 8 Emerging patterns from the in-depth interviews

Converging and diverging tendencies emerging from the Austrian interviews

Comparative analysis of the interviews reveals both strong convergences and notable divergences. Among the common elements, the most fundamental is the primacy of light. Light is not merely a physical parameter but the organising principle of production and the cognitive boundary within which innovation must operate. Every respondent, irrespective of scale or specialisation, refers to light as the determinant variable against which all technological change must be measured. As one producer explained, *"Our whole system depends on light. If you take ten percent away, you lose the balance of the entire process"* (Interview 3). This shared epistemology ensures that experimentation never becomes speculative. Photovoltaic installations, heating systems, or automation devices are evaluated according to their impact on photosynthetic performance. Such collective discipline transforms innovation into a continuous exercise in calibration rather than disruption.

Another unifying feature is the integration of moral and operational reasoning. The energy transition is simultaneously narrated as a matter of responsibility and managerial foresight. Producers link renewable energy to care for resources and to autonomy in energy supply, while also framing it as a tool for cost control and long-term stability. As one farm manager observed, *"The biggest motivation for renewables is independence—if prices rise or gas stops, we can still heat and work"* (Interview 2). This pragmatic orientation allows sustainability to acquire tangible economic value: it becomes measurable, actionable, and legitimate within existing production systems. The convergence between ecological and economic rationalities constitutes one of the defining strengths of the Austrian innovation model.

Divergences, by contrast, arise primarily from differences in scale, generational outlook, and institutional embedding. Large enterprises interpret innovation as a strategic investment horizon, often engaging in collaborations with universities or pilot consortia. Smaller and family-run businesses focus on immediate operational reliability. Their scepticism toward complex technologies is not rooted in opposition but in the prudence born of thin margins and limited risk tolerance. *"For a small business like ours, experiments must be safe. If a mistake costs one harvest, we're finished,"* explained one grower from Lower Austria (Interview 4). This divergence generates a two-speed innovation regime in which experimentation and consolidation coexist. Rather than fragmenting the sector, this dynamic equilibrium allows

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knowledge to circulate adaptively through observation, imitation, and informal mentoring.

The agrivoltaics question crystallises this pluralism. Some producers—typically those integrated into research or funding networks—are willing to test agrivoltaics configurations on partial surfaces. Others maintain a waiting posture, demanding evidence on light transmission and crop performance before investing. *"It's interesting, but I will wait until someone proves that the yields stay the same,"* stated a greenhouse operator from Styria (Interview 5). The contrast does not divide the sector but reflects differentiated exposure to uncertainty. A culture of verification unites these positions: adoption is conditional upon proof. The shared criterion remains empirical validation rather than ideological allegiance.

Generational differences introduce further nuance. Younger managers tend to present innovation as cultural transformation, merging ecological awareness with entrepreneurial drive. Senior producers articulate modernisation as stewardship—an obligation to preserve the technical integrity of agricultural practice. Their caution toward automation or artificial intelligence reflects not resistance but the desire to maintain practical control over production processes. Intergenerational dialogue thus functions as a mechanism of balance: enthusiasm and experience negotiate the rhythm of change, ensuring that innovation remains situated within the long temporalities of agriculture. Moreover, institutional positioning adds another layer of differentiation. Producers involved in cooperative networks or EU-funded programmes express higher trust in governance mechanisms and show greater readiness to co-invest in experimental systems. Independent operators are more sceptical toward bureaucracy and often regard regulatory procedures as misaligned with agronomic temporalities. This divergence underscores the necessity of designing policy instruments that are temporally synchronised with production cycles. Innovation policy, the interviews suggest, is credible only when it resonates with the rhythms of cultivation and the temporalities of yield. The main converging and diverging trends in the interviews are presented in Table 9.

Analytical dimension	**Converging themes**	**Diverging themes**	**Interpretative analysis**
1. Epistemic core: the primacy of lighting	All producers identify light as the fundamental variable structuring agricultural production and innovation. Light is perceived not merely as a physical input but as the epistemic boundary within which experimentation must occur.	No substantial conceptual divergence: only small-scale variations linked to greenhouse type, crop specificity, or regional exposure.	Light functions as a shared epistemic constraint shaping technological legitimacy. Innovation is conceived as a practice of calibration rather than disruption, reinforcing an ethos of empirical precision.

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2. Scale and institutional position	General agreement that innovation is essential for the long-term viability of farming enterprises.	Larger, research-oriented farms pursue strategic experimentation and pilot collaborations; smaller producers prioritize reliability, incremental change, and cost containment.	Austrian agriculture operates within a two-speed innovation regime, balancing experimentation and consolidation while maintaining cross-scalar knowledge diffusion.
3. Attitudes toward agrivoltaics	Broad curiosity and conceptual acceptance of agrivoltaics as a dual-use solution that aligns food and energy production. All participants emphasize the need for empirical validation before large-scale implementation.	Larger or institutionally connected enterprises show greater readiness to test agrivoltaics models; smaller and independent farmers adopt a cautious 'wait-and-see' stance.	Agrivoltaics acts as a laboratory of reflective modernization: adoption is conditional, data-driven, and dependent on proven agronomic equivalence.
4. Generational outlook	Consensus that innovation is indispensable for maintaining competitiveness and environmental stewardship.	Younger farmers frame innovation as cultural transformation and ecological entrepreneurship; older farmers stress stewardship, continuity, and ethical prudence.	Intergenerational interaction produces temporal reflexivity: enthusiasm and experience coalesce, ensuring that innovation remains socially and morally grounded.
5. Institutional trust and policy alignment	Shared recognition that institutional support mechanisms play a decisive role in enabling innovation.	Producers involved in EU-funded networks express higher trust and engagement, while independent actors display skepticism toward bureaucratic inefficiency and misaligned timelines.	Divergent perceptions underscore the need for temporal and procedural coherence between policy instruments and agronomic cycles to ensure the credibility of innovation governance.

Table 9 Comparative analysis of converging and diverging themes in the Austrian farmers interviews.

Table 9 underscores the coexistence of strong epistemic cohesion and differentiated innovation trajectories within Austrian agriculture. Across all analytical dimensions, producers operate within a shared pragmatic framework structured around three core principles: the centrality of light as a production constant, the functional evaluation of technology through measurable outcomes, and the reliance on empirical validation as the benchmark of credibility. Divergences arise along the axes of enterprise scale, generational perspective, and institutional capacity, generating a multi-speed innovation landscape where experimentation and consolidation reinforce each other.

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Agrivoltaics exemplifies this configuration, functioning as a regulated domain of reflective modernization in which technological adoption remains contingent on verifiable performance and calibrated to operational risk.

The Austrian interviews show a negotiated modernisation system: a gradual, evidence-driven change that advances through coordination rather than disruption. Progress is not achieved by accelerating technological substitution, but by aligning innovation with the structural realities of production, labour and the environment. In this sense, innovation becomes a disciplined practice of adaptation: a process of balancing technical optimisation with contextual feasibility and aligning new systems with the cumulative intelligence of farming practice. The Austrian case therefore represents a unique model of sustainable modernisation, integrating technical precision, empirical governance and contextual accountability to redefine innovation as a collective, continuously self-correcting endeavour.

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ANALYTICAL REPORT OF THE INTERVIEWS IN ISRAEL

General Overview

Within the Israeli case study, ten in-depth interviews—comprising five Arab and five Jewish farmers, in order to capture different perspectives and attitudes toward innovation and sustainability—were conducted with agricultural producers and farm managers across a range of production systems, geographical areas, and organizational scales in the complex farming context of Israel. The objective was to examine how these different actors conceptualize innovation, assess its risks and benefits, and envisage the potential integration of agrivoltaics systems in their production environments.

All interviews were conducted by the Israeli research team following the common methodological framework established during the REGACE 2023 Spring School. The team adopted the shared semi-structured interview protocol used across all partner countries, ensuring cross-national comparability and coherence in question sequencing and analytical focus. Interviews were conducted at the beginning of the second semester of 2023 across diverse agro-climatic zones—from the northern Kibbutzim and Arab villages of Galilee to the arid southern Moshavim—covering a wide variety of crops, including vegetables, orchards, and greenhouse cultivation. Each interview was video and audio recorded, fully transcribed, and translated into English through a double-checking process to guarantee semantic fidelity from both languages. All the subjects identifying details were removed to comply with the project's anonymity standards.

Table 10 below summarizes the socio-professional characteristics of the interviewees, reflecting the diversity of the Israeli agricultural landscape. Participants differ in scale, production type, and technological advancement, yet all share substantial direct experience in cultivation and an operational awareness of renewable energy solutions, particularly solar systems already implemented in the country's agricultural infrastructure.

Interviewee	Age	Gender	Location / Region	Cultivation Type	Greenhouse / System
Int. 1 A	31	M	Undisclosed	Bell peppers	Yes
Int. 1 J	45	M	Undisclosed	Peppers, chili peppers	Yes
Int. 2 A	52	M	Jish (North)	Apples, peaches, cherries	No
Int. 2 J	77	F	Undisclosed	Tomatoes, cucumbers, strawberries	Yes
Int. 3 A	50	F	Jatt (Center)	Tomatoes, cucumbers, zucchini, peppers, eggplant	Yes
Int. 3 J	70	M	Yated, Be'er Sheva (South)	Vegetables, flowers	Yes

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Int. 4 A	60s	M	Kafr Qara (North)	Cucumbers	Yes
Int. 4 J	64	M	Amiauz (South)	Tomatoes, peppers, eggplants, broccoli	Yes
Int. 5 A	65	M	Undisclosed	Greenhouse crops	Yes
Int. 5 J	52	M	Kibbutz Amir (North)	Orchards (grapefruit, plums, kiwi)	No

Table 10 Socio-professional characteristics of the Israeli interviewees

The Israeli sample displays a balanced distribution between Arab and Jewish farmers (five and five, respectively), ensuring the inclusion of diverse cultural, institutional, and territorial perspectives on agricultural innovation. The participants represent a wide age range—from early thirties to late seventies—thus allowing intergenerational comparisons between younger, more entrepreneurial actors and older producers embodying continuity and experiential knowledge. Gender representation is limited, with only two women included in the corpus, reflecting the still male-dominated structure of agricultural labor and ownership in Israel.

Geographically, the interviewees span from the northern regions (Galilee and Upper Jordan Valley) to the southern Negev area, covering both cooperative systems (Kibbutzim and Moshavim) and privately managed Arab villages. This spatial distribution captures the contrast between technologically advanced collective farms and smaller, family-based holdings with more constrained access to capital and innovative infrastructures.

In terms of production typologies, the sample is dominated by greenhouse cultivation—present in eight of the ten cases—indicating the centrality of controlled-environment agriculture in Israel's adaptive response to climatic and water constraints. The coexistence of open-field orchards, vegetable production, and mixed crops highlights a diversified yet technologically intensive farming landscape. Overall, the table reflects a heterogeneous but epistemically coherent group of practitioners whose practical engagement with greenhouse technologies and solar infrastructures provides a robust ground for analyzing the prospective integration of agrivoltaics systems.

Tendencies Emerging from the Interviews in the Israeli Context

A first and overarching tendency emerging from the Israeli corpus of interviews concerns the normalization of technological innovation as an intrinsic and unavoidable dimension of farming. Across all interviews, innovation appears not as an external disruption but as a constitutive element of everyday practice—woven into the routines, expectations, and professional identities of farmers. The respondents consistently describe technology as both a necessity for competitiveness and an inherent feature of Israel's agrarian modernity, shaped by decades of state-led experimentation, collective learning, and adaptation to ecological scarcity. As one farmer explained, *"Technology in agriculture helps us use it for everything—energy, robotics, photography—everything that makes our work easier and more efficient"* (Interview 1_j). Another

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producer, reflecting on his long experience, emphasized, *"We are in the era of speed and innovation. Before there was manpower; now it is fully technologically operated. I am in favor of constant innovation because it helps people advance"* (Interview 4_a). Yet this normalization is accompanied by structural caution: *"Technology is present in everything, but it is also expensive, and this cost is difficult for the farmer to bear"* (Interview 3_a). Together, these narratives illustrate a pragmatic ethos in which technological change is accepted as a structural condition of survival and progress yet continuously moderated by economic and contextual feasibility.

Table 11 synthesizes the principal analytical dimensions emerging from the Israeli interviews, mapping the empirical tendencies and interpretative patterns that define the country's agrarian innovation landscape.

Analytical dimension	**Empirical tendencies**	**Interpretative patterns**
Technological innovation as structural imperative	Innovation is viewed as a necessary condition for competitiveness and adaptation; ambivalence regarding social effects of automation.	Technological realism: progress accepted as structural yet mediated by experience and ethical caution.
Energy transition and autonomy	Strong consensus on solar energy as practical and environmental necessity; challenges linked to cost and bureaucracy.	Energy transition conceived as pragmatic optimization rather than ideological commitment.
Agrivoltaics as conditional innovation	High interest paired with uncertainty; adoption contingent upon light transmission and empirical proof.	Agrivoltaics functions as a testbed for reflective modernization: innovation must demonstrate equivalence before scaling.
Scale and institutional position	Kibbutzim and Moshavim function as innovation hubs; smallholders advance through cautious imitation.	A distributed innovation system where experimentation and consolidation coexist.
Generational outlook	Younger actors prioritize diversification and entrepreneurship; older producers value continuity and restraint.	Intergenerational complementarity ensures steady, evidence-based modernization.

Table 11 Analytical synthesis of emerging tendencies in the Israeli corpus of interviews

Table 11 distils how technological modernization, energy transition, and agrivoltaics experimentation intersect with institutional scale and generational dynamics, revealing a system characterized by pragmatic adaptation, empirical evaluation, and intergenerational balance. Taken together, these dimensions depict a field of continuous calibration, in which technological change is neither externally imposed nor ideologically framed but gradually domesticated through cycles of testing, adjustment, and mutual learning. The resulting innovation culture reflects a distinctly Israeli synthesis of technological optimism and operational realism—one that privileges experimentation while maintaining an acute awareness of resource limits and contextual constraints.

First, the technological innovation dimension reveals an epistemic orientation anchored in technological realism: farmers conceive innovation as an unavoidable requisite for

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competitiveness, environmental adaptation, and long-term resilience. The normalization of technology in daily practice—ranging from irrigation sensors and remote monitoring to mechanized harvesting—illustrates how experimentation has become embedded in professional identity. Yet this acceptance remains tightly calibrated by practical experience. As one respondent summarized this mindset succinctly: "If the machine can work better than people and save time, we take it—but only after we see that it really works in our conditions" (Interview 2_j). Innovation, therefore, does not replace the logic of experience but extends it, transforming technological progress into a continuous process of verification and adaptation. In this sense, modernization is domesticated within the lived rationalities of farming practice rather than driven by abstract modernization narratives or policy prescriptions.

Second, the energy transition and autonomy dimension consolidates this pragmatic ethos. Across the corpus, solar energy is almost universally regarded as a functional necessity—a cornerstone of resilience in a context of climatic stress, water scarcity, and energy dependency. Renewable infrastructures are conceived not as political statements but as strategic investments that guarantee autonomy and stability. As one kibbutz manager explained, "We produce energy mainly for our needs; it's not ideology—it's efficiency. The sun is our only stable resource" (Interview 3_j). This widespread consensus is, however, moderated by systemic obstacles such as bureaucratic delays, fragmented regulatory frameworks, and uneven access to subsidies. As another producer observed, "We can install panels, but the government procedures take months; meanwhile, production cannot wait" (Interview 4_j). Consequently, sustainability is reframed as operational optimization: a form of incremental adaptation that privileges economic rationality and reliability over visionary transformation. This incrementalism reflects a deeply ingrained techno-pragmatism, whereby energy autonomy is pursued through practical feasibility rather than ideological commitment.

Within this framework, agrivoltaics emerges as a paradigmatic instance of conditional innovation. Both Jewish and Arab farmers express high interest but persistent caution, underscoring the importance of empirical verification as a precondition for legitimacy. "If the crops stay the same, then it's worth trying; if not, we stop immediately," stated one farmer from the Negev (Interview 5_a). For many respondents, agrivoltaics functions less as a disruptive innovation than as a reflective experiment—a testbed for aligning technological opportunity with agronomic rationality. Adoption follows a sequential logic: small-scale trials, sensor-based monitoring, and progressive scaling only after measurable equivalence in yield and quality is established. This evidentiary culture exemplifies Israel's broader epistemic regime, in which innovation legitimacy depends on quantified performance and demonstrated resilience within site-specific ecological conditions.

The dimension of scale and institutional position further illustrates how Israel's farming system sustains innovation through asymmetrical yet complementary capacities. Kibbutzim and Moshavim operate as structured innovation hubs, hosting pilot projects

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and disseminating data through cooperative platforms and regional extension networks. These institutions act as stabilizing infrastructures that enable risk-sharing, collective learning, and rapid diffusion of validated technologies. Smallholders, particularly in Arab rural areas and peripheral zones, exhibit adaptive imitation, appropriating innovations once their agronomic and financial viability has been confirmed within larger cooperative systems. The result is a two-speed but mutually reinforcing innovation regime, where institutionalized experimentation and peripheral learning coexist within a single epistemic field. Rather than reproducing inequality, this asymmetry fosters a distributed innovation system that sustains coherence through observation, replication, and trust-based communication.

Finally, generational dynamics add a temporal dimension to this configuration. Younger farmers tend to frame modernization as entrepreneurship and diversification, integrating renewable energy, data analytics, and market-oriented experimentation into their production strategies. Older producers, by contrast, conceptualize innovation through the prism of continuity, viewing technology as a tool to preserve rather than transform established practices. As one senior farmer remarked, "We use new technologies, but we never let them replace our experience; they must follow our rhythm" (Interview 4_a). This intergenerational dialogue functions as a mechanism of epistemic equilibrium, where enthusiasm and prudence are continuously negotiated. The coexistence of exploratory and conservative attitudes ensures that technological change proceeds through reflection rather than rupture, maintaining the long temporalities that structure agricultural knowledge and community identity.

The Israeli corpus thus delineates a distinctive configuration of agrarian modernity in which innovation is institutionalized as a structural condition of existence. Farming appears not as a site of passive technological reception but as an active laboratory of adaptive modernization—anchored in empirical discipline, operational pragmatism, and intergenerational continuity. In this setting, technological progress unfolds as a relational process: negotiated among producers, institutions, and ecological realities, and continuously recalibrated to align efficiency with endurance.

Converging and Diverging Tendencies Emerging from the Interviews in Israel

A comparative synthesis of the Israeli interview corpus is essential in order to capture the interplay between convergent epistemic tendencies and the differentiated institutional and socio-economic conditions that shape innovation dynamics. By structuring the analysis around key dimensions—from epistemic orientation to the regulatory environment—the table reveals shared cognitive and normative frameworks underpinning Israel's agricultural modernisation. It also highlights variations linked to scale, institutional embeddedness and generational positioning. Thus, the table illustrates how attitudes towards innovation, energy transition and agrivoltaics experimentation are filtered through different material conditions and organisational

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contexts, providing a nuanced perspective on the co-production of similarity and difference in Israel's hybrid innovation landscape, as demonstrated in Table 12.

Analytical dimension	Converging themes	Diverging themes	Interpretative analysis
Epistemic orientation	Universal emphasis on empirical verification and light management as criteria for legitimacy.	Degree in technical knowledge and infrastructure access varies by scale.	Shared epistemic realism anchors innovation in measurable agronomic outcomes.
Scale and institutional context	Broad consensus on the necessity of technological modernization.	Kibbutzim and Moshavim pursue initiative-taking pilots; smallholders advance through cautious learning.	A two-speed innovative regime balanced by inter-scalar knowledge diffusion/transfer.
Attitudes toward agrivoltaics	Conceptually accepted as a dual-use solution aligning energy and agriculture.	Readiness tied to financial and regulatory capability.	Agrivoltaics acts as a laboratory of reflective modernization—conditional and data-driven.
Generational outlook	Common belief in modernization as continuity.	Younger actors link it to entrepreneurship; elders to preservation.	Intergenerational interaction produces temporal balance and continuity in innovation.
Regulatory environment	Shared recognition of bureaucratic obstacles as primary constraint.	Institutionalized farms navigate permitting more easily than smallholders.	Regulatory asymmetry shapes the pace but not the direction of innovation.

Table 12 Comparative synthesis of converging and diverging tendencies in the Israeli corpus of interviews.

The comparative synthesis presented in Table 12 explains how epistemic cohesion and structural differentiation can coexist within the Israeli farming sector. Despite clear differences in ownership, scale, institutional embedding and access to resources, the interviews collectively reveal a shared cognitive orientation towards empiricism and practical verification. This pervasive epistemic realism, grounded in the conviction that technological innovation attains legitimacy only through demonstrable farming efficacy, constitutes the principal axis of convergence across the corpus. As one experienced farmer explained, 'When you see that something works in the field — when it saves water or improves the harvest — then it becomes real innovation, not before' (Interview 2_j). This view exemplifies the centrality of verification and measurement as the epistemic anchors of Israeli agricultural modernisation.

Nevertheless, there is still heterogeneity in technical competence and infrastructural capacity. Technologically equipped kibbutzim and moshavim are well placed to initiate and monitor pilot schemes, whereas smaller, family-run farms, particularly those owned by Arab farmers, tend to advance through observation, selective imitation, and incremental adaptation. This stratified configuration results in a dual regime of leadership and emulation. Collective farms act as institutional laboratories for

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experimentation and diffusion, while smaller holdings engage in secondary innovation cycles once the feasibility of this approach has been demonstrated in resource-intensive contexts. Rather than reinforcing hierarchy, this dynamic interaction fosters reciprocal observation and the circulation of knowledge across different scales. As one Arab producer remarked in Interview 3_a, "We wait to see how it works in the kibbutz first; if the results are good, we adapt it to our conditions". Such statements illuminate how trust, observation and contextual learning constitute the informal infrastructure of technological diffusion in Israel's agricultural system.

Attitudes towards agrivoltaics provide a particularly revealing illustration of this systemic equilibrium. While the concept of dual land use, combining agricultural and energy functions, is widely accepted, the readiness to adopt such systems is conditional on financial stability, regulatory understanding and infrastructural support. Agrivoltaics appear most feasible within well-capitalised Jewish farming contexts, while remaining comparatively constrained among smaller Arab farms. For institutionalised actors, dual-use systems are a logical progression from greenhouse innovation, but for smallholders, they are a future goal dependent on external incentives and empirical validation. In this framework, agrivoltaics becomes a technological and epistemic laboratory — a site where efficiency, land stewardship and the procedural rigour of innovation intersect.

The generational outlook introduces a further axis of differentiation structured around temporality. Across age cohorts, modernisation is associated less with rupture than with continuity, albeit through different idioms. Younger farmers express innovation in terms of entrepreneurship, diversification, and digital management, while older producers express it in terms of stewardship and procedural control. Intergenerational dialogue therefore acts as a stabilising force, ensuring that modernisation occurs through reflection rather than rupture.

Finally, the regulatory environment emerges as a shared constraint and a factor that sets us apart. Bureaucratic complexity, lengthy permitting processes and overlapping jurisdictions are widely recognised as barriers to timely adoption. Institutionalised farms, particularly kibbutzim, navigate these processes with relative ease thanks to their accumulated experience and administrative capacity. In contrast, smallholders remain exposed to uncertainty and delay. This asymmetry affects the speed, but not the direction, of technological diffusion, reinforcing a model of gradual, path-dependent modernisation.

When viewed as a whole, these tendencies delineate a configuration of reflective and pragmatic modernisation in which shared epistemic norms coexist with asymmetrical capacities for experimentation, institutional mediation, and regulatory adaptation. Israeli agriculture thus emerges as a paradigmatic field of adaptive innovation, reconciling scientific rationality with socio-cultural embeddedness and technological ambition with empirical restraint. Within this configuration, innovation evolves not as

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a linear process of diffusion, but as a recursive negotiation between knowledge, experience, and institutional context. The coexistence of collective experimentation and selective imitation sustains a dynamic equilibrium in which technological change is continuously recalibrated in light of economic, infrastructural, and ecological realities. Israel's agricultural sector therefore embodies an iterative model of modernisation: empirically disciplined, institutionally plural and epistemically cohesive yet attuned to differentiation in terms of scale, identity and territorial context. It shows that cohesion and diversity, collective learning and contextual pragmatism do not operate in opposition, but in productive complementarity, ensuring the resilience and legitimacy of agricultural transformation.

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ANALYTICAL REPORT OF THE INTERVIEWS IN GERMANY

General overview

In-depth interviews with prospective end users of innovative technologies constitute a central methodological component of the REGACE project, designed to capture farmers' perspectives on technological change, sustainability, and the potential integration of agrivoltaics systems. Even in the case of the German interviews corpus (6 interviewees in total), the method aimed to identify how agricultural producers across varying scales and production systems conceptualize innovation, assess its risks and benefits, and adapt it to their operational and infra-regional contexts. The interviews were conducted by the German research team trained during the 2023 Spring School, on the ground of a shared methodological framework and a semi-structured protocol for data collection. This ensured comparability with other national cases within the REGACE consortium. Also, the German team members participated in identifying interviewees, conducting the interviews, and transcribing and translating the material.

All six interviews were performed during 2023–24, recorded, transcribed in German language, and subsequently translated into English following a double verification process. Identifying details were removed to ensure full anonymity and compliance with research ethics. The resulting corpus provides a rich empirical basis for analyzing how German producers interpret and negotiate innovation in agriculture.
Table 13 synthesizes key contextual and attitudinal information derived from six in-depth interviews conducted in Germany.

Interviewee	Age	Gender	Role	Location	Cultivation	Greenhouse
Int. 1	n/a	m	farmer	Wittenberg, Saxony-Anhalt	Tomatoes, peppers, strawberries	Yes
Int. 2	n/a	m	Farming manager	Küstriner Vorland OT Manschnow, Brandenburg	Tomatoes, cucumbers, bulbs, balcony plants	Yes
Int. 3	n/a	m	Farmer	Großwoltersdorf OT Altglobsow, Brandenburg	Vegetables, fruits, herbs, flowers	No
Int. 4	n/a	m	Farmer	Kempen, North Rhine-Westphalia	Flowers	Yes
Int. 5	n/a	m	Farming specialist	Watzkendorf / Blankensee, Mecklenburg-Vorpommern	Fruits and vegetables	Yes
Int. 6	n/a	m	Farmer	Brandenburg	Fruits and vegetables	No

Table 13 Synthesis of the socio-professional data of the interviewees in Germany

Table 13 provides an overview of the socio-professional characteristics of the producers interviewed, including their locations, cultivation systems, and greenhouse configurations. The sample encompasses a diverse range of agricultural enterprises—from large greenhouse-based commercial operations to smaller open-field farms—reflecting the structural diversity of German agriculture. Despite its reduced size, the

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sample of the interviewees offers an analytically representative picture of the sector's complexity, covering diverse regions and operational logics. All interviewees demonstrate direct experience with cultivation systems, making them well-positioned to assess technological integration and the practical challenges of innovation.

Tendencies emerging from the interviews in the German context

The first salient finding from the German interviews pertains to the conceptualization of innovation as a necessary and adaptive process within the broader trajectory of agricultural modernization. Across all cases, producers regard technological change as essential for maintaining competitiveness, addressing labor shortages, and responding to energy and environmental challenges. Innovation is not perceived as a rupture with tradition but as a gradual evolution shaped by empirical reasoning, operational feasibility, and institutional context. As one farmer put it, *"We're always testing things step by step—nothing gets introduced unless we've seen that it really works in our own fields"* (Interview 1). This emphasis on experiential learning underscores how "learning-by-doing" and iterative validation function as the core mechanisms through which technological innovation becomes both credible and applicable.

The concepts of sustainability and energy transition represent fundamental components within the discourse on innovation. Participants consistently associate technological progress with resource efficiency, renewable integration, and environmental adaptation. Many have already installed photovoltaic systems, implemented water recirculation, or adopted biomass heating; however, they stress that bureaucratic and administrative obstacles often delay or complicate these transitions. As one interviewee explained, *"We would like to expand our solar system, but the paperwork takes longer than the construction itself"* (Interview 2). The prevailing approach is pragmatic—innovation is adopted selectively, guided by cost-efficiency, technical reliability, and regulatory feasibility rather than ideological enthusiasm. For several producers, sustainability operates as a form of functional optimization rather than a normative commitment. One respondent summarized this logic by stating, *"If the technology helps us save energy and work more efficiently, then it's sustainable enough for me"* (Interview 3).

Agrivoltaics has emerged as a particularly significant yet contested domain of innovation. Most participants express strong interest in dual-use land systems that combine energy generation with crop production. Nevertheless, concerns about light transmission, crop performance, and bureaucratic complexity persist. As noted by one producer, *"The idea is good, but we need proof that the yield doesn't go down before we risk our main production"* (Interview 4). Consequently, adoption remains conditional upon the empirically demonstrated viability of these systems. This cautious openness reflects a broader epistemic culture of reflective modernization, where innovation is subjected to iterative testing, verification, and gradual integration into established production routines.

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Generational and structural diversity also shape these tendencies. Younger producers display a pronounced openness to digitalization, automation, and AI-based management systems, while older farmers tend to privilege procedural stability and proven methods. Larger enterprises often act as innovation hubs, conducting pilot projects and integrating digital infrastructures that smaller farms later emulate. Despite these differences, both groups share a strong commitment to efficiency, continuity, and adaptive resilience—values that anchor technological progress within a framework of empirical realism and long-term viability. These trends are presented in Table 14.

Analytical dimension	**Empirical tendencies**	**Interpretative patterns**
Innovation and adaptation	Innovation is perceived as an adaptive and continuous process essential for competitiveness, labor efficiency, and environmental response. Emphasis on learning-by-doing and empirical validation.	Innovation as an incremental evolution grounded in experience and institutional context rather than disruption.
Sustainability and energy transition	Strong engagement with resource efficiency and renewable technologies (PV, biomass, water recirculation). Administrative and regulatory hurdles slow implementation.	Sustainability pursued pragmatically as functional optimization rather than ideological commitment.
Agrivoltaics and dual-use systems	Considered promising yet uncertain; interest tempered by concerns over light transmission, productivity, and bureaucratic complexity. Adoption depends on proven viability.	Agrivoltaics as an experimental domain of reflective modernization where innovation is tested and gradually integrated.
Generational and structural dynamics	Younger producers are more open to digitalization and AI; older farmers emphasize reliability and procedural stability. Larger enterprises act as innovation hubs; smaller ones follow incremental improvement.	A differentiated but coherent innovation ecosystem combining experimentation, continuity, and adaptive learning.

Table 14 Analytical synthesis of emerging tendencies in the German corpus of interviews

Despite evident generational and structural differences, the German corpus reveals a shared commitment to sustainable production, operational efficiency, and adaptive resilience. This shared orientation unites diverse enterprises within a common framework of pragmatic modernization, in which innovation serves to reinforce continuity and ensure long-term viability rather than to induce rupture.

Collectively, these dynamics delineate a polycentric innovation landscape propelled by interaction among enterprises, cooperatives, and regional networks. Knowledge dissemination occurs laterally—through peer exchange, demonstration projects, and professional associations—rather than hierarchically. This distributed system fosters resilience by embedding innovation within daily practice and accumulated experience.

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Technological change advances through incremental diffusion, ensuring that adaptation remains empirically grounded and context-specific. The resulting model of modernization is both networked and reflexive, achieving a balance between competitiveness and ecological responsibility. It evolves through cooperative endeavors, knowledge-sharing, and adaptive learning, rather than through top-down directives or rapid acceleration.

Converging and diverging tendencies emerging from the interviews

A comparative analysis of the German interviews reveals a dynamic equilibrium between shared orientations and structural differences in how innovation is conceptualized, practiced, and embedded within agricultural systems. Across the corpus, a strong convergence emerges around the empirical and pragmatic nature of innovation, which is consistently understood as an adaptive mechanism for coping with environmental volatility, economic pressures, and competitiveness demands. Innovation is not perceived as a disruptive force but as a calibrated process of adjustment—an ongoing negotiation between experimentation and operational stability. As one respondent remarked, *"Innovation is part of our daily work—it happens when we find small improvements that make production easier, not when we change everything at once"* (Interview 2).

At the same time, clear divergences arise along the lines of scale, institutional positioning, and generational outlook. Larger enterprises with dedicated research and development capacities often function as experimental nodes, functioning as early adopters and demonstrators of emerging technologies. Their ability to absorb risk, mobilize investment, and collaborate with external research partners enables them to pilot new approaches and evaluate their technical and economic viability. As one manager explained, *"We can afford to experiment because we have the data and the partnerships to evaluate the results properly"* (Interview 4). Smaller producers, by contrast, advance through incremental adaptation, privileging reliability, cost-efficiency, and proven methods. A family farmer described this pragmatic approach by stating, *"We prefer to see how things perform elsewhere before we invest—our margin for error is very small"* (Interview 1). This coexistence of high-intensity and gradual innovation pathways generates a distributed system of experimentation and consolidation, wherein technological advances diffuse horizontally through observation, imitation, and regional collaboration.

Institutional and regulatory frameworks occupy an ambivalent position within this innovative landscape. On the one hand, supportive energy policies and incentive mechanisms provide important levers for technological upgrading and renewable integration. On the other hand, bureaucratic inefficiency, inconsistent policy implementation, and complex approval procedures continue to hinder timely adoption—especially for agrivoltaics installations. As one participant observed, *"The technology is ready, but the bureaucracy is not. The process is so slow that many*

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farmers give up before starting" (Interview 5). In response to these limitations, informal networks, cooperatives, and professional associations function as compensatory infrastructures that sustain innovation diffusion through peer mentoring, shared equipment, and knowledge exchange. These relational mechanisms substitute for formal governance gaps and ensure that modernization proceeds through cooperation and adaptive learning rather than institutional prescription. Generational factors add another crucial dimension to this configuration. Younger producers tend to associate innovation with entrepreneurship, diversification, and digitalization, expressing strong confidence in precision farming and data-driven decision-making. *"For us, innovation means digital tools and sensors—data gives us control and saves time,"* noted a younger producer (Interview 6). Older farmers, conversely, interpret modernization as a continuation of stewardship, emphasizing reliability, accumulated expertise, and the incremental refinement of existing practices. One senior respondent reflected, *"You cannot just replace experience with technology. Machines don't understand the soil like we do"* (Interview 3). The interplay between these generational perspectives creates a form of temporal reflexivity that regulates the rhythm of transformation, ensuring that innovation remains continuous yet grounded in the practical wisdom accumulated over decades.

Table 15 summarizes the principal converging and diverging tendencies identified in the German interviews.

Analytical dimension	Converging themes	Diverging themes	Interpretative analysis
Epistemic orientation	Shared emphasis on empirical validation, efficiency, and learning-by-doing.	Differences in innovation intensity linked to capital and enterprise scale.	A pragmatic, evidence-based epistemology structures technological adoption.
Scale and institutional context	Consensus on innovation is an essential item for competitiveness and sustainability.	Large farms experiment strategically; small farms consolidate cautiously.	A multi-speed innovation regime balancing experimentation and stability.
Agrivoltaics adoption	Broad curiosity about dual-use energy systems.	Adoption limited by light transmission concerns and bureaucratic hurdles.	Agrivoltaics functions as a conditional and empirically driven test field.
Policy and regulation	General agreement on the need for clearer, more supportive frameworks.	Diverging levels of institutional trust between larger and smaller enterprises.	Innovation advances through negotiation rather than direct policy facilitation.
Generational outlook	Shared perception of modernization as continuity and adaptation.	Younger actors emphasize digital tools; older actors stress procedural control.	Intergenerational dialogue ensures reflective and sustained innovation.

Table 15 Comparative analysis of converging and diverging tendencies in the German interviews.

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As illustrated in Table 15, the German innovation landscape is defined by empirical reasoning, pragmatic adaptation, and distributed learning, which operate across diverse institutional, territorial, and generational configurations. The corpus consistently reveals a shared conviction that technological progress must be grounded in verifiable performance, operational reliability, and demonstrable agronomic benefit rather than in abstract narratives of modernization. This pervasive "epistemic realism" reflects a sectoral culture in which credibility derives from observation, measurement, and the reproducibility of results. Innovation, in this sense, acquires legitimacy only when it can be seen, tested, and replicated under real production conditions—a principle that anchors modernization in experience rather than prescription.

Yet within this common epistemic horizon, producers diverge significantly in their capacity and tempo of engagement with technological change. Differences in scale, institutional position, and access to resources produce a spectrum of innovative strategies ranging from experimental to conservative. Larger enterprises function as strategic laboratories for applied experimentation, mobilizing capital, data, and partnerships to explore emergent technologies under controlled yet operationally realistic conditions. One interviewee captured this advantage succinctly: *"Big farms can run pilots because they can afford mistakes. We can't—we learn from what they try first"* (Interview 7). Smaller farms, by contrast, pursue incremental innovation through selective adoption and adaptation of already validated solutions, guided by risk aversion and cost efficiency. Together, these modalities generate a multi-speed innovation system in which progress advances through feedback loops of observation, imitation, and local adaptation. Rather than dividing the sector, this asymmetry fosters interdependence: large-scale experimentation produces evidence that sustains smaller farms' confidence in adopting proven methods, while smallholders contribute experiential feedback that refines and stabilizes innovation outcomes. The result is a self-regulating ecosystem of modernization, balancing exploratory dynamism with systemic stability.

Agrivoltaics epitomizes this configuration as a field of conditional experimentation where technical feasibility, economic rationale, and ecological compatibility must converge before large-scale adoption can occur. While producers recognize its potential to reconcile agricultural and energy production, they remain cautious about unresolved issues of light transmission, maintenance, and long-term yield performance. As one farmer explained, *"If agrivoltaics can really prove that yields stay stable, then it makes sense. But until then, we watch and wait"* (Interview 2). This cautious optimism situates agrivoltaics within Germany's wider culture of reflective modernization, where technological advancement is pursued through iterative testing, cooperative evaluation, and empirical accountability. Farmers interpret technology not as a disruptive substitution but as an opportunity to calibrate productivity and sustainability within the same spatial and temporal framework.

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Modernization, thus, in the German agricultural sector unfolds as a negotiated and dialogic process, sustained by interaction among enterprises, cooperatives, research institutions, and policy actors. Progress emerges through relational governance rather than directive intervention—through learning communities that translate global innovation logics into locally validated practices. This continuous interplay between experimentation and verification embeds innovation within the moral and ecological boundaries of agricultural life. In doing so, it produces a distinctive model of adaptive modernization: empirically disciplined, socially cohesive, and environmentally accountable, where transformation is achieved not by rupture but by collective calibration across scales, systems, and generations.

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ANALYTICAL REPORT OF THE INTERVIEWS IN ITALY

General Overview

In-depth interviews with prospective end users of innovative technologies represent a core methodological component of the REGACE project, designed to capture farmers' and agricultural stakeholders' perspectives on technological change, sustainability, and the potential integration of agrivoltaics systems within their production environments.

In the Italian case, ten interviews were conducted across the regions of Lazio, Tuscany, and Abruzzo, involving producers, agronomists, cooperative managers, and representatives of agricultural associations. The aim was to understand how Italian actors in the agri-food sector conceptualize innovation, assess its risks and benefits, and adapt technological change to their operational, regulatory, and ecological contexts.

The ten Italian in-depth interviews were coordinated by the national research team following the shared methodological framework established during the 2023 Spring School. A semi-structured interview protocol ensured cross-national comparability with the other REGACE member states' corpora. The Italian team participated in the full research cycle: identification of interviewees, conduction of field interviews, transcription, and English translation. Each interview was recorded and transcribed between April and August 2023, with subsequent anonymization of identifying details to ensure compliance with ethical and data-protection standards.

The resulting corpus provides a rich empirical basis for analyzing how Italian agricultural producers interpret and negotiate innovation under rapidly changing socio-economic and environmental conditions. It reflects the structural diversity of the sector, encompassing small family-run farms, large enterprises, and cooperative networks engaged in organic, biodynamic, and conventional systems. Table 16 provides an overview of the socio-professional characteristics of the producers interviewed, including their regional distribution, cultivation systems, and greenhouse configurations.

Interviewee	Age	Gender	Location / Region	Cultivation Type	Greenhouse / System
I1	51	M	Lazio	Mixed crops, social farm with agro-photovoltaic park	Yes
I2	40	M	Tuscany	Organic and biodynamic cereals, vegetables, fruit	No
I3	52	M	Lazio	Cereals, fodder, lupins	No
I4	59	M	Lazio	Mixed: kiwi, vineyards, livestock, floriculture	Yes
I5	38	M	Lazio	Cereals, fodder, legumes, aromatic plants	No
I6	33	M	Lazio	Kiwi orchards, rotational crops	Yes

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Interviewee	Age	Gender	Location / Region	Cultivation Type	Greenhouse / System
I7	36	M	Lazio	Greenhouse horticulture	Yes
I8	38	M	Abruzzo	Livestock, fodder	No
I9	—	M	Lazio	Vineyard and wine production	No
I10	—	M	Lazio	Organic cereals, hazelnuts, olives	No

Table 16 Synthesis of the socio-professional data of the interviewees in Italy

Tendencies Emerging from the Interviews in the Italian Context

The Italian corpus delineates a paradigm of innovation that is reflexive, adaptive, and contextually embedded. Across all interviews, technological change is perceived not as an external disruption or radical departure from tradition, but as a structural necessity — a process that must remain compatible with ecological balance, production continuity, and the lived rationalities of agricultural practice. In this sense, innovation operates less as a force of rupture than as a mode of adjustment: a continuous process of calibration between technical functionality, social legitimacy, and environmental equilibrium.

Italian producers describe technological modernization as an incremental endeavor rooted in observation, trial, and verification. Rather than adopting technologies wholesale, they selectively integrate those that demonstrate clear empirical benefits and align with the socio-ecological conditions of their territories. This approach reflects a deep-seated epistemic orientation grounded in pragmatic realism: knowledge and progress must prove themselves in the field before being normalized into practice. As one farmer explained, "We adopt new technologies when they prove to make our work easier, more efficient, and sustainable—but never blindly".

Across the corpus, technological innovation is consistently associated with the enhancement of operational efficiency, the mitigation of labor shortages, and the pursuit of environmental sustainability. However, innovation is embraced only when it demonstrates tangible advantages and contextual coherence. As articulated by a Tuscan producer, *"I am very much in favour of technological innovation in all cases where it does not have a negative effect on our ecosystem and does not erase our traditions."* This position epitomizes a distinctly Italian epistemic synthesis — combining empirical rationality with the preservation of local cultural and ecological systems. Progress, in this light, is legitimized through evidence and continuity rather than acceleration or disruption.

Within this broader framework, the energy transition emerges as a domain of pragmatic adaptation rather than ideological commitment. The interviewees converge on the idea that renewables are indispensable for ensuring both economic viability and environmental resilience. Yet, their endorsement is tempered by spatial and regulatory

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constraints. Farmers reject large-scale photovoltaic conversions that displace productive land, advocating instead for integrated and multifunctional models. As one agronomist from Lazio stated, "It is imperative to achieve a harmonious balance between energy production and agriculture through the intelligent utilization of already developed spaces—roofs, industrial areas, or degraded land." This formulation encapsulates a functional environmentalism in which sustainability is operationalized through resource optimization, spatial efficiency, and the principle of coexistence rather than through symbolic adherence to green agendas.

At the same time, producers display awareness of the institutional complexity that characterizes Italy's agricultural innovation landscape. Bureaucratic inertia, fragmented governance, and inconsistent regional policies are recurrently mentioned as structural impediments to innovation. Respondents describe regulatory uncertainty and slow authorization processes as critical barriers to technological adoption, particularly in the case of agrivoltaics and digital farming systems. In response, many have developed informal strategies of adaptation, relying on peer networks and cooperative learning to navigate these challenges. As one interviewee remarked, "We cannot always wait for the Ministry or the Region; we move forward by sharing what works among ourselves."

Within this context, agrivoltaics emerges as both a promising and contested innovation frontier. Farmers recognize its potential to reconcile energy generation with agricultural productivity, yet their enthusiasm is moderated by calls for empirical validation and technical guarantees. Concerns persist regarding light transmission, yield stability, and the agronomic compatibility of photovoltaic infrastructures. Consequently, adoption remains contingent upon verifiable evidence from pilot projects and demonstrable cost-effectiveness. For many, agrivoltaics symbolizes the Italian model of reflective modernization—a space of experimentation in which innovation is continuously tested, observed, and morally domesticated before being scaled.

This cautious openness reflects a distinctive cultural pattern of modernization—slow, negotiated, and evidence-driven—where progress unfolds through iterative learning rather than imposed acceleration. Italian farmers conceptualize innovation as a cooperative process involving empirical testing, institutional coordination, and social validation. As one Lazio farmer concluded, *"We need to see results in the field before investing; technology must adapt to our rhythm, not the other way around."* These common trends and their interpretative patterns are presented in Table 17.

Analytical dimension	**Empirical tendencies**	**Interpretative patterns**
Innovation and tradition	Innovation valued for efficiency and resilience but aligned with cultural continuity and product quality.	Modernization framed as adaptive evolution rather than disruption.

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Analytical dimension	Empirical tendencies	Interpretative patterns
Energy transition	Renewables supported as economic and environmental necessity; resistance to converting fertile land for energy.	Sustainability pursued through balance between production and autonomy.
Agrivoltaics	Broad curiosity and pilot engagement; expectation of proof and regulatory clarity.	Conditional experimentation within reflective modernization.
Institutional framework	Awareness of bureaucratic delays and fragmented policies hindering implementation.	Innovation constrained by administrative inertia and uneven governance.
Generational dynamics	Younger farmers embrace digital tools and diversification; elders prioritize continuity and experience.	Intergenerational complementarity ensures gradual, knowledge-based innovation.

Table 17 Analytical synthesis of emerging tendencies in the Italian corpus of interviews

The Italian case reveals a form of modernization grounded in reflexivity, empirical discipline, and contextual negotiation. The agricultural transition toward renewable energy and advanced technologies progresses through a delicate interplay between experimentation and caution, ambition and continuity. Innovation, far from being a top-down imperative, becomes a socially embedded process of adaptation—anchored in the experiential intelligence, moral economy, and pragmatic reasoning that define Italy's rural world.

Converging and diverging tendencies emerging from the interviews in italy

A comparative analysis of the Italian interviews reveals a robust convergence in epistemic orientation and sustainability objectives, tempered by distinct divergences in institutional capacity, enterprise scale, and generational outlook. Across regions and production systems, interviewees share a clear conviction that innovation must be empirically substantiated, economically rational, and operationally feasible in order to acquire legitimacy within the agricultural field. This consensus on evidence-based modernization forms the cognitive backbone of Italy's farming innovation culture. Yet, beneath this shared orientation, the modalities of adoption, investment, and experimentation vary substantially according to farm size, territorial configuration, and differential access to public incentives or technical assistance.

The Italian agricultural landscape thus embodies a pattern of negotiated modernization—a process in which collective epistemic foundations coexist with multiple, locally situated trajectories of implementation. Large-scale enterprises, consortia, and professional associations typically institutionalize innovation through structured research partnerships, EU-funded experimentation, and coordinated investment strategies. Their organizational architecture allows them to absorb risks, test advanced technologies such as agrivoltaics systems, digital sensors, or bioplastic applications, and engage with research institutions in pilot projects. As one cooperative

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manager explained, *"We can test things because we have the means and the partners. If it works, others will follow."*

By contrast, small and medium-sized farms, constrained by financial and administrative limitations, tend to advance through incremental learning and contextual adaptation. Their modernization pathway prioritizes low-risk experimentation—optimizing irrigation systems, adopting precision machinery within affordable margins, or integrating renewable tools on a modular basis. This gradual approach is not a sign of technological resistance but rather a form of pragmatic selectivity, ensuring that innovation remains coherent with production rhythms and ecological constraints. As one smallholder observed, "We innovate step by step; every change must fit our soil, our crops, and our daily work."

This coexistence of large-scale institutional innovation and smallholder adaptation generates a multi-speed innovation regime, where experimentation and consolidation operate in synergy rather than competition. Big enterprises provide technical validation and data through pilot projects, while smaller actors function as long-term stabilizers, translating models into sustainable local practice. Such complementarity fosters distributed innovation—an ecosystem in which modernization emerges collectively through diffusion, imitation, and shared learning rather than through centralized planning or market coercion.

Institutional factors further shape this configuration. The interviews highlight a broad consensus on the strategic importance of innovation, but also a widespread frustration with Italy's fragmented governance. Bureaucratic inertia, uneven regional incentive schemes, and delays in authorization procedures continue to impede technological deployment—particularly for agrivoltaics and renewable infrastructures. Nonetheless, this institutional fragmentation is partly compensated by informal governance mechanisms, such as farmers' cooperatives, consortia, and peer networks, which operate as flexible platforms for mutual learning and experimentation. As one participant explained, "We can't wait for the government to make things simple—we move ahead together, exchanging what works."

Within this systemic interplay, agrivoltaics stands out as a revealing case of conditional innovation. Producers accept its dual-use potential and recognize its environmental and economic promise, yet remain cautious due to regulatory opacity and agronomic uncertainties. For many, the true test of agrivoltaics lies not in its conceptual appeal but in its empirical performance. As one farmer summarized, "It's an excellent idea, but until we have real data on yields and light, it's still a hypothesis." The sector's cautious optimism positions agrivoltaics as a laboratory of reflective modernization, where the balance between productivity and sustainability is continually assessed through observation, dialogue, and iterative adaptation.

Generational dynamics further enrich this picture. Younger farmers—often better connected to European programs and digital platforms—tend to interpret innovation

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through the language of entrepreneurship, diversification, and technological curiosity. They view renewable systems, precision agriculture, and digital tools as levers of competitiveness and autonomy. Older producers, conversely, conceptualize modernization as a process of custodial stewardship, emphasizing continuity, procedural reliability, and the preservation of agronomic know-how. The intergenerational dialogue between experimentation and experience produces a temporal equilibrium, ensuring that change unfolds progressively and responsibly. As a young producer from Lazio put it, *"Innovation is essential, but it must respect our timing and the identity of our land."*

Table 18 summarises the main converging and diverging tendencies identified in the Italian interviews.

Analytical dimension	Converging themes	Diverging themes	Interpretative analysis
Epistemic orientation	Broad consensus on the need for empirically validated, economically rational, and operationally feasible innovation. Evidence-based modernization forms a shared cognitive foundation.	Variations in the modalities of adoption and experimentation linked to enterprise size, territorial configuration, and access to incentives.	A reflective and empirically grounded epistemic culture ensures innovation legitimacy through verification and adaptive learning.
Scale and institutional context	Agreement that innovation is essential for competitiveness and sustainability across production systems.	Large-scale enterprises and consortia institutionalize research partnerships and EU-funded pilots, while small and medium farms advance through incremental learning.	Italian agriculture operates as a multi-speed innovation regime, where experimentation by larger actors complements consolidation by smaller ones, generating distributed innovation.
Agrivoltaics adoption	General acceptance of agrivoltaics as a promising dual-use model integrating energy and food production.	Adoption delayed by regulatory opacity, light transmission concerns, and uncertainty regarding agronomic performance.	Agrivoltaics functions as a laboratory of reflective modernization, testing the compatibility between productivity and environmental adaptation through iterative experimentation.
Policy and regulation	Shared recognition of innovation's strategic importance and the need for institutional coherence.	Persistent frustration with bureaucratic inefficiency, fragmented governance,	Innovation advances through hybrid governance models combining formal institutions with informal

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Analytical dimension	Converging themes	Diverging themes	Interpretative analysis
		and uneven regional incentive structures.	cooperative and peer-based mechanisms.
Generational outlook	Common belief that modernization must proceed through balance and continuity, ensuring social and ecological stability.	Younger farmers emphasize digitalization, diversification, and entrepreneurship, while older producers focus on procedural reliability and knowledge preservation.	Intergenerational dialogue fosters temporal equilibrium, aligning experimentation with experience and sustaining gradual, territorially grounded modernization.

Table 18 Comparative analysis of converging and diverging tendencies in the Italian interviews.

From the outcomes of the analysis of the interviews the Italian agricultural sector emerges as a distributed and reflexive innovation ecosystem, where shared epistemic commitments coexist with asymmetrical capacities and diverse temporalities of change. The convergence around empirical reasoning, functional sustainability, and adaptive learning provides coherence and stability, while divergence in scale, governance, and generational disposition ensures pluralism and resilience. Italian modernization thus advances through collective calibration rather than rupture, combining empirical rigor, social trust, and intergenerational dialogue to sustain a model of progress that is both evidence-based and territorially grounded.

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CROSS-NATIONAL SYNTHESIS: Converging and diverging tendencies across the five cases

The comparative synthesis of interviews conducted across Italy, Austria, Germany, Greece, and Israel reveals a consistent yet diversified landscape of agricultural modernization. Across all national contexts, technological change is perceived not as disruption but as an adaptive and pragmatic process, guided by operational feasibility, economic calculation, and empirical verification. Farmers in each country approach innovation as a gradual form of adjustment rather than a rupture with existing practice, embedding new technologies within familiar agronomic, managerial, and organizational routines. This shared orientation toward applied experimentation produces a strong epistemic convergence: modernization is understood as a sequence of measurable improvements, grounded in the observation of results and the incremental refinement of production systems. Despite structural differences among countries, this pragmatic and evidence-based approach provides a common framework through which agricultural innovation is recognized, tested, and institutionalized.

A major convergence across the five cases lies in the epistemic logic of innovation. Italian, Austrian, German, Greek, and Israeli producers all emphasize empirical substantiation and technical reliability as the necessary preconditions for technological legitimacy. In each setting, new tools or processes are accepted only once they have demonstrated verifiable improvements in efficiency, productivity, or environmental performance. While Italian producers express this in terms of empirical rationality and contextual adaptation, Austrian farmers frame it through precise measurement and operational optimization. German respondents stress experiential validation and the role of peer exchange, while Greek producers link innovation to agronomic observation and continuous calibration. Israeli farmers, shaped by long-standing exposure to arid conditions and resource constraints, articulate a model of performance-based experimentation that privileges quantifiable outcomes. In all cases, the modernization process follows a logic of verification rather than prescription: technologies gain acceptance through proof of function and replicability within specific production contexts.

A second unifying tendency concerns the interpretation of sustainability and energy transition as pragmatic objectives integrated into production rationality. Farmers in all countries view renewable energy and resource efficiency as instruments for cost stabilization, autonomy, and risk management rather than as symbolic commitments. In Austria and Germany, renewable energy systems such as biomass heating, photovoltaic installations, and thermal circulation are primarily adopted to enhance production efficiency and reduce dependency on volatile energy markets. Italian and Greek producers interpret energy transition as a form of resource management closely aligned with local agronomic cycles, while Israeli producers perceive it as a strategic requirement for maintaining productivity under environmental constraints. In each case, sustainability is conceptualized as functional optimization within the production process, where environmental and economic objectives converge through technological efficiency and long-term viability. All the converging tendencies among the 5 different national contexts are presented in Table 19.

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Analytical dimension	Common tendencies	Interpretative insight
Epistemic orientation	Innovation is accepted only after empirical verification and practical demonstration of efficiency, productivity, or sustainability.	A common empirical rationality defines modernization as a process of evidence-based adjustment rather than ideological or policy-driven change.
Innovation Logic	Technological change is viewed as a gradual and adaptive process integrated into existing production systems.	Modernization advances through incremental experimentation, observation, and replication rather than through disruptive transformation.
Sustainability and energy transition	Renewable energy and efficiency technologies are seen as tools for operational stability, autonomy, and long-term viability.	Environmental sustainability is approached as a component of managerial and economic rationality.
Institutional practice	Informal networks, cooperatives, and peer collaborations supplement formal policy structures.	Distributed innovation systems ensure knowledge circulation and resilience beyond regulatory constraints.
Generational outlook	Younger farmers promote digitalization and experimentation; older producers ensure continuity and operational control.	Intergenerational collaboration generates equilibrium between technological renewal and procedural stability.

Table 19 Common trends in the 44 interviews in the 5 different national contexts

On the other hand, significant divergences emerge when examining institutional capacity, scale, and governance. In Italy, Austria, and Germany, larger enterprises and cooperative structures act as innovation hubs, equipped with capital resources, technical expertise, and institutional partnerships that facilitate experimentation with automation, agrivoltaics, and digital agriculture. Smaller and medium-sized farms, conversely, adopt technologies gradually, relying on proven systems and low-cost optimization methods. This differentiation by scale produces a multi-speed innovation regime where experimental initiatives coexist with conservative adaptation. Similar configurations appear in Greece and Israel, where smaller farms advance incrementally, prioritizing reliability and functionality, while larger operations or consortia drive technological development. Across the five national contexts, modernization thus evolves through a distributed structure in which experimentation and consolidation are interdependent rather than oppositional. The flow of innovation depends less on centralized programs than on lateral diffusion through demonstration, replication, and peer exchange.

Institutional frameworks further define the rhythm and scope of innovation. The Austrian and German cases show how well-established cooperative networks and research partnerships create infrastructures that translate experimentation into standardized practice. Nonetheless, producers in these countries express dissatisfaction with bureaucratic inefficiency, fragmented regulations, and administrative delays. Italian farmers describe similar challenges, citing complex authorization processes and

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uneven regional incentives as obstacles to technological implementation. Greek and Israeli respondents echo these concerns, highlighting inconsistent procedures, slow approvals, and insufficient coordination between policy and production. Despite these limitations, producers across all five countries compensate for institutional constraints through horizontal collaboration and informal governance. Cooperative associations, producer groups, and regional networks serve as platforms for technical exchange and shared learning. These decentralized mechanisms sustain innovation through self-organized coordination, ensuring that adaptation continues even when formal policy support is limited or inconsistent.

Agrivoltaics represents a central point of convergence across all cases and an ideal lens through which to examine national differences. Conceptually, farmers in all five countries acknowledge the potential of agrivoltaics systems to reconcile agricultural and energy production on the same land surface. However, adoption remains conditional and empirically driven. Italian and German producers emphasize the need for precise data on light transmission, yield stability, and maintenance costs; Austrian interviewees highlight the necessity of technical validation before large-scale diffusion; Greek farmers focus on maintaining crop integrity and production equilibrium; Israeli producers prioritize quantitative evaluation under resource-limited conditions. Across these contexts, agrivoltaics functions as a controlled experimental field where innovation is guided by observation, measurement, and the gradual accumulation of empirical evidence. This cautious integration reinforces the broader pattern of reflective modernization observed across all five national corpora: technological advancement proceeds through stepwise verification and the replication of tested outcomes.

Generational dynamics introduce additional variation within this shared framework. In all countries, younger producers display greater openness to digital tools, automation, and data-driven management, associating technology with competitiveness and strategic renewal. Older farmers tend to emphasize experience, procedural control, and continuity in production methods. Yet these perspectives do not conflict; rather, they create complementarity within agricultural enterprises. Younger farmers introduce technological experimentation, while older producers ensure operational stability and institutional knowledge. The interaction between these cohorts fosters an internal balance that moderates the pace of modernization. In Austria and Germany, this intergenerational dynamic is embedded in cooperative training and apprenticeship systems; in Italy and Greece, it is sustained through family continuity; in Israel, it manifests as collaboration within technologically integrated farm units. Across all contexts, generational interplay supports gradual modernization by aligning innovation capacity with practical experience.

National and regional contexts shape distinct variants of the shared modernization logic. Italian agriculture exemplifies a model of negotiated innovation, where modernization is adjusted to local constraints through stepwise experimentation. Austrian producers articulate a technologically realist approach centered on precision, efficiency, and empirical accountability. The German corpus illustrates adaptive pragmatism, characterized by networked learning and distributed experimentation. Greek farmers express a framework of practical empiricism, emphasizing observation and iterative adjustment. Israeli producers, operating under structural constraints of water scarcity and limited arable land, represent an institutionalized model of

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experimental rationality, combining technical innovation with resource optimization. These variations do not fragment the broader pattern but rather express its contextual adaptability: a single logic of empirical modernization manifested in multiple structural and cultural forms. All the formats of divergences emerging from the interviews in the 5 national contexts are presented in Table 20.

Analytical dimension	**Differentiation by context**	**Country-specific characteristics**	**Interpretative implication**
Scale and resources	Larger enterprises act as experimental hubs; smaller farms adopt gradually through proven, low-cost technologies.	Italy, Austria, Germany – multi-scale innovation ecosystems; Greece, Israel – smallholder pragmatism.	Modernization proceeds through a multi-speed regime balancing experimentation with consolidation.
Institutional framework	Degree of regulatory coherence and bureaucratic efficiency varies significantly.	Austria, Germany – stable cooperative systems; Italy – fragmented governance; Greece, Israel – limited institutional coordination.	Institutional asymmetry produces uneven innovation trajectories, compensated by informal governance.
Agrivoltaics adoption	All countries share conceptual acceptance, but operational readiness differs.	Austria, Italy, Germany – empirical testing phase; Greece – cautious evaluation; Israel – performance-driven experimentation.	Agrivoltaics serves as a controlled testing ground for integrating energy and agriculture within diverse institutional conditions.
Innovation infrastructure	Varies from centralized research partnerships to decentralized peer networks.	Austria, Germany – strong cooperative R&D; Italy – mixed model; Greece, Israel – bottom-up learning systems.	Structural diversity reinforces system-level adaptability through differentiated innovation pathways.
Cultural and territorial adaptation	Modernization logic expressed differently according to context.	Italy – negotiated adaptation; Austria – precision efficiency; Germany – adaptive pragmatism; Greece – applied empiricism; Israel – performance pragmatism.	National variations reflect the same empirical foundation applied through context-specific mechanisms.

Table 20 Diverging tendencies across the 5 national corpuses of interviews

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Collectively, the five national cases present a comprehensive, multi-scalar model of agricultural modernisation that extends across the Euro-Mediterranean and Near Eastern regions. This model is characterised by a reliance on empirical validation, the gradual adoption of technology, distributed innovation and systemic coordination between producers, cooperatives, and research institutions. In all contexts, the modernisation process advances through cumulative testing, observation and peer-based learning rather than linear diffusion or centralised policy control. A shared commitment to verification and operational feasibility ensures internal coherence, while differences in institutional architecture, resource endowment and governance structures sustain pluralism and long-term adaptability.

Each national context contributes its own unique configuration to this composite system. Italy exemplifies a negotiated approach to innovation in general and agrivoltaics in particular. Austria takes a managerial approach to both themes. Germany envisages innovation in farming and APV through the lens of distributed experimentation. Greece moves forward through applied empiricism. Israel uses performance-oriented pragmatism to address both phenomena. Together, these five configurations delineate a polycentric architecture of modernisation in farming, in which technological innovation is embedded within specific institutional ecologies, while also contributing to a broader regional dynamic of coordinated transformation.

Based on forty-four in-depth interviews and a comparative analysis of five corpora, this study reveals a shared epistemic foundation grounded in empirical rationality and functional sustainability. This foundation is coupled with a variety of institutional and structural adaptations. In all contexts, innovation emerges as an integrated process involving the alignment of technology, resource management and production efficiency. The outcome is a distributed, iterative model of modernisation that evolves through verification, replication, and continuous learning. While the pace and organisation of change vary according to enterprise scale and governance configuration, the underlying rationale remains consistent: modernisation is neither spontaneous nor externally imposed, but rather progressively constructed through aligning technical feasibility, institutional adaptation, and economic rationality.

The current trajectory of agricultural innovation within the REGACE partner countries is defined by this synthesis of empirical discipline and structural differentiation. It portrays modernisation as a cumulative, reflexive and adaptive process that integrates experimentation with operational pragmatism, achieving systemic progress through iterative coordination across a shared Euro-Mediterranean landscape of transformation.

B. The questionnaire

As a format for detecting general perception on apv in the 5 state partners (substitutes the 3 focus groups)

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Descriptive Analysis of the Agrivoltaics Survey Dataset

This study is based on a pilot survey conducted for exploratory purposes. As a result, the sample is not statistically representative of the broader population, but it does provide preliminary insights into perceptions, attitudes, and potential response patterns. The primary aim of this pilot phase is to test the clarity of the questionnaire, evaluate the reliability of the measurement scales, and identify any issues related to item interpretation or survey administration.

Therefore, the findings should be interpreted with caution and should not be generalized to the entire target population. However, the results offer valuable insights that can help refine the survey instrument and guide the design of a subsequent large-scale data collection using a probabilistic or stratified sampling strategy.

1. Dataset Overview

The dataset under analysis contains the results of a structured questionnaire designed to investigate perceptions, experiences, and adoption propensities toward Agrivoltaic (APV) systems in greenhouses. A total of 148 valid responses were collected between April 2 and October 6, 2025, through an online survey platform. The questionnaire included 14 variables, comprising both categorical and open-ended textual responses. These variables capture respondents' socio-demographic characteristics (country, profession, age group), -their previous experience with APV systems, perception of APV as a technology for sustainable plant and energy production, and the main factors influencing adoption decisions.

2. Geographical Distribution

Respondents came from five different countries, representing a diverse European and Mediterranean context (see Figure 1). The distribution of responses by country is as follows:

Country	Number of Respondents	Percentage
Israel	49	33.1%
Italy	41	27.7%
Greece	25	16.9%
Austria	17	11.5%
Germany	16	10.8%

The predominance of respondents from Israel (33%) and Italy (28%) reflects both the diffusion of APV pilot projects and ongoing academic or research collaborations in

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these countries. The presence of respondents from Greece, Austria, and Germany enriches the dataset with a variety of regional perspectives within Europe.

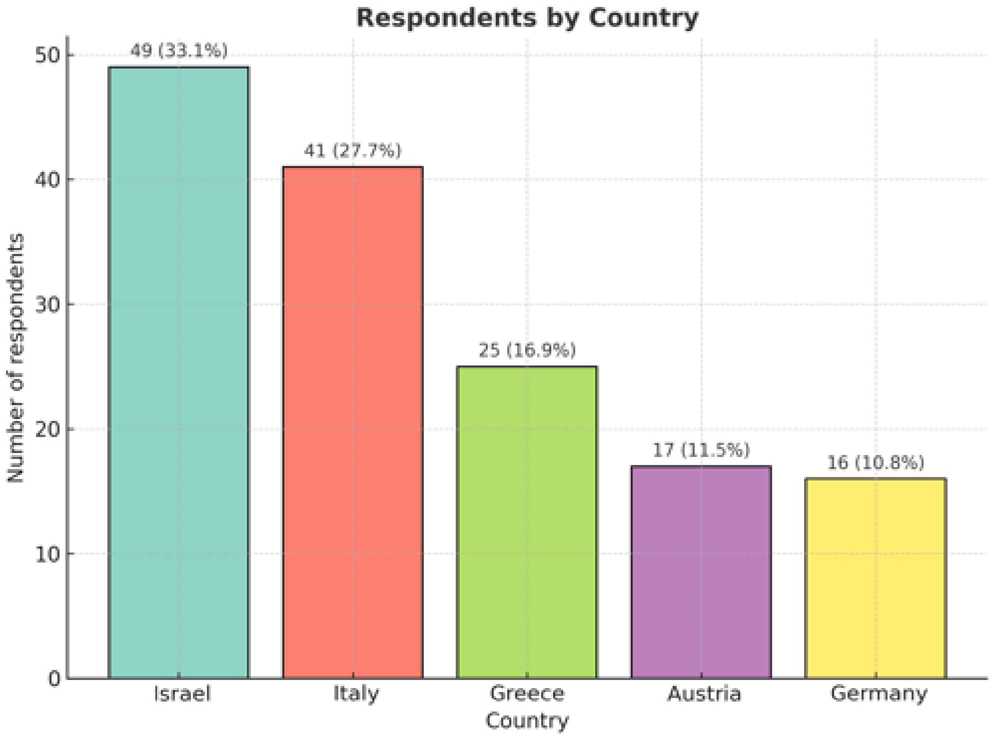

Figure 1 Respondent by Country

Among the Israeli respondents (n = 49), the questionnaire was completed in three languages, Hebrew (25 cases), Arabic (14 cases), and English (10 cases), reflecting the multilingual context of the country and the inclusiveness of the survey design.

3. Socio-Demographic Profile

After data cleaning and harmonization of professional categories, the sample comprises 21 distinct professions. The largest group by far is Farmers (89 respondents, 60.1%), followed by Citizens interested in the topic (27 respondents, 18.2%) and Researchers (18 respondents, 12.2%). Minor representation is observed among Students (2.0%), Part-time workers, Chemists, and Agricultural Science students, each accounting for less than 1% of the sample (see Figure 2). This composition highlights the strong engagement of the agricultural community, while also reflecting broader social interest in agrivoltaics solutions beyond professional boundaries, involving citizens, researchers, and young learners.

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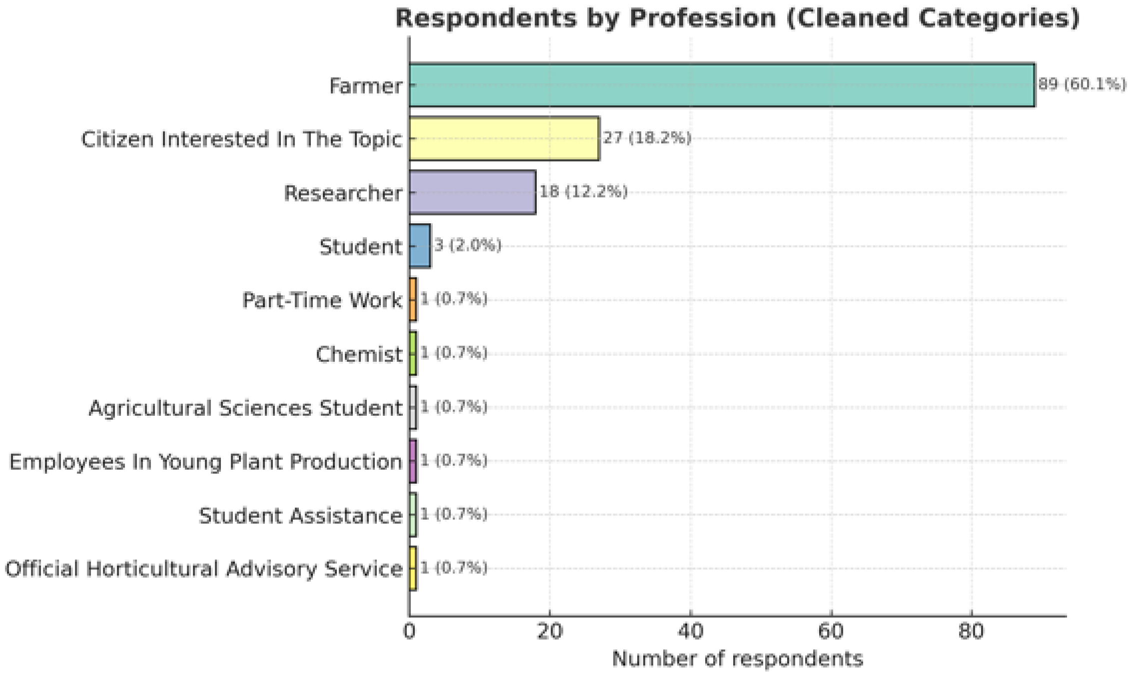

Figure 2 Respondents by profession

The age distribution of respondents shows a broad and balanced representation across adult age classes (see Figure 3). The most represented group is 59–67 years (35 respondents, 23.6%), followed by 49–58 years (29 respondents, 19.6%) and 29–38 years (27 respondents, 18.2%). Younger participants aged 19–28 account for 14.9% of the sample, while older respondents (over 67) constitute a smaller share (6.8%).

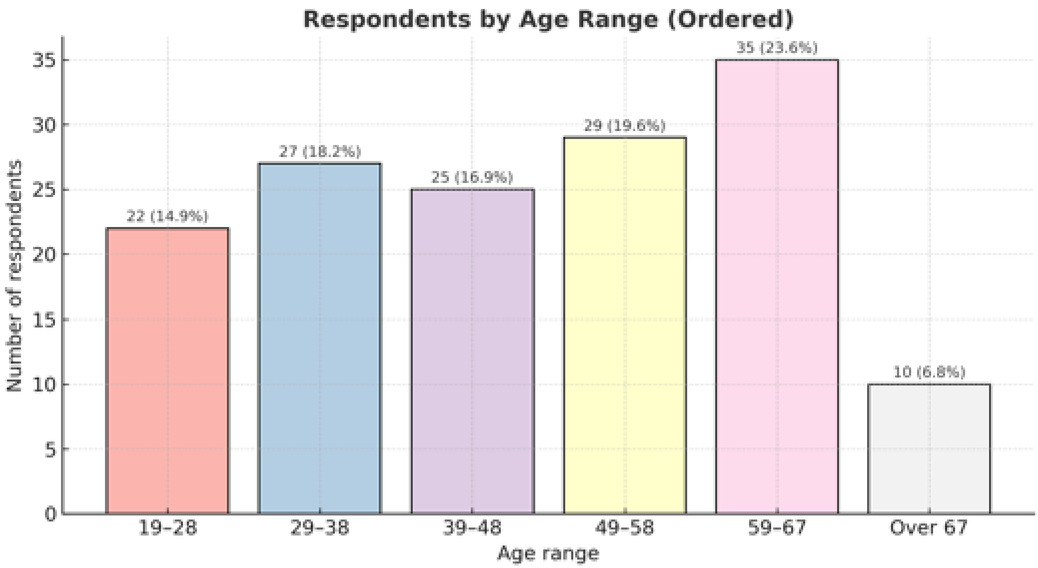

Figure 3 Respondents by Age

This structure reflects the predominant participation of middle-aged and senior professionals, which is consistent with the demographic profile of individuals more

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directly involved or interested in agrivoltaics activities. At the same time, the presence of younger respondents ensures intergenerational diversity and a potential openness to innovation within the surveyed population.

4. Experience and Perception of APV Systems

Most respondents (approximately 80%) have no prior direct experience with agrivoltaic installations. Despite this, the perception of APV as a dual-use technology for energy and agricultural production is predominantly positive. The most frequent answer is 'Very positive' (44 respondents), followed by 'Positive' and 'Neutral'. Similarly, the propensity to adopt APV solutions is generally high: the most common responses are 'Very likely' (34 respondents) and 'Likely', confirming a strong willingness to integrate agrivoltaic systems within existing agricultural or entrepreneurial practices (Figure 4).

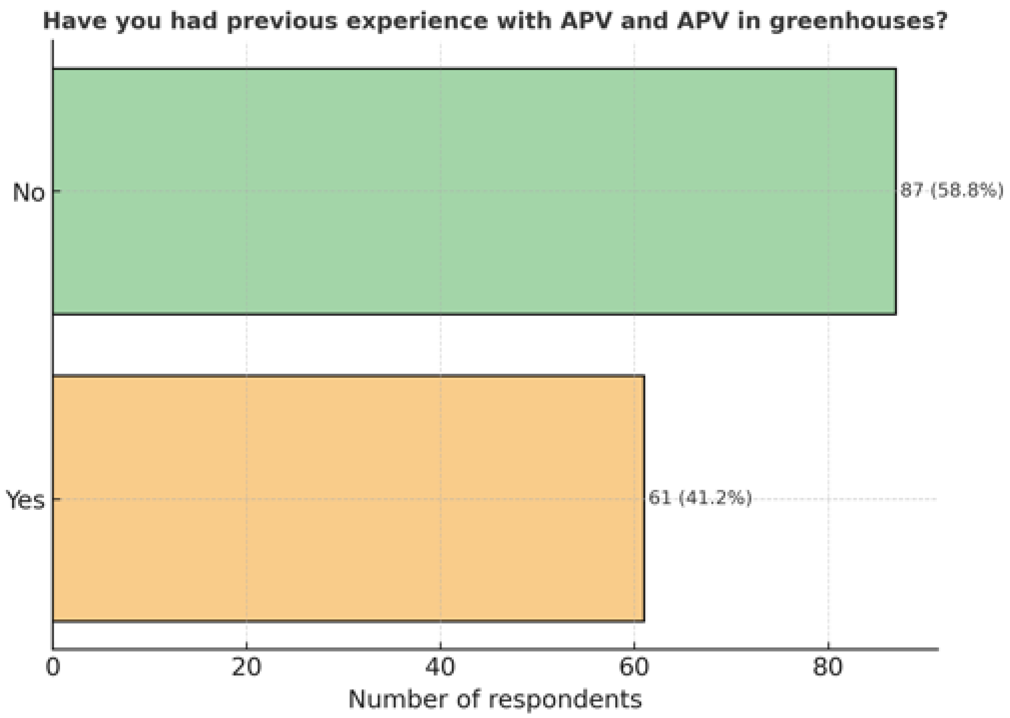

Figure 4 Previous Experience with Agri-Photovoltaics (APV) and Greenhouse APV Systems

The data indicate a predominantly positive perception of agricultural photovoltaics (APV) in greenhouse settings. Nearly half of the respondents (45.9%) expressed a very positive evaluation, while an additional 27.7% reported a positive perception. This means that more than two-thirds of the participants hold a favorable view of integrating APV into greenhouse systems (see Figure 5).

A smaller segment (23.6%) reported neutral attitudes, which may suggest limited direct experience or indecision while awaiting further evidence regarding agronomic, technical, or economic outcomes. Only a small proportion of respondents (2.7% in total) expressed negative or very negative views, indicating minimal opposition to the

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technology. Overall, these findings highlight a high level of acceptance and a generally supportive stance toward the use of APV technologies in greenhouse environment.

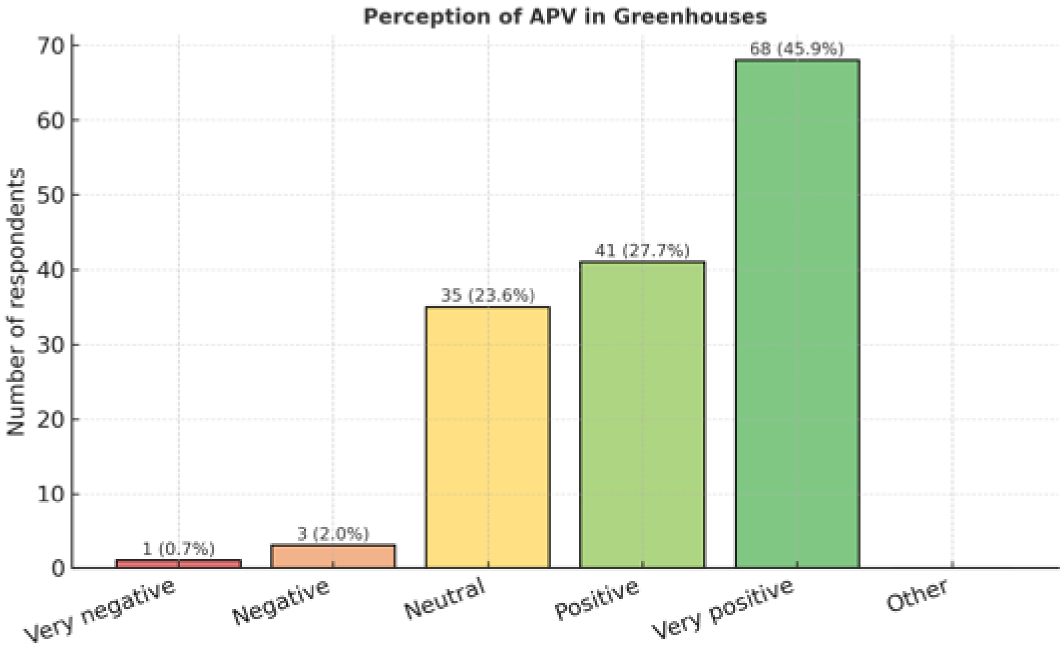

Figure 5 Perception of Agri-Photovoltaics (APV) in Greenhouse Systems

The distribution of responses denotes a predominantly favourable disposition toward the adoption of APV solutions. A substantial share of participants reported a *high* or *very high* likelihood of adoption (20.3% and 32.4%, respectively), indicating a broadly positive orientation toward APV technologies. Approximately one-quarter of respondents (23.6%) expressed a neutral position, which may reflect either limited familiarity with APV systems or the need for additional technical and economic evidence to support their decision-making (see Figure 6). Only a marginal proportion of respondents declared a low propensity to adopt APV (4.1% in total). These results suggest that the potential for APV diffusion is considerable, provided that informational, financial, and operational uncertainties are adequately addressed.

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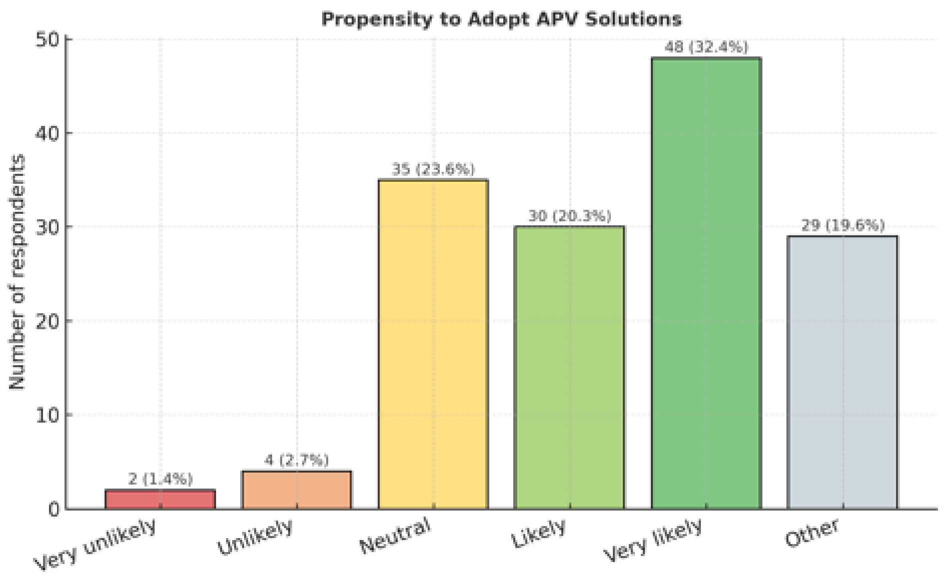

Figure 6 Willingness to Adopt Agri-Photovoltaic (APV) Solutions

5. Cross-country differences in socio-demographic profiles and APV perceptions

The cross-tabulations with row-standardized percentages, along with the chi-square tests, reveal systematic differences across countries in both the socio-demographic structure of respondents and their attitudes toward agrivoltaic (APV) systems. As illustrated in the contingency tables and stacked bar charts, the composition of professions and ages varies significantly between countries, reflecting distinct agricultural sectors and market conditions.

For instance, in Germany, a larger proportion of respondents are younger and professionally connected to agricultural consultancy or academic training. In contrast, Italy and Greece have a higher percentage of farmers with more extensive practical experience in cultivation. These structural differences are statistically significant ($\chi^2 = 288.48$, $p < .001$ for profession; $\chi^2 = 264.07$, $p < .001$ for age) and influence the context in which APV is assessed.

A similar trend emerges regarding previous experience with APV systems, which is strongly linked to the country ($\chi^2 = 405.38$, $p < .001$). Respondents in Germany and Israel report a greater exposure to APV or integrated photovoltaic systems, while those in Italy and Greece demonstrate comparatively lower familiarity. This discrepancy suggests varying levels of technological adoption and policy support.

Furthermore, differences among countries are evident in how respondents perceive APV in greenhouses and their willingness to adopt such systems. Respondents from Israel and Germany tend to have more positive or "very positive" perceptions and higher likelihoods of adopting APV systems soon. In contrast, Italian and Greek respondents often express caution, uncertainty, or a preference to delay adoption. These

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differences are statistically robust ($\chi^2 = 202.57$, $p < .001$ for perception; $\chi^2 = 439.63$, $p < .001$ for propensity to adopt).

The analysis of reasons for either postponing or immediately adopting APV systems indicates that adoption pathways are influenced by country-specific economic and knowledge conditions. In countries where APV deployment is more advanced (e.g., Germany), concerns primarily focus on the predictability of cost-benefit and return on investment. Conversely, in countries where APV is less established (e.g., Italy and Greece), uncertainty arises from a lack of information, unclear agronomic impacts, and perceived technological novelty. The association of these attitudes with country is significant for both motivations to wait ($\chi^2 = 467.16$, $p < .001$) and reasons to adopt ($\chi^2 = 474.69$, $p < .001$). Interestingly, general evaluative statements about agriphotovoltaics as a concept do not differ significantly across countries ($\chi^2 = 584.00$, $p = .198$), indicating the presence of a shared discursive positive frame around the idea of combining energy production with agriculture. In other words, the idea is widely accepted, but conditions for concrete implementation vary by national market maturity, policy incentives, and perceived agricultural risk.

The results indicate that strategies for adopting Agricultural Production Technologies (APV) should be tailored to each country. This should take into account:
The varying profiles of agricultural sectors, such as their experience and orientation towards innovation, the maturity of national energy policies, and the levels of agronomic knowledge and perceived uncertainty among stakeholders.

Consequently, a one-size-fits-all communication or policy model would not be effective. Instead, it is recommended to provide targeted support and implement context-specific demonstration projects to reduce uncertainty and encourage informed adoption.

6. Open-Ended Opinions on Agrivoltaics: a sentiment analysis

The open question 'What are your thoughts on the topic of agriphotovoltaics?' received 146 valid responses, 140 of which are unique. Most comments express optimism and support, describing APV as 'an innovative approach with numerous advantages' or 'a great opportunity for sustainable agriculture'. A smaller portion of respondents express caution, calling for more research and evidence on the economic feasibility and long-term ecological impact.

The responses to the question "What are your thoughts on agriphotovoltaics?" indicate that respondents frequently associate agriphotovoltaics with terms such as "energy," "solar," "agriculture," "production," "greenhouse," "crops," and "farmers." These are operational and productive concepts, indicating that participants primarily view agriphotovoltaics as a practical system that enables the joint production of food and energy (see Figure 7).

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Figure 7 Word Cloud of Perceptions on Agriphotovoltaics

The strong presence of terms like "energy," "electricity," and "production" indicates that respondents view agrivoltaics as a positive opportunity for generating renewable energy. Meanwhile, words such as "agriculture," "greenhouse," and "crops" highlight that agricultural activity remains central to this concept. Additionally, the prominence of the term "income," which appears alongside "farmers" and "electricity," suggests a perceived economic benefit. This indicates that the agrivoltaic system may help stabilize or improve farm revenues. The sentiment word cloud reveals a mixed perception of agrivoltaics, with both positive and negative terms present (see Figure 8).

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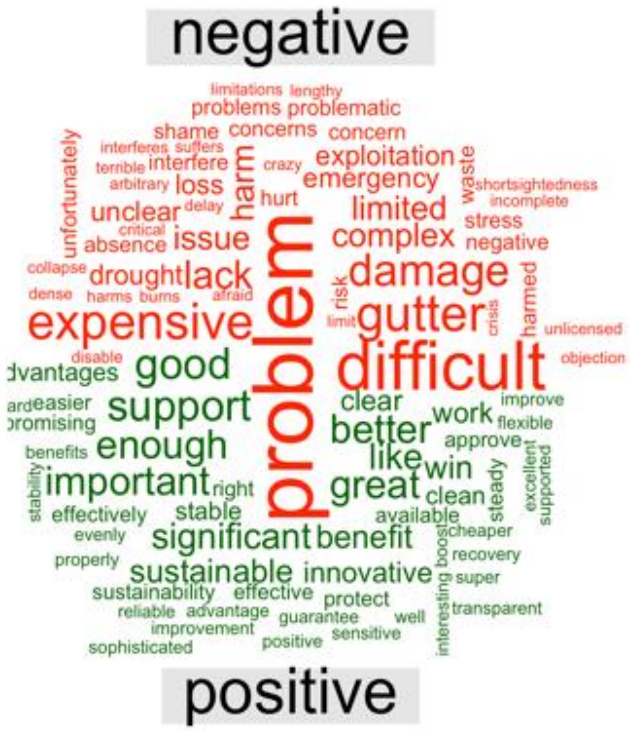

Figure 8 Sentiment Word Cloud of Perceptions on Agriphotovoltaics

On the positive side (green), frequently used words such as "important," "support," "sustainable," "innovative," "benefit," "great," and "significant" suggest that many respondents acknowledge the strategic value and potential advantages of agrivoltaic systems. This is particularly evident in terms of sustainability, stability, and innovation. However, the negative cluster (red) is also significant. Words such as "problem," "difficult," "damage," "expensive," "limited," and "unclear" imply that respondents associate agriphotovoltaics with practical barriers, including economic costs, regulatory uncertainty, technical implementation challenges, and perceived risks to crops.

The central position and size of the word "problem" indicate that concerns play a significant role in the discourse, even when positive expectations are also present. The sentiment expressed is positive in intention but cautious in practice. Respondents see value in agrivoltaics, yet they emphasize the necessity for clearer regulations, more affordable installation, and evidence of agricultural compatibility before fully endorsing widespread adoption.

The descriptive analysis highlights a generally favorable perception of agrivoltaic systems across countries and professional groups, even among participants without direct experience. While costs and technological uncertainties represent the main obstacles, the environmental and economic advantages of APV are widely acknowledged. These findings suggest that policy support, financial incentives, and

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knowledge dissemination could play a decisive role in fostering the diffusion of agrivoltaic technologies.

The open-ended question examined the factors that influence the decision to adopt Agricultural Photovoltaic (APV) systems. Common reasons for delaying adoption often include the technology's immaturity, high installation costs, and uncertainty about long-term profitability. On the other hand, the main reasons for immediate adoption are typically related to the production of clean energy, the reduction of energy costs, and the integration of agricultural production with renewable energy generation.

Discussion and Conclusion

Overall, the findings suggest that while agrivoltaics (APV) is widely recognized in various countries as a promising method for combining agricultural production with renewable energy generation, the willingness to adopt APV systems is heavily influenced by national contexts. Differences in professional backgrounds, age distributions, and prior exposure to APV technologies highlight the distinct institutional, educational, and market environments that shape perceptions and evaluations of this innovation. In countries with established renewable energy infrastructures and well-defined incentive frameworks, such as Germany and Israel, respondents generally display greater familiarity, more positive attitudes, and stronger intentions to adopt APV. In contrast, in countries like Italy and Greece, where structural uncertainties persist, stakeholders exhibit greater hesitation, voicing concerns about economic risks, technical feasibility, and agronomic impacts. The lack of significant differences in how countries generally evaluate Agricultural Production Value (APV) suggests that skepticism towards it is not based on ideology but is instead pragmatic and influenced by specific contexts. This distinction is crucial for policymaking, as it suggests that targeted informational interventions, demonstration sites, transparent performance metrics, and reliable financial incentives can effectively encourage hesitant stakeholders to adopt APV. Additionally, communication strategies should be customized to fit the socio-professional profiles that are most common in each country—focusing on innovators and technical advisors in some regions, while emphasizing experienced farmers and agricultural associate. The results emphasize that Agricultural Production Value (APV) is not just a technological advancement but a socio-technical transition. This transition requires alignment between knowledge systems, economic incentives, and local agricultural cultures. Therefore, effective deployment depends not only on enhancing system performance but also on connecting with the emotional, experiential, and trust-based aspects of decision-making within farming communities.

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Chapter 3 – Participation

1. WORLD CAFÉ METHODOLOGY

Participatory methodologies have progressively assumed a central role in socio-technical innovation processes, especially when technological transition intersects with place-based knowledge regimes, heterogeneous actor constellations, and environmental uncertainties. As innovations increasingly touch upon domains that are materially embedded and socially contested—such as energy infrastructures, food production, and environmental governance, the need to involve those affected by transformation has become not only a normative aspiration but also a functional prerequisite for successful implementation. Participation, in this perspective, is not reduced to a procedural formality; it operates as an epistemic device that enables the surfacing, translation, and circulation of diverse knowledge—technical, experiential, tacit, and institutional.

Within this evolution, the World Café has emerged as a widely adopted method aimed at fostering situated, multi-actor problem-definition and deliberation, and at enabling the co-production of knowledge across epistemic communities. Rather than assuming consensus as a starting point or endpoint, the technique acknowledges conflict, uncertainty, and divergent expertise as productive conditions for collective reasoning. Its dialogic architecture supports the progressive emergence of shared categories of meaning, while preserving the plurality of interpretive frames through which innovation is perceived and valued.

The relevance of such an approach becomes particularly evident in contexts where innovation is not merely a matter of technical performance, but a public issue under negotiation—one that unfolds within complex webs of legality, economic redistribution, ecological trade-offs, and cultural imaginaries. In these situations, the acceptability and durability of new technologies depend on their capacity to align with local ways of knowing and doing, and to articulate credible promises regarding social and environmental futures. The World Café, by bringing diverse actors into sustained interaction, creates an arena in which possible futures are collectively examined, contested, and tentatively prioritized.

Crucially, the method allows multiple viewpoints to coexist, confront each other, and give rise to shared orientations without erasing differences. It therefore counters the technocratic drift that often characterizes innovation governance, re-politicizing decisions that might otherwise be confined within expert domains. Through iterative exchanges and rotation of participants across thematic tables, the World Café constructs a dynamic environment where previous individual understandings become relationally recalibrated. Issues that at first appear fragmented—economic constraints, regulatory uncertainties, operational capacities, identity-based attachments to professional practices—can be recomposed into broader, more systemic visions of change.

The World Café, then, resonates with contemporary demands for participatory governance in socio-technical transitions. It enables dialogue across actor categories that traditionally operate in isolation, enhances the legitimacy of policy and research directions, and nurtures forms of collective intelligence that are essential for navigating

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innovation pathways under conditions of complexity. By situating public engagement at the very heart of technological transformation, it contributes to balancing innovation imperatives with democratic accountability, and to ensuring that future trajectories remain socially anchored and institutionally robust.

1.2 The World Café Approach: Epistemic Foundations, Participatory Design, and Institutional Meaning

The adoption of the World Café methodology within the REGACE project emerges from a precise epistemological stance: socio-technical innovation in agriculture and renewable energy cannot be governed solely through expert knowledge, laboratory performance metrics, or policy directives formulated at a distance from practice. The development of agrivoltaics as an integrated system—simultaneously agricultural, energetic, and environmental—touches upon livelihoods, organizational routines, and material landscapes. Its feasibility depends not only on how panels perform under controlled conditions but on how they transform work practices, cost structures, microclimates, cultivation rhythms, and community expectations. For these reasons, the project has rejected generic or extractive stakeholder consultation and instead adopted a format that treats engaged practitioners as co-interpreters and co-authors of innovation trajectories.

The World Café, as designed for REGACE, is grounded in a constructivist and relational epistemology. It proceeds from the assumption that knowledge relevant to innovation is distributed and situated: farmers, greenhouse managers, and sectoral entrepreneurs hold practical expertise and tacit understanding that cannot be replaced by external assessments. What the method enables is a form of "epistemic symmetry" about the innovation, in which scientific knowledge and operational experience meet as complementary resources rather than hierarchical domains. This is not a trivial aspect: participants were not casual passers-by nor generic citizens, but carefully selected professionals who work daily with greenhouse production, energy infrastructures, or climate-sensitive farming systems. They entered the discussion not to receive information but to confront it: to verify, contest, nuance, and contextualize innovation claims based on their own technical literacy.

From a procedural point of view, the method has been adapted to the specificity of APV experimentation. Before entering deliberation, participants are exposed directly to the technology: visits inside pilot greenhouses, observation of crops under different irradiation regimes, technical demonstrations of panel behavior, discussions on CO_2 capture or grid connection constraints. This "experiential grounding" is fundamental. It ensures that every voice participating in the café rests on a shared object of experience, reducing asymmetries in symbolic authority between researchers and practitioners. It transforms technology from an abstract vision into a situated material condition, enabling critique rooted in concrete perception. This phase functions as a form of cognitive equalization: practical engagement narrows the gap between institutional expertise and the embodied knowledge of workers operating in the field.

Only after this deliberately immersive encounter with the innovation, the collective reasoning unfolds. Participants are invited to move between discussion tables, encountering different colleagues and problem framings at each rotation. Through this

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mobility, interpretations circulate: concerns raised by a greenhouse manager in one table are carried to another and reframed by a producer accustomed to different climatic pressures or business models. Rather than isolating individual contributions, the format encourages progressive hybridization of partial viewpoints and the emergence of more complex diagnoses of feasibility, risk, and opportunity. Unlike extractive consultations where input is collected to be later "processed" by experts, here the processing is performed publicly and in a democratic manner: ideas are confronted, expanded, corrected, and sometimes rejected through direct interaction among peers.

The integration of additional facilitation modes—open space technology, thematic clustering, fishbowl dynamics—amplifies this reflexive circulation. Participants are afforded both the freedom to voice individual concerns and the obligation to interact with others' perspectives**.** What results is a dense deliberative field in which divergences become visible and, rather than being neutralized, become "productive disruptions". A farmer may praise the potential for energy self-sufficiency while another, equally knowledgeable, raises doubts about microclimate impacts or long-term maintenance ability. These frictions, brought to the surface in a structured yet open environment, become manageable tensions: they delineate what must be resolved for adoption to be credible and legitimate. The REGACE Project model designed for the participatory sessions is presented in Table 21.

Participatory Session Phase	**Description**	**Function**	**Outcomes**
1. Experiential grounding	Participants engage directly, under REGACE team guidance, with the technology through pilot-site visits, observing crop performance, panel behavior, and key technical aspects such as CO_2 capture and grid connection.	Creation of a *shared experiential basis* among all participants, reducing symbolic or cognitive asymmetries between researchers and practitioners.	Transforms technology from abstract concept to tangible experience. Establishes cognitive equalization across roles. Enables critique grounded in direct observation and embodied understanding.
2. Integrative facilitation modalities	The process integrates additional facilitation methods such as *Open Space Technology*, *thematic clustering*, and *fishbowl dynamics* to deepen interaction Tand synthesis.	Enhancement of the reflective depth and inclusiveness of the deliberation process by accommodating different communication styles	Supports synthesis across thematic clusters Encourages active participation from diverse actors.

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Participatory Session Phase	Description	Function	Outcomes
		and interaction intensities.	Consolidates insights into shared understandings or actionable orientations.

Table 21 Phases and functions for the REGACE Project participatory sessions

The social value of this methodology set up for the context of REGACE, lies first in mutual recognition: acknowledging that those operating the greenhouses are not end-users in a passive sense, but possess a form of expertise that is not simply local but professional, strategic, and future-oriented**.** This recognition corrects a common distortion in innovation governance, where technological promise is assumed to prevail over lived experience. Here, experience is treated as a form of collective anticipatory intelligence**,** capable of identifying opportunities and problems which are invisible to external observers before they become material successes or failures.

Second, the world café functions as a site of translation of ideas and perception. Highly technical issues—grid stability, seasonal mismatch between generation and consumption, light scattering behavior—are re-articulated in operational language that renders them discussable without simplification. Conversely, concerns expressed by farmers—crop shading, infrastructural vulnerability, labor constraints—are reintroduced into the scientific discourse as parameters that must be analytically accounted for. The world café then acts as a boundary infrastructure where knowledge circulates among partcipants and research teams without being flattened.

Third, the format promotes collective orientation among the participants. The objective is not to dissolve differences but to produce shared problem definitions and conditions of acceptability**.** When practitioners collectively state that investment costs remain the primary barrier, or that training on digital system control must accompany any installation, they effectively articulate research and policy-relevant directions for innovation ecosystems. What emerges are not individual opinions but institutional signals: priorities that research, governance, and industry must address if agrivoltaics is to scale responsibly.

This approach proves particularly powerful in the anticipatory dimension of governance. Participants are encouraged to think not only about how APV works today, but what it could become**,** what futures it enables or obstructs**,** who is empowered by its deployment**,** and what responsibilities accompany its adoption**.** Futures are treated not as expert predictions but as shared imaginaries that require negotiations among those who shape it. By foregrounding this temporal horizon, the world café prevents innovation from being framed as an inevitable trajectory and instead positions it as a shared choice—one that must satisfy social, economic, and environmental preconditions defined by those who will ultimately live with its consequences.

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It follows that what the World Café produces for REGACE is not just anecdotal feedback from different contexts but a strategic, rooted knowledge asset. Through collective synthesis and clustering, practitioner contributions are activated as analytical resources: they define realistic feasibility constraints, operational thresholds, legitimacy conditions, and new research needs. They reveal when tech enthusiasm is fragile, when risks are underestimated, and where institutional bottlenecks reside. They warn against technocratic lock-in, the risk that technology advances faster than the capacity of farmers and local systems to adopt, mantain and sustain it.

In this sense, the World Café operates as institutional intelligence in action. It strengthens responsiveness in innovation trajectories and maintains alignment between the pace of technological development and the absorptive capacity of agricultural systems. It creates governance conditions in which resistance is not deferred until late-stage deployment, but addressed upstream, when redesign remains possible and participation can still alter the direction of change.

The format of world café designed for and adopted in REGACE is not a generic participatory exercise but an infrastructural component of innovation governance of the project. It ensures that agrivoltaics evolves not as an external imposition but as a co-produced transition, sensitive to territorial knowledge, supportive of practitioners' autonomy, and legitimate in the eyes of those responsible for ensuring food production under increasingly demanding climatic conditions. The World Café synthesizes technical potential and lived reality, shaping a future of agricultural energy systems that is not only efficient but socially intelligible, institutionally accountable, and operationally viable.

The world café set up during the REGACE Project are presented in Table 22

Location & Hosting Partners	Date	Participants
Fattoria Solidale del Circeo – Italy	07 Feb 2024	9 farmers
Bio-Gärtnerei Watzkendorf – Germany	23 Jul 2024	7 farmers
Humboldt University – Berlin (Germany)	23 Jan 2025	8 farmers
BOKU University – Vienna (Austria)	04 Feb 2025	10 experts
University of Thessaly – Volos (Greece)	10 Feb 2025	10 farmers
Fattoria Solidale del Circeo – Italy	12 Sep 2025	8 farmers
University of Thessaly – Volos	03 Oct 2025	9 farmers
Germany (University von Humboldt)	13 Oct 2025	10 farmers

Table 22 Location and participants of the world cafés

1.2.1 Implementation Limitations and Operational Context

The initial methodological framework of REGACE envisaged the organisation of three World Cafés in each partner country, ensuring analytical balance and comparable participatory depth across national contexts. This objective, however, was constrained by a combination of geopolitical and infrastructural contingencies that reshaped the

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effective implementation. The armed conflict in Israel, which began on 7 October 2023 and persisted until the truce of October 2025, made the organisation of participatory activities in that country impossible for security reasons. The physical safety of participants and collaborators remained the determining factor in the consortium's decision-making process, leading to the suspension of all in-person events planned in Israel for the entire duration of the project.

An alternative scenario—holding the Israeli World Cafés through online modalities—was examined during the first half of 2024. After consultation with local partners and methodological experts, the consortium concluded that such a virtual format would be inadequate to reproduce the epistemic richness and experiential character of the World Café method. The participatory approach adopted by the team relied on the integration of deliberation, field observation, and direct interaction with technological prototypes. The visit to the agrivoltaic pilot in Kafr Qara constituted a crucial component of this experiential framework. A purely remote setting would have reduced participants' exposure to the material and contextual dimensions of the installation, undermining the methodological integrity of the exercise. The decision not to proceed with virtual adaptation thus reflected a commitment to maintaining the quality of knowledge co-production rather than a withdrawal from engagement.

A second limitation derived from the temporal misalignment between the participatory schedule and the infrastructural readiness of the national pilot sites. The installation and grid connection of the agrivoltaic systems in Pontinia (Italy), Volos (Greece), and Watzkendorf (Germany) experienced delays due to bureaucratic procedures, supply-chain interruptions, and technical integration challenges. These constraints, compounded by heterogeneous national regulatory conditions, affected the sequencing of activities and reduced the available timeframe for on-site engagement. The original plan of three World Cafés per country was therefore revised to reflect what was realistically achievable within the project's operational window.

Within the eighteen months available for implementation, the team conducted three World Cafés in Germany, two in Italy, two in Greece, and one in Austria. The Austrian session, held within a university research facility rather than a productive greenhouse environment, engaged primarily scientific and institutional actors. Although this context yielded valuable insights into the governance of research-driven innovation, it provided a more limited interface with agricultural practitioners. The asymmetry between experimental and applied contexts thus became a defining characteristic rather than a methodological shortcoming, reflecting the diversity of infrastructures and research logics across the consortium.

This reconstruction of operational conditions clarifies the interdependence between this work and the other components of REGACE. The team operated as a transversal domain linking technological development, socio-economic evaluation, and policy modelling. The procedural adjustments required to address infrastructural and

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geopolitical contingencies were managed through continuous coordination with the teams responsible for technology implementation and impact assessment. Such collaboration ensured that, despite the reduction in the number of participatory events, the methodological consistency and analytical objectives were preserved.

Although the final number of World Cafés differed from the original plan, the qualitative density of interactions compensated for the numerical reduction. Each session captured a specific intersection of technological, agronomic, and institutional dynamics, revealing how agrivoltaic innovation was perceived and negotiated in different contexts. The comparative synthesis of these dialogues generated a multidimensional understanding of agrivoltaics as both a technical system and a socio-political process. Furthermore, the iterative exchange between this work package and the other work packages facilitated the translation of participatory insights into operational and policy-oriented outputs, strengthening the project's interdisciplinary coherence.

From a scientific perspective, the constraints encountered highlight the sensitivity of participatory research to external contingencies such as infrastructural readiness and political instability. Methodological rigour in this domain depends not only on adherence to the original design but also on adaptive governance that preserves epistemic integrity while responding to disruption. The experience demonstrates that flexibility, when grounded in collaborative coordination, can reinforce rather than weaken scientific credibility.

In conclusion, the implementation trajectory should be interpreted not as a limitation but as an empirical reflection of the co-evolution between technological infrastructures and participatory practice. The eight World Cafés ultimately realised generated substantial analytical material, enriching both this work package and the broader REGACE consortium. These dialogues revealed key patterns of convergence and differentiation among stakeholders, illuminating the socio-technical conditions that shape the feasibility and legitimacy of agrivoltaics across Europe. The following sections build upon these findings, examining first the individual contexts of Pontinia, Volos, Vienna, Watzkendorf, and Berlin, before advancing a comparative synthesis that situates these experiences within Europe's evolving framework for energy–agriculture integration.

2. 1ST WORLD CAFÉ IN ITALY

Italy, Pontinia - 7 february 2024

2.1 General Overview

The first World Café took place on 7 February 2024 at the *Fattoria Solidale del Circeo* in Pontinia (Italy). The session was coordinated by Professors Cristina Cornaro and

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Andrea Volterrani from the University of Rome Tor Vergata, supported by Dr. Marco Serra and Dr. Maria Cristina Antonucci (CNR), Dr. Ronen Katz (Trisolar), and Dr. Marco Berardo di Stefano (Fattoria Solidale del Circeo).

9 participants representing farms, cooperatives, and social agriculture initiatives took part in the discussions. The multidisciplinary facilitation team from Tor Vergata ensured methodological consistency and inclusivity.

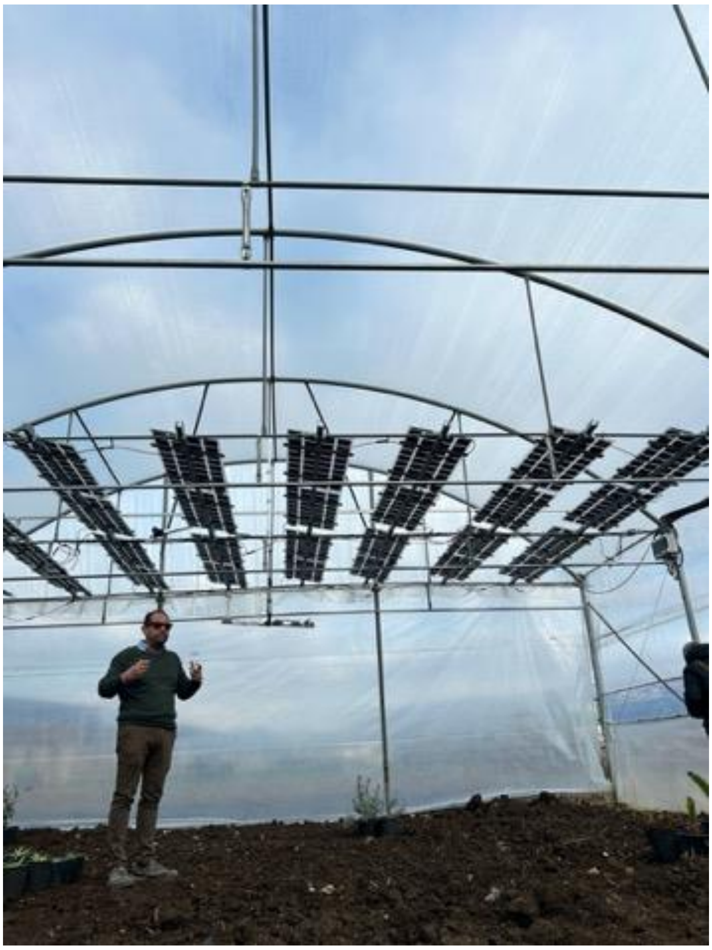

Figure 9 The first World Café in Italy

The agenda was structured around the following phases:

1. Presentation of the REGACE agrivoltaics system and its technical features;
2. Guided visit to the greenhouse and discussion of the experimental crops;
3. Open Space session to collect initial reactions regarding opportunities, risks, and possible developments;
4. Thematic World Café tables focusing on each dimension;
5. Collective synthesis through a Fishbowl discussion.

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This design enabled a balance between hands-on observation and structured dialogue, allowing participants to relate the technological aspects of the project to their own farming experience.

The Italian World Café marked the first application of the participatory approach foreseen by the project. The event successfully combined technical demonstration with stakeholder dialogue, creating a productive space for reflection and feedback.

Participants showed strong curiosity and engagement throughout the day. Direct exposure to the functioning greenhouse installation helped them to visualise the implications of the technology for everyday agricultural work. Discussions were pragmatic and focused, revolving around three central questions: *Is it economically viable? Can it work in practice? What are the conditions for it to succeed?*

The exchanges produced a coherent set of insights that were subsequently clustered into three analytical categories: opportunities, risks, and future developments.

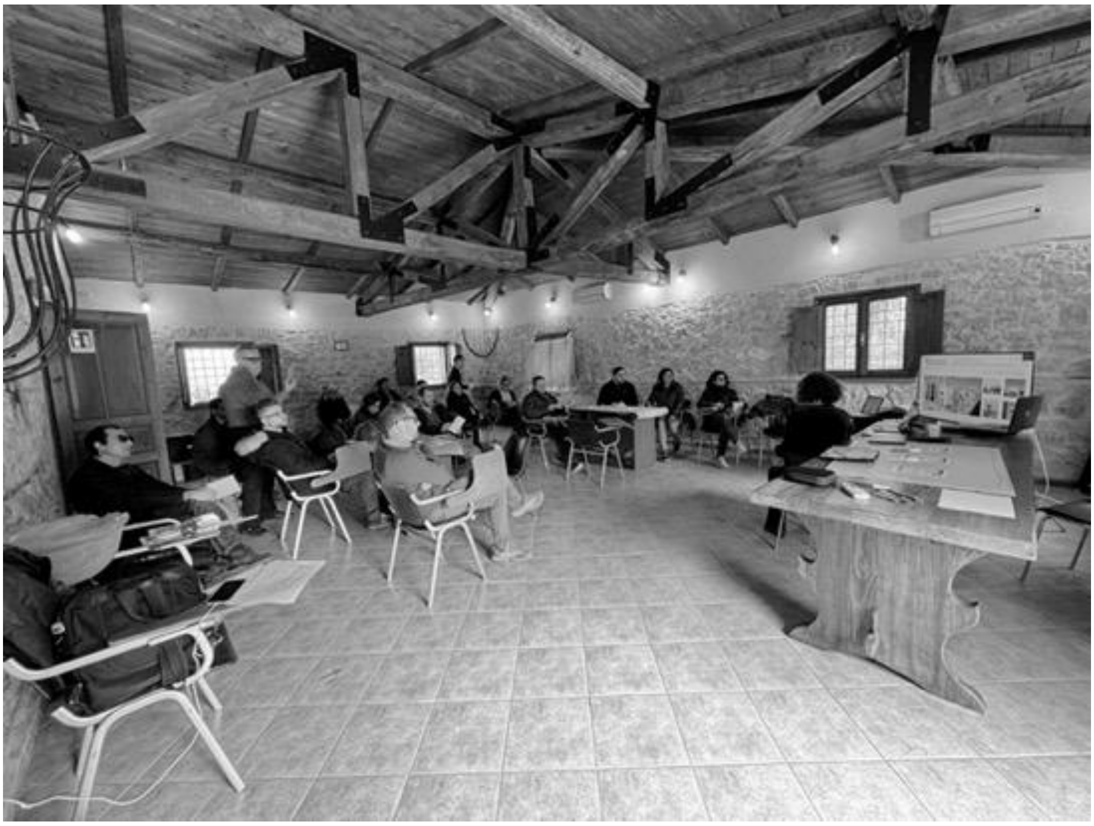

Figure 10 The first World Café working with participants

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2.2 Emerging tendencies

2.2.1 Opportunities

Participants recognised agrivoltaics as a promising approach to improving the economic resilience of agricultural enterprises. The possibility of combining food production with on-site renewable energy generation was seen as an effective way to diversify income sources and reduce exposure to energy price volatility.

Several farmers underlined the advantage of using self-produced energy for irrigation systems, storage facilities, and electric agricultural machinery. The system was also associated with the potential for technological modernisation, enabling a gradual transition towards precision farming and digital monitoring tools.

Some participants highlighted the collective dimension of agrivoltaics, suggesting that local energy communities could enhance both economic and social sustainability. Cooperative energy management, in their view, would allow small producers to share benefits and reduce costs.

2.2.2 Perceived critical issues

Despite the generally positive outlook, several barriers were identified. The most significant concern related to the high initial investment cost and the length of the payback period. Participants stressed that without targeted public support, such as grants or subsidised loans, the technology would remain out of reach for small and medium-sized farms. Operational and technical issues were also discussed. Farmers emphasised the importance of simple and reliable maintenance procedures and expressed concern about possible interference with existing farming operations. Attention was also drawn to training needs, particularly regarding the management of hybrid systems that combine agricultural and energy components.Environmental considerations were not secondary. Some participants questioned the long-term sustainability of panel materials, their recyclability, and the potential ecological impact of installation structures, particularly where concrete foundations might affect soil permeability.

2.2.3 Future Developments

The participants agreed that further experimentation and long-term monitoring were necessary to assess the agronomic and economic impacts of the system. They proposed several directions for future development:

- Integration of agrivoltaics with irrigation, microclimate regulation, and digital monitoring systems;
- Introduction of service-based models, where suppliers provide installation, maintenance, and system management as a single package;

- Strengthening of training and capacity-building programmes for farmers and technicians;
- Establishment of a clear and stable regulatory framework to ensure investment predictability;
- Development of community-scale models to support local self-consumption and cooperative ownership.

All the emerging trends from the world café discussion are presented in Table 23.

Category	**Main trends and insights**	**Illustrative stakeholder perspective**
Opportunities	• Dual-use of land enables simultaneous food and energy production, improving farm resilience and income diversification. • Use of self-produced electricity for irrigation, storage, and machinery increases energy autonomy. • Supports technological modernisation, encouraging precision agriculture and digital monitoring. • Potential to form local energy communities that share surplus power and costs, fostering cooperation.	"If the system helps us cut energy bills and use power for our irrigation pumps, that's a concrete advantage."
Perceived critical issues	• High investment cost and long payback period remain the main obstacles, especially for small and medium farms. • Need for public support instruments (grants, loans, incentives) to offset financial barriers.• Operational concerns about maintenance, downtime, and interference with farming activities. Training gaps on hybrid energy–agriculture systems.	"Without financial aid, this is not affordable for most farms—costs come first."

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Category	Main trends and insights	Illustrative stakeholder perspective
	Environmental questions about panel materials, recyclability, and the impact of installation structures on soil permeability.	
Future Developments	•Expand experimentation and long-term monitoring of agronomic and economic results. Integrate APV systems with irrigation, climate-control, and digital monitoring technologies. Adopt service-based business models bundling installation, maintenance, and data management. Provide structured training and capacity-building for farmers and technicians. Ensure policy stability and regulatory clarity to attract investment.• Encourage community-scale or cooperative models for local self-consumption.	"The idea of community ownership could make it viable—if we share energy, we share benefits."

Table 23 Key Tendencies Emerging from World Café 1 (Italy): Opportunities, Risks, and Future Developments

2.3 Diverging and Converging Themes

Across the discussion tables, participants progressively arrived at a set of converging perspectives, which became increasingly clear as the dialogue evolved. The potential of agrivoltaics to support a more sustainable and resilient agricultural model was widely acknowledged. Farmers, technicians, and local actors expressed confidence that the dual use of land for energy and food production constitutes a promising direction for future development, particularly in a context of rising energy costs and growing climatic pressure on crops.

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Figure 11 The World Café method

This general openness toward innovation was, however, consistently tempered by a shared awareness of the economic barriers that still stand in the way of implementation. The initial investment required for installing photovoltaic systems in greenhouses emerged as the most critical constraint, especially for small and medium-scale farms that lack the financial flexibility to absorb long-term returns on capital. Participants also emphasized that the technological shift implied by agrivoltaics demands new forms of knowledge and operational support. They highlighted the need for targeted training and for ongoing technical assistance capable of ensuring proper system management, from maintenance to optimization of energy flows and crop performance under modified microclimatic conditions.

Finally, there was widespread agreement that policy and regulatory frameworks will determine whether agrivoltaics remains an experimental niche or becomes an accessible, mainstream component of European agriculture. Stable institutional guidance, transparent procedures, and incentive schemes calibrated to different farm scales were repeatedly cited as prerequisites for enabling farmers to commit to such an innovation with confidence and clarity. These elements trace a coherent picture of the participants' perception: agrivoltaics is seen not only as desirable but potentially

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transformative — provided that economic risks are mitigated, professional competencies are strengthened, and the institutional environment evolves in step with the technological opportunity. At the same time, some differences in emphasis emerged between participants. Farmers focused primarily on short-term feasibility and return on investment, while researchers and facilitators highlighted the importance of continued experimentation and system optimisation. These differences reflect complementary viewpoints rather than conflict, underscoring the value of dialogue between scientific and practical expertise. The main outcomes of the converging and diverging perspectives are summarized in Table 24.

Dimension	**Main insights**	**Analysis and interpretation**
Converging perspectives	Broad consensus that **agrivoltaics is a credible strategy** for sustainable agricultural development. Agreement that **high upfront investment costs** are the primary barrier to adoption.• Shared recognition of the **need for training, technical support, and financial instruments**. Expectation that **clear institutional guidance and incentive schemes** will determine future uptake.	Participants across all backgrounds recognised both the potential and the challenges of agrivoltaics systems. The discussion revealed a common understanding that innovation must be accompanied by structured support, both financial and technical.
Diverging perspectives	**Farmers** emphasised short-term feasibility, cost–benefit balance, and operational simplicity. **Researchers and facilitators** focused on long-term experimentation, optimisation, and environmental monitoring. Differences reflected **distinct professional priorities** rather than disagreement.	These variations illustrate complementary standpoints: practitioners seek immediate viability, while researchers aim for system refinement. The coexistence of both viewpoints reinforces the importance of ongoing dialogue and co-design within the REGACE participatory framework.

Table 24 Converging and Diverging Perspectives from World Café 1 (Italy)

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2.4 Discussion of the results

The Italian World Café offered a detailed snapshot of how agricultural actors perceive agrivoltaics at this early stage of experimentation. The discussion confirmed that the technology is broadly regarded as a promising innovation capable of addressing several of the pressures currently affecting the agricultural sector—energy dependence, economic fragility, and environmental uncertainty. However, it also became clear that enthusiasm alone is not sufficient to guarantee adoption. The willingness of farmers to integrate such systems into their production routines depends on a combination of economic, technical, and institutional factors that must converge to create favourable conditions for transition.

A general sense of readiness for innovation was evident throughout the session. Participants showed curiosity and openness towards the technology, recognising its coherence with the broader shift toward sustainable energy use and the digitalisation of agriculture. Many saw agrivoltaics as a logical next step in the ongoing evolution of farming, one that could bring agriculture closer to national and European energy transition goals. At the same time, this conceptual acceptance was tempered by pragmatism. Farmers' interest remained closely tied to tangible evidence: they wanted to see real data on productivity, maintenance requirements, and energy yields before committing to investment. For them, innovation must translate into visible, measurable benefits rather than remain at the level of principle. The general attitude could be described as "cautious optimism"—a readiness to engage, provided that practical demonstrations continue and that adoption does not expose farms to excessive financial risk.

Economic sustainability emerged as the decisive factor shaping attitudes toward agrivoltaics adoption. For most participants, the question was not whether the technology is desirable, but whether it is financially viable. Farmers were quick to identify the economic gap between large-scale installations—often supported by corporate capital—and the realities of small and medium-sized enterprises operating in agriculture. The need for adequate policy instruments, such as low-interest loans, subsidies, or long-term incentive schemes, was repeatedly mentioned as a precondition for uptake. Participants also reflected on the volatility of energy markets and the uncertainty of selling surplus electricity, reinforcing the perception that financial predictability is as important as technical reliability. The session made it clear that the viability of agrivoltaics will hinge on embedding innovation within stable and equitable economic frameworks capable of distributing both risks and benefits across the agricultural sector.

Closely linked to the economic dimension was the recognition that knowledge and technical support are essential for any meaningful transition. The discussion revealed that while farmers are highly skilled in crop management, they often feel underprepared to handle the technological and electrical components of hybrid systems. Many

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expressed a desire for dedicated training programmes, demonstration farms, and advisory networks capable of translating complex technical information into accessible, practice-oriented guidance. This need for learning goes beyond operational know-how; it also includes understanding how agrivoltaics fits into broader business models, energy accounting, and regulatory compliance. The conversation thus highlighted a dual demand: on one hand, for localised technical assistance during installation and maintenance; on the other, for continuous institutional support that sustains confidence and reduces the perceived risk of technological dependency.

Environmental considerations were discussed in similarly nuanced terms. Participants readily acknowledged the ecological promise of agrivoltaics—reducing land consumption through dual use, lowering emissions, and improving resource efficiency. Yet they also warned against the assumption that these benefits are automatic. There was broad agreement that environmental balance and site-specific design must remain central to any future development. Farmers insisted that each installation should be tailored to its microclimatic and agronomic context, taking into account crop types, soil characteristics, and local weather conditions. The discussion returned several times to the potential impact of shading on growth and yield, and to the importance of long-term field trials to understand these effects in measurable terms. Participants also raised questions about the life cycle of materials, waste management, and recyclability—signalling a sophisticated awareness of sustainability that goes beyond energy generation alone.

The Italian World Café revealed that agrivoltaics sits at the intersection of promise and prudence. The technology is perceived as aligned with the sector's long-term trajectory, yet its success depends on transforming optimism into concrete operational and institutional support. Economic feasibility, continuous learning, and environmental calibration emerged as mutually reinforcing pillars of acceptance. When considered together, these insights underscore a fundamental lesson: innovation in agriculture cannot advance through technology alone but requires an ecosystem of trust, capacity, and governance that makes transition both possible and desirable.

2.5. CONCLUSIONS

2.5.1 Strategic Conclusions

The first Italian World Café showed that agrivoltaics is widely regarded as both credible and desirable, a field of innovation that promises to align agricultural production with the broader goals of energy transition. Yet participants were equally clear that this potential will only materialise if the technology is embedded in conditions that are economically fair, environmentally responsible, and institutionally coherent. The conversation revealed a sector that is open to change but still constrained by structural limits—financial, technical, and regulatory—which must be addressed in parallel if agrivoltaics is to become a viable path for the future of farming.

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From an economic standpoint, participants viewed agrivoltaics as a stabilising opportunity in a sector increasingly exposed to uncertainty. Producing renewable energy on-site was seen as a way to lower operating costs, hedge against energy price volatility, and build longer-term resilience for farms with modest margins. At the same time, this optimism was tempered by realism. For many small and medium-sized producers, the initial investment required for installation remains prohibitively high. Without targeted public instruments—grants, low-interest financing, cooperative investment models, or predictable feed-in arrangements—the technology risks being confined to larger, capital-intensive operations. Farmers were clear that adoption cannot depend on individual initiative alone: it requires a structural framework that distributes costs and benefits more equitably across the agricultural landscape. In this sense, the economic dimension of agrivoltaics is also a social one, tied to inclusion and fairness as much as to profitability.

A second conclusion concerns knowledge and capacity building, which emerged as an indispensable condition for innovation. Farmers' openness to experimentation was evident, but many expressed uncertainty about the technical complexity of hybrid systems that integrate energy production with greenhouse or field operations. They asked for guidance, not only on installation and maintenance but on how such systems fit within broader farm management strategies and regulatory requirements. The World Café discussions underscored that training, demonstration sites, and local advisory networks are essential—less as supplementary measures than as part of the innovation process itself. Knowledge transfer must also extend to institutions and intermediaries, ensuring that local authorities, cooperatives, and technical bodies can provide clear and consistent information. The path to adoption, in other words, is as much about building shared competence and trust as it is about deploying hardware and infrastructure.

The third area of reflection relates to technological and environmental integration. Participants repeatedly stressed that agrivoltaics should not be treated as a one-size-fits-all solution. Its design and performance must respond to local agronomic, climatic, and ecological conditions. Balancing energy production with crop health and yield was seen as a central challenge, one that calls for adaptive technologies such as transparent or semi-transparent panels, adjustable shading systems, and integrated irrigation or climate-control mechanisms. There was also a lively discussion around the environmental footprint of materials—panel recyclability, soil permeability, and the eventual decommissioning of installations. These considerations reflect a mature understanding among stakeholders: sustainability will be measured not by rhetoric but by the capacity to prove, through ongoing experimentation, that agrivoltaics genuinely improves environmental performance without displacing traditional farming practices.

Finally, participants converged on the need for policy coherence and governance alignment. The current regulatory landscape, divided between agricultural and energy sectors, was described as fragmented and at times opaque. Farmers expressed

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frustration with overlapping procedures and shifting incentive schemes that create uncertainty and delay. A stable and transparent policy environment, supported by coordination between local, national, and European authorities, was viewed as a precondition for investment and long-term planning. Agrivoltaics, as the discussions made clear, sits at the intersection of multiple policy domains—rural development, renewable energy, land use, and environmental protection. Effective governance will therefore depend on the ability to link these spheres through clear institutional cooperation and predictable regulatory pathways.

The findings from the 1st Italian World Café suggest that the potential of agrivoltaics is not confined to the technology itself, but is also contingent on the ecosystem that provides support. It is evident that economic feasibility, technical knowledge, environmental design and policy alignment are mutually dependent elements of the same process. Farmers' demands were not for a ready-made solution, but rather for conditions that would render innovation plausible, safe, and rewarding. The ensuing discourse has delineated the contours of a collective agenda, which calls for a collaborative engagement between knowledge producers, policy makers, and land cultivators. The true potential of agrivoltaics is realised through such collaborative efforts, which represent more than just the implementation of a novel technology; rather, they constitute a collective strategy for the sustainable renewal of European agriculture.

2.5.2 General Reflections

Beyond its empirical outcomes, the Italian World Café offered a clear demonstration of how participatory methods can strengthen the social legitimacy of technological innovation. The event illustrated that the success of agrivoltaics depends as much on dialogue as on design. Farmers were not approached as passive beneficiaries of research, but as interlocutors whose everyday knowledge can meaningfully shape the trajectory of innovation. Their observations—rooted in practical experience, risk awareness, and local know-how—proved indispensable for grounding technical ambitions in social reality. This encounter between scientific expertise and field experience generated a sense of joint ownership, turning what might have been a consultation exercise into a shared process of reflection and learning.

The discussions also exposed the deeper cultural dimension of agrivoltaics. Participants tended to view the technology not only as a new production system but as part of a broader shift in agricultural identity—towards more autonomous, resource-efficient, and environmentally conscious forms of practice. For some farmers, producing both food and energy on the same land symbolised a renewed balance between productivity and stewardship, between independence and interdependence. This perspective linked innovation to values such as responsibility, care for the landscape, and local self-reliance. In this way, agrivoltaics became a lens through which broader questions about the future of rural life were articulated: how to remain competitive while preserving

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ecological integrity, and how to integrate technological progress into existing social fabrics.

These reflections underline that agrivoltaics is not simply a technical solution but a social project—one that requires mutual trust, long-term commitment, and institutional responsiveness. Participants made it clear that cooperation between farmers, researchers, and policymakers must go beyond the pilot stage and evolve into a sustained partnership. The credibility of the transition will rest on transparency in decision-making, equitable access to benefits, and continuous feedback loops between field experience and regulatory design.

In this light, agrivoltaics can be understood as a strategic interface between the green transition and rural development. By coupling renewable energy generation with sustainable food production, it directly contributes to the European Union's overarching objectives of climate neutrality, circular resource use, and territorial cohesion. Yet this alignment will only deliver its full promise if the social and territorial dimensions of innovation are treated with the same seriousness as the technical ones. Maintaining that balance—between efficiency and inclusion, between ambition and care—will be essential for ensuring that agrivoltaics becomes not only a technological milestone but also a model for how Europe can pursue ecological transformation through shared responsibility and collective intelligence.

Category	Insights
Opportunities	Diversified income possibilities (energy+crops)
	Energy autonomy for farming
	Operational innovation
	Creation of energy communities with other farmers
Risks	High capital cost
	Maintenance complexity
	Need for continuous training
	Environmental management of materials
Future Developments	Integration with irrigation and climate systems,

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Category	Insights
	Service-based models
	Capacity-building
	Stable regulatory framework
Strategic Priorities	Financial support mechanisms
	Technical training
	Environmental optimisation
	Coherent multi-level governance

Table 25 Priorities from World Café 1 (Italy)

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3. 2nd WORLD CAFÉ IN GERMANY (WATZKENDORF)

3.1 General Overview

The conversations during the world café revealed a cautious but tangible interest in agrivoltaics as a possible trajectory for innovation in German farming. Farmers recognised that producing electricity within the greenhouse environment could serve multiple strategic objectives: reducing reliance on external energy suppliers, mitigating the economic strain of rising electricity prices, and strengthening the sector's contribution to climate-neutral agricultural models. Some participants also suggested that early adoption of APV could bolster the environmental credentials of organic farms and support their competitive positioning in a market increasingly attentive to energy footprints and sustainability criteria.

Figure 12 The second World Café in Germany

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3.2 Emerging tendencies

This general openness toward the new technology was tempered by a clear set of conditions identified as necessary for any future investment decision. First, the technology must prove itself economically realistic for the small and medium-sized greenhouse structures that characterise German horticulture. Business models based exclusively on large-scale installations were viewed as unsuited to the fragmented nature of the sector. Second, participants stressed that thermal management inside the greenhouse is a critical variable. If the panels exacerbate heat stress or impede ventilation, both crop performance and the efficiency of the solar modules may deteriorate, producing negative outcomes for the farm.

Participants also pointed to institutional uncertainties concerning authorisation procedures, the rights and responsibilities surrounding energy and data flows, and the reliability of grid connection for surplus electricity. Without transparent rules on these fronts, farmers remain reluctant to assume financial risk. Operational aspects were equally central: any APV solution must offer accessible maintenance and ideally incorporate a degree of automation to avoid adding labour burdens to already intense production cycles. The possibility of retrofitting existing structures was considered an advantage, reducing disruption and avoiding the sunk costs associated with replacing functioning greenhouses. The main trends emerging from the discussion of the world café are presented in Table 26.

Thematic area	Key trends	Implications for APV deployment
Economic feasibility	Technology must be viable for small/medium greenhouses Large-scale–only business models seen as unsuitable	APV must adapt to the fragmented structure of German horticulture; incentive schemes must support diverse farm sizes
Microclimate and system performance	Heat stress and ventilation are critical concerns Risk that shading and thermal effects may reduce both yield and PV efficiency	Requires refined panel design, dynamic control systems, and site-specific agronomic validation
Regulatory and institutional environment	Uncertainty around permits, energy management rights, and data governance Lack of clarity in the institutional environment deters investment	Policy harmonization, streamlined procedures, and clear rulemaking needed to build trust
Grid integration	Concerns about reliability and conditions for feeding surplus energy into the grid	Infrastructure must evolve in parallel; farmers need guaranteed access and fair pricing models

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Thematic area	Key trends	Implications for APV deployment
Operational management	Maintenance must be simple and affordable Automation viewed positively to avoid increasing labor burden	Service models, training, and remote monitoring should be integrated into system design
Structural compatibility	Retrofitting existing greenhouses considered advantageous	Solutions must minimize disruption and avoid sunk costs tied to total reconstruction
General Attitude Toward Innovation	Neither scepticism nor unconditional approval Openness remains conditional on tangible benefits	Evidence-based demonstrations and pilot evaluations will shape long-term adoption decisions

Table 26 Trends emerging in the 2nd world café discussion

These inputs depict a sector that is neither sceptical nor uncritically enthusiastic. Rather, farmers displayed a conditional openness grounded in pragmatic evaluation. The success of APV in Germany — at least within protected-crop farming — will depend on whether technological advances are accompanied by coordinated measures across regulatory, financial, and infrastructural domains. As expressed repeatedly during the session, farmers seek evidence-based assurances that the system can enhance productivity and economic security, rather than expose their businesses to additional vulnerability. Only under such circumstances would agrivoltaics move from an interesting concept to a credible innovation pathway for German greenhouse agriculture.

3.3 Discussion of results

The German World Café revealed a particularly analytical approach to agrivoltaics (APV) among participating growers. Rather than responding primarily to the novelty of the technology, as observed in other national contexts, farmers in Watzkendorf concentrated on the practical and regulatory conditions that would determine whether APV could be integrated into everyday greenhouse operations. Their reactions reflected a structured decision-making process shaped by production constraints, market dynamics, and their direct accountability for business outcomes.

A key focus of the discussion concerned the economic architecture in which German horticulture operates. Participants explained that most commercial greenhouses in the region are modest in size and operate on relatively thin margins. Under these conditions, significant capital investment carries a high level of exposure. They also pointed to a seasonal mismatch between solar production and greenhouse energy needs: electricity demand is highest in winter, whereas photovoltaic generation peaks in summer. This misalignment complicates assumptions about self-consumption and revenue streams.

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Further, the limited grid stability in rural areas — together with slow and sometimes opaque procedures for connecting renewable systems — raises doubts about whether surplus energy could be fed into the grid in a reliable and economically meaningful manner. Without long-term evidence on payback timelines or mechanisms to share financial risk, farmers signaled reluctance to move forward.

Figure 13 The German World Café among participating growers

As one participant expressed:

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"Before we invest, we need to know how yields, energy flows, and regulations will behave — not for one season, but sustainably."

Attention turned next to day-to-day operational realities. Farmers emphasized that any new system must reduce complexity, not introduce additional burdens. Several pointed to the high humidity inside greenhouses, which may accelerate corrosion and reduce the transparency and performance of photovoltaic modules through condensation and dust accumulation. Concerns were also raised about access to qualified technicians who can provide prompt maintenance — a challenge already present in rural areas for existing technologies.

Workers' safety was highlighted as a non-negotiable priority, particularly given the proximity of electric systems to irrigation networks and metal structures. Moreover, participants questioned whether shading from the modules might block airflow around the crop canopy, heightening the risk of fungal pressure and diminishing labour comfort.

These reflections led to strong support for full-service contractual models — bundling installation, monitoring, cleaning, and repair — so that APV becomes a managed asset rather than an additional operational obligation.

The group also examined how APV might alter greenhouse microclimates. While partial shading can help buffer heath stress during periods of extreme temperatures, the modules could simultaneously reduce convective cooling**,** trapping warm air beneath the structure. Paradoxically, such thermal buildup could decrease both crop performance and solar efficiency, producing counterproductive outcomes on both sides of the dual-use relationship.

Participants therefore argued for dynamic control systems**,** allowing the panels to adapt to climatic variability and specific crop requirements — a technical improvement they see as essential before broader adoption is contemplated.

The conversation also extended to the broader institutional conditions surrounding APV deployment, reflecting farmers' attention to the governance structures that would accompany such technological integration. Rather than focusing solely on the hardware, participants consistently emphasized the importance of regulatory clarity and transparency in all aspects of system ownership and operation. A recurring concern related to the management of data generated by energy production systems: farmers wished to avoid situations in which valuable operational information would be controlled exclusively by technology providers or energy companies, thereby restricting their autonomy in optimizing processes or negotiating market conditions. This apprehension was closely linked to a broader worry about dependency risks and potential forms of vendor lock-in, especially where proprietary software or exclusive maintenance agreements could limit future flexibility.

In addition, participants stressed the need for unequivocal compliance with German regulations governing construction, occupational safety, and greenhouse infrastructure. Any uncertainty in this sphere translates directly into investment hesitancy, since deviations from regulatory expectations can lead to costly delays or retrofitting

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requirements. For farmers, therefore, institutional confidence is inseparable from technological confidence: only when the legal and safety environment is fully clarified can APV systems be considered a credible and responsible option for greenhouse agriculture.

The possibility that greenhouse operators could be held liable for failures or safety incidents associated with unfamiliar electrical systems surfaced as a major source of concern. Participants described APV as institutionally risky unless roles, responsibilities, and rights are unequivocally codified.

Across all thematic areas, participants expressed a willingness to explore APV solutions — provided that the technology is validated in real agricultural conditions and accompanied by the necessary structural supports. Their collective stance may be summarized as a combination of openness to long-term sustainability benefits **and** short-term caution about unresolved risks.

This readiness to innovate is conditional rather than speculative: German growers **expect** clear evidence, clear rules, and clear operational support before committing resources to APV. The issues shaping their perspective are synthesised in Table 27.

Pillar of acceptance	Stakeholder expectations
Economic	Fair payback models Cost reductions Specific subsidies
Technical	Crop-specific smart shading Automation of functioning Energy storage capacity
Institutional	Simplified authorization system Grid connections and stability guarantees Data rights
Operational	Availability of maintenance workforce Modular retrofitting
Environmental	Robust cooling system Shading harmony

Table 27 Pillars of acceptance and corresponding stakeholder expectations for agrivoltaics adoption

Innovation in this domain is therefore not embraced for its novelty alone but is judged on its capacity to demonstrate predictable performance, transparent oversight, and clearly distributed responsibilities. Farmers are willing to experiment, yet they cannot assume the sole burden of technological or financial risk in an already demanding production environment. For APV to move from trial to adoption, it must be embedded within a governance system that ensures operational continuity, regulatory clarity, and fair access to benefits. Only when reliability is proven in practice — and institutional support mechanisms function coherently — can agrivoltaics be considered a truly credible and future-oriented innovation for German greenhouse agriculture.

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3.4 CONCLUSIONS

3.4.1 Strategic Conclusions

The discussions held during the first German World Café showed that farmers see agrivoltaics a an innovation capable of integrating smoothly into existing greenhouse systems, particularly within organic production. Instead of regarding APV as a disruptive shift, participants tended to interpret it as a logical step forward: a way to strengthen long-established commitments to resource efficiency, climate-aware farming, and reduced environmental impacts. The prospect of generating electricity on-site — and thereby limiting dependence on increasingly unstable energy markets — was highlighted as especially relevant in a context where energy expenditures weigh heavily on production costs. Some farmers also underlined that being among the first to combine food and energy production could give their businesses a more recognisable sustainability profile, potentially improving market positioning.

Despite this generally positive orientation, participants pointed to a number of elements that currently inhibit broader uptake. Above all, the investment required for APV remains substantial, and uncertainty persists about the long-term return, since remuneration models for surplus electricity are not yet consistent or predictable. Questions were also raised about the regulatory side: How should authorization procedures be handled? Who controls and benefits from energy and agronomic data? How can connection to the electricity grid be guaranteed? The absence of clear answers to these issues discourages growers who might otherwise be interested in experimenting with technology.

Technical suitability was another matter of concern. Farmers stressed that any APV configuration must match the delicate microclimatic balance inside greenhouses. In particular, they emphasized the risk that solar modules could trap additional heat, negatively affecting both crop performance and the efficiency of the panels themselves. Above all, participants insisted that any new system must safeguard yield quantity and product quality — the economic foundation of their farms — and should not complicate workflows or maintenance needs. All the strategic priorities emerging in the Watzkendof world café are presented in Table 28.

Priority area	Perceived needs
Financial feasibility	Stable incentive mechanisms reduction of upfront costs predictable compensation for surplus electricity
Regulatory and procedural clarity	Clear authorisation pathways, standard rules on data management transparent responsibilities for grid connection
Greenhouse-specific technical solutions	Improved thermal managemet crop-specific shading control

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Priority area	Perceived needs
	designs adaptable to existing greenhouse layouts
Grid and storage infrastructure	Faster connection procedures, support for storage integration improved grid resilience in rural areas
Operational competence and maintenance access	Training programmes, service availability near farms, full-service installation packages to reduce operational burden
Evidence-based demonstration	Long-term data on yield effects, economic returns, daily operational performance in German conditions

Table 28 Priority areas and perceived needs identified for the adoption and scaling of agrivoltaics greenhouse systems

From this discussion points emerges that the key to successful APV deployment in Germany is not only the refinement of the technology itself, but also the establishment of the necessary conditions that would render its adoption a realistic prospect. Such conditions would include targeted financial support, stable rules and support schemes, improved infrastructure for grid connection and energy management, and practical assistance for everyday operation. Should these enabling factors be addressed, APV has the potential to become an important component of Germany's controlled-environment agriculture. Conversely, the potential risks associated with the latter remain largely unrealised.

3.2. General Reflections

In addition to the substantive insights gathered on agrivoltaics technology, the German World Café highlighted the importance of directly involving farmers in innovation processes. The participants indicated that their involvement should extend beyond the consultation phase, emphasising their desire to assume an active role in shaping the introduction and adaptation of APV systems to real agricultural conditions. The establishment of trust through early dialogue, transparent communication, and demonstrable results was identified as being of paramount importance to ensure that new technologies are not perceived as externally imposed changes that add risk without providing tangible value.

The discussions also demonstrated that APV should not be regarded as merely an energy add-on to existing greenhouses. In order to achieve successful integration, it is necessary to adopt a broader, systemic perspective. Farmers emphasised that the technology must align with local cultivation practices, crop requirements, and the market realities of horticultural production. It is their conviction that a methodology which acknowledges the idiosyncrasies inherent in each agricultural enterprise – encompassing its labour organisation, the range of products it produces, and its business strategy – is the only one with the potential to engender widespread adoption.

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A further salient point that emerged from the analysis is that the transition towards APV involves multiple levels of change concurrently. A range of factors influence farmers' willingness to adopt, including economic considerations, operational ease, environmental performance and legal clarity. The presence of any weakness in one of these dimensions has the potential to compromise the integrity of the entire system. Consequently, the effective development of agrivoltaics in Germany cannot be driven solely by technological optimism; it must be grounded in coordinated policies, reliable support structures, and continuous knowledge exchange among all actors involved.

Overall, the German participants conveyed a pragmatic but open attitude. They recognised the potential contribution of APV to a more resilient and climate-aware greenhouse sector, but at the same time stressed that innovation will succeed only if it fits with the day-to-day realities of agricultural work. APV is therefore best understood not as a ready-made solution but as a collaborative process — one that requires ongoing adjustment, responsiveness to field experience, and shared responsibility for both risks and benefits.

The German participants to the world cafè of July the 23rd 2024 exhibited a pragmatic yet receptive demeanor. The participants acknowledged the potential contribution of APV to a more resilient and climate-aware greenhouse sector. However, they emphasised that innovation will only be successful if it aligns with the day-to-day realities of agricultural work. APV is therefore best understood not as a ready-made solution but as a collaborative process — one that requires ongoing adjustment, responsiveness to field experience, and shared responsibility for both risks and benefits.

4. 3rd WORLD CAFÉ IN GERMANY

Berlin, Von Humboldt University Greenhouses - 23 January 2025

4.1. General overview

The third World Café, held within the REGACE framework, took place on 23 January 2025 at Humboldt University in Berlin. The session was overseen by Prof. Uwe Schmidt and Prof. Thorsten Rocksch, with Dr. Lisa Mersmann providing support for facilitation activities. Representing the University of Rome Tor Vergata, Professor Andrea Volterrani and Dr. Maria Cristina Antonucci (CNR) participated as scientific facilitators for the social research work package. The study involved eight farmers who were engaged in the practice of greenhouse farming.

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Figure 14 The third World Café in Germany

The agenda was structured around the following phases:

1. Presentation of the REGACE agrivoltaics system and its technical features;
2. Guided visit to the greenhouse and discussion of the experimental crops;
3. Open Space session to collect initial reactions regarding opportunities, risks, and possible developments; focus on extreme weather conditions and financial sustainability;
4. Thematic World Café tables focusing on each dimension;
5. Collective synthesis through a Fishbowl discussion.

This design enabled a balance between hands-on observation and structured dialogue, allowing participants to relate the technological aspects of the project to their own farming experience.

The discussion sessions were characterised by a positive atmosphere of cooperation and attentive participation. Farmers exhibited a strong interest in the technical functioning of the farm, the management of energy resources, and the responses of the crops, while concurrently engaging in critical reflection on long-term risks and the decision-making responsibilities associated with them, especially facing extreme weather conditions and financial sustainability of this innovation. This combination of openness and procedural seriousness faced to the potential critical aspects confirmed the relevance of participatory methodologies for shaping credible innovation pathways.

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4.2 Emerging tendencies

4.2.1 Opportunities

World cafè participants asserted that APV represented a promising direction for the enhancement of energy sovereignty within the horticultural sector. The capacity to produce electricity at the point of consumption was regarded as a potentially decisive factor for protecting farms against price volatility and future supply vulnerabilities. It was asserted by certain growers that early investment in renewable technologies could serve to reinforce their reputation as enterprises that are environmentally committed. The potential for the gradual expansion of APV surfaces over time was interpreted as a strategic advantage, facilitating flexible planning and progressive integration with complementary greenhouse technologies.

The benefits envisaged were therefore less speculative than programmatic: growers recognise that energy production could serve immediate operational goals while positioning the sector as an active protagonist in the ongoing sustainable transition.

4.2.2 Perceived critical aspects and material durability

The evaluation of risks was predominantly focused on the behaviour of APV components within the microclimatic conditions of a greenhouse. It has been observed by farmers that elevated levels of humidity, condensation, crop residues and CO_2-rich atmospheres present more stringent durability challenges than open-field conditions. Concerns were expressed regarding the longevity of photovoltaic surfaces – also due to changing weather conditions (extreme heath in summer and extreme cold in winter) particularly the distinction between glass and polymer-based modules, and the need for protective strategies against corrosion and sensor malfunctioning.

A secondary dimension of risk pertained to maintenance reliability: failures in rotating elements or monitoring devices had the potential to expeditiously compromise both energy output and crop performance, causing serious impact on the profits of the farming activity The participants advanced the argument that economic sustainability is inextricably linked to material robustness and the predictability of service structures, especially with changing climate conditions.

4.2.3 Future technological directions

The world café revealed a shared conviction that APV cannot be considered a static technology. Growers have expressed interest in the development of adaptive and automated systems that are capable of modulating shading according to crop physiology and external conditions. Furthermore, the potential benefits of rethinking panel geometry, including variations in spacing and height, to support optimal photosynthesis and efficient ventilation throughout the growing season, were discussed. This standpoint positions APV as a component of a more extensive technological restructuring of greenhouse operations. This is not merely an energy layer, but rather a transformative element whose design must co-evolve with horticultural science and digital agriculture practices.

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4.2.4 Financial Sustainability and Investment Exposure

The most significant factor determining acceptability was economic feasibility. Farmers emphasised that investment decisions must be based on verified data describing returns over time, including the correlation between APV use and yield preservation. There is a paucity of consensus regarding the stability of remuneration mechanisms for surplus energy and the fairness of current grid access arrangements. The participants of the Berlin world café of January 23, 2025 asserted that innovation should not be contingent upon farmers assuming full business risk. The request for contract models that combine installation, monitoring, and maintenance within integrated service solutions was made, with the objective being to ensure performance guarantees and to reduce uncertainty. In the absence of a realistic financial structure, the technological potential remains merely theoretical, according to the participating farmers.

4.2.5 Adaptation to Extreme Climatic Conditions

The second world café in Germany took place during the winter months, and the discourse on climate adaptation has underscored a particularly salient issue in the context of APV in greenhouses: the potential for modules to accumulate heat during peak radiation, thereby exerting a deleterious effect on crops precisely during the period of maximum energy generation. It has been observed by growers that there is a discrepancy between the temporal alignment of electricity production and plant well-being. This discrepancy necessitates meticulous calibration in order to circumvent counterproductive outcomes. This tension indicates that greenhouse-based APV systems must enhance their capacity to modulate heat and airflow, particularly in response to the escalating frequency of heatwaves. Consequently, the ability of the technology to withstand extreme weather conditions was identified as a prerequisite for its credibility in Germany's evolving climate. The key trends emerging from the third world cafè are presented in Table 29.

Analytical Dimension	Main Insights	Illustrative Stakeholder Perspective
Opportunities	Energy autonomy and strengthened sustainability profile	"Energy independence would support our business identity as greener farms."
Risks	Durability concerns, vulnerability of moving components, harsh greenhouse climate	"The microclimate here is harsher than in open fields — technology must withstand it."

Table 29 Key trends emerging in the Berlin world café

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4.3 Discussion of results

The Berlin world café of 23rd January 2025 provided a comprehensive overview of the current interpretation of agrivoltaics (APV) among German farmers specialising in the greenhouse sector. Participants evaluated APV not as an experimental innovation, but rather as a prospective element of the operational architecture of greenhouse production. The evaluation criteria employed reflected the practical realities of everyday farming, encompassing aspects such as system simplicity, reliability, and demonstrable compatibility with labour routines and environmental control. Consequently, innovation was met with acceptance on the condition that it served to reinforce the continuity of crop management, as opposed to introducing novel vulnerabilities to farms.

A recurrent theme in the discourse pertained to the distinction between the promises made by APV and its present capabilities. Farmers expressed strong support for the strategic direction associated with APV, including reduced dependency on external energy markets, protection from price volatility, and alignment with climate objectives. However, this strategic desirability was consistently framed as dependent on structural viability. The process of adoption is not solely contingent on technological aspiration, but rather on the existence of favourable conditions.

These insights confirm that the progression from interest to adoption is a multi-dimensional transition. It is evident that technical refinement in isolation is inadequate in addressing the complex challenges confronting the field, without concomitant progress in the realms of financial instruments, regulatory clarity, and the provision of knowledge and support services. In instances where these dimensions align, the discrepancy between potential and practice can be mitigated; conversely, where they diverge, progress can be impeded. The dimensions of assessment, as well as the interpretation thereof by the participating farmers and the possible conditions for rapid and certain acceptance of APV in their farming activities, are presented in Table 30.

Dimensions of assessment	**Interpretation by farmers**	**Required conditions for acceptance**
Operational integration	APV must reinforce crop stability and workflow continuity	Thermal balance and accessible maintenance
Economic credibility	Investments must offer proven and secure returns	Transparent payback models and risk sharing
Regulatory certainty	Permissions and responsibilities must be unambiguous	Clear governance frameworks
Technological robustness	Equipment must withstand greenhouse microclimates	Reliable materials and actuation
Knowledge and support	Farmers cannot bear the entire learning burden	Local expertise and service structures

Table 30 Dimensions of APV assesments and farmers condition of acceptance

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The outcomes of this analysis indicate that farmers' assessments of agrivoltaics are informed by a thorough evaluation of both operational effectiveness and institutional reliability. The convergence of these dimensions suggests that APV will only be perceived as adoptable when technology, governance, and support infrastructures evolve in parallel rather than sequentially. The level of readiness for innovation is contingent upon the provision of credible assurances that energy production will not compromise, but rather reinforce, the fundamental agricultural functions of greenhouse farming.

Figure 15 The outcomes of World Café

4.4 Conclusions

4.4.1 Strategic Conclusions

At the Berlin World Café on 23 January, farmers identified the potential of agrivoltaics (APV) as a strategic resource for the future of greenhouse-based agriculture in Germany. The significance of this initiative lies in its recognition of the pivotal role it plays in fostering energy sovereignty and environmental responsibility. In the contemporary business landscape, these factors have become pivotal for maintaining competitiveness in the face of mounting pressures from emerging markets and evolving policy frameworks. For these farmers, APV represents more than a mere technological addition; it is a potential means of achieving long-term resilience. In this sense, it enables the agricultural sector to play an active role in the transition to a climate-friendly economy, rather than merely adapting to its consequences.

However, the level of interest in APV is contingent on a thorough examination of the structural environment in which the innovation would be implemented. Farmers have repeatedly emphasised that any commitment to implementation must be supported by

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compelling evidence that APV can function within the stringent agronomic and economic constraints of greenhouse farming. The inherent uncertainties surrounding the durability of photovoltaic components under enclosed microclimatic stress, the allocation of liability in cases of technical failure, the potential complexity of maintenance, and the unfamiliarity of energy market interfaces all contribute to a risk exposure evaluation characterised by caution. Farmers have expressed concerns that they should not be expected to assume the operational, financial and jurisdictional risks of a novel system alone, particularly given the absence of compelling evidence supporting its cost-benefit equilibrium.

Consequently, the strategic viability of APV is contingent upon a concerted alignment of multiple enabling conditions. It is imperative that economic sustainability is supported by reliable incentive structures and risk-sharing arrangements. These structures must acknowledge the financial vulnerability of small and medium-sized farms. Technical integration must guarantee that the primary productive function of the greenhouse is safeguarded and that any energy gains do not compromise the yield or quality of the crop. Regulatory frameworks must provide clarity regarding permissions, responsibilities, and data use, ensuring that farmers are not left navigating ambiguous legal or infrastructural systems. Finally, the development of local maintenance expertise and advisory services is essential to reducing operational uncertainty and reinforcing trust in technology over time.

These outcomes of the world café indicate that the adoption of APV is not an automatic response to technological promise but rather a negotiated decision, in which farmers actively weigh opportunities against the institutional and environmental conditions that render innovation feasible. When economic, technical, regulatory and organisational factors reinforce each other, APV can realistically emerge as a stabilising asset within the context of German greenhouse farming. In instances where misalignment persists, it is probable that adoption at the farm level will remain constrained to pilot experiences and experimental trials, as opposed to attaining mainstream strategy status.

Strategic factors	**Requirement expressed by farmers**	**Implications for implementation**
Economic realism	Stable incentives shared risk	Public and private finance must lower exposure for individual farmers
Technical compatibility	Preservation of crop performance and climate control	APV must be designed around agricultural needs, not vice versa
Institutional commitment	Clear procedures on authorisation, liability and data	Regulatory coordination will determine investor confidence
Workforce capacity	Skilled and timely technical assistance	A support ecosystem must accompany infrastructure deployment

Table 31 Strategic Determinants of APV Adoption in Greenhouse Farming

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4.4.2 General Reflections

The Berlin World Café confirmed, according to the participants' feedback, that integrating emerging technologies into agricultural systems cannot be approached as a one-directional transfer of knowledge. Farmers made it clear that they expect the development of agrivoltaics to proceed through modes of engagement that extend well beyond the occasional consultation. They acknowledge that technological systems not only reshape infrastructures, but also the routines, identities and responsibilities that constitute agricultural practice. The development of agrivoltaics is therefore contingent on sustained dialogue, in which practitioners are co-authors of feasibility rather than passive recipients of innovation.

Contributions from the World Café suggest that APV should be considered an evolving socio-technical arrangement rather than a standardised technological package. Its acceptability will depend on its ability to align with the primary objectives of farming and accommodate the ecological and organisational specifics of greenhouse production. Participants emphasised that innovation must reinforce, rather than disrupt, the foundations of productive continuity. From this perspective, co-design is essential: only through iterative feedback can technical decisions remain grounded in real operational environments and be tested against the priorities of those responsible for crop outcomes.

These reflections also emphasise the importance of innovation governance. The long-term integration of APV requires frameworks that facilitate collective learning, provide transparency over decision-making processes, and distribute responsibilities and benefits in a way that is perceived as equitable. Although material performance and energy efficiency remain important markers of success, they alone are insufficient to generate adoption. Farmers will only adopt innovations if they perceive that the institutions promoting them are responsive to their constraints and that the economic and legal conditions surrounding adoption are stable and comprehensible.

Therefore, the future of APV in German greenhouse-based agriculture depends as much on the relationships within which the technology is embedded as on the engineering of the system itself. The transition will be shaped by the ability of stakeholders to maintain open communication, negotiate differences in expertise and risk, and institutionalise collaboration as an integral part of innovation. When positioned within a framework of shared responsibility and cumulative learning, agrivoltaics can progress from an experimental demonstration to a credible pathway for sustainable transformation.

5. 4th WORLD CAFÉ IN AUSTRIA

Vienna – BOKU University Campus Greenhouses - 4 February 2025

5.1 General overview

The Austrian World Café, which was held as part of the REGACE project, took place on 4 February 2025 at BOKU University in Vienna. The coordination of the activity

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was overseen by Univ.-Prof. Dipl.-Ing.Sc.Ag. Dr sc.agr. Anna Keutgen and Priv.-Doz. Dr Norbert Keutgen (BOKU University) was involved in the project, along with Professor Andrea Volterrani (University of Rome Tor Vergata) and Dr Maria Cristina Antonucci (CNR – University of Rome Tor Vergata), who were responsible for the social research component.

Figure 16 The fourth World Café in Austria

In contrast to the well-established greenhouse enterprises present in the German, Greek and Italian contexts, the Austrian case study is characterised by a distinct infrastructural and social configuration. Controlled-environment cultivation is confined to small experimental greenhouses within the university campus, as opposed to being situated in commercial agricultural facilities. Consequently, the participants were academic scientists and technical personnel working on agronomic and photovoltaic researh instead of farmers. Although not directly involved in REGACE's operational decisions, these participants were tasked with reflecting on the technical feasibility and systemic implications of agriphotovoltaics (APV) from a scientific perspective.

The agenda was structured around the following phases:

1. Presentation of the REGACE agrivoltaics system and its technical features;
2. Guided visit to the University lab and discussion of the experimental crops;
3. Open Space session to collect initial reactions regarding opportunities, risks, and possible developments; focus on extreme weather conditions and financial sustainability;

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4. Thematic World Café tables focusing on each dimension;

5. Collective synthesis through a Fishbowl discussion.

This contextual shift elucidates the rationale behind Austria's decision to host only a single World Café within the stipulated project timeline. Nevertheless, the experience culminated in a substantial enrichment of the perception model. The session demonstrated that APV is regarded as a promising method for transforming university greenhouses into energy-productive scientific infrastructure. This would enable experimentation on the interaction between plants and light, CO2 capture, and energy management. However, the participants emphasised that technical refinement, reliable microclimate control and institutional planning are essential prerequisites for the meaningful transfer of the model to commercial farming.

The Vienna World Café expanded the analytical scope of REGACE beyond the concerns of practitioners, illuminating how experts conceptualise APV as a generative frontier.

5.2 Emerging tendencies

The data collected in Vienna reflect a specific research-oriented environment in which agrivoltaics (APV) is not yet embedded in agricultural production but rather situated within a scientific and experimental infrastructure. Participants engaged in analytical and technically informed reasoning, oriented towards system refinement rather than immediate deployment. In this sense, APV was examined not as a response to economic pressures, market shifts, or energy volatility—as in other national cases—but as a technological and ecological problem space requiring rigorous interdisciplinary verification.

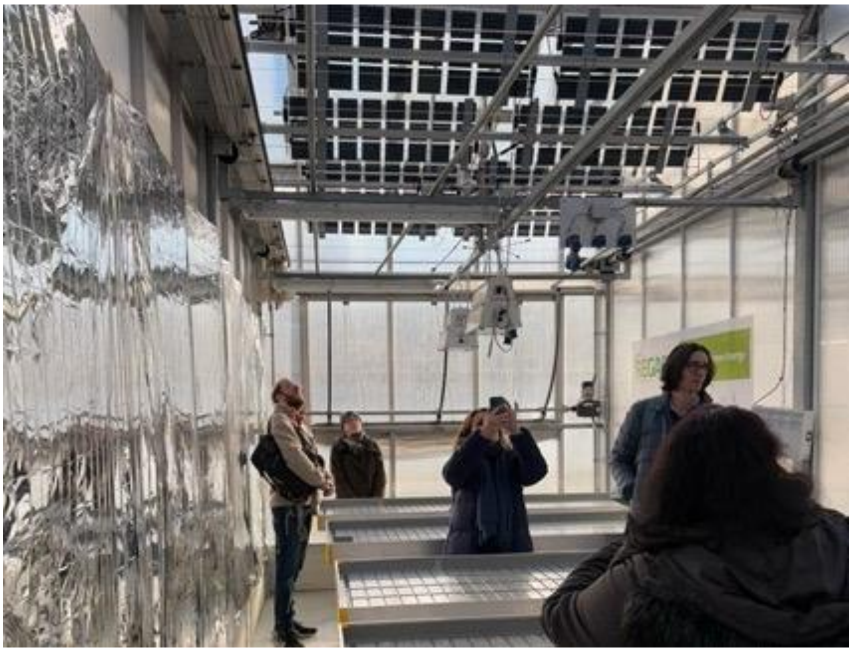

Figure 17 Agrivoltaics in Austrian greenhouse

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The discourse was conducted in a conducive environment characterised by collaborative engagement, underpinned by rigorous critical inquiry, mutual respect across diverse scientific disciplines, and a propensity to explore both the possibilities and the unknowns inherent in the subject matter, without the constraints of immediate operational outcomes. This distinctive constellation positions the Austrian World Café as a complementary configuration within the participatory design. Rather than the perspective of professional farmers, the perception captured in Vienna reveals how research institutions evaluate the foundations upon which APV's broader social translation will depend.

5.2.1 Opportunities

Participants interpreted APV primarily as an infrastructural enhancement capable of transforming the role of university greenhouses from solely experimental sites into dual-purpose environments that actively contribute to sustainable energy generation. The integration of solar modules is expected to have three key impacts. Firstly, it will strengthen the capacity to test dynamic shading effects under authentic radiative conditions. Secondly, it will lead to the development of new approaches to light spectrum control. Thirdly, it will refine knowledge on plant–energy relationships. The potential institutional benefits were also emphasised.

5.2.2 Perceived risks and system constraints

The discussion revealed a series of potentially unresolved technical variables that must be examined cautiously before APV can be considered methodologically sound in highly controlled research units. Participants highlighted the fact that the installation of photovoltaic elements invariably modifies the microclimate in ways that have the potential to distort experimental baselines. Specifically, the phenomenon of trapped humidity, the diminished efficacy of convective cooling processes, and the modification of irradiation dynamics have the potential to compromise the reliability of data and the long-term functionality of components. The durability of module surfaces under the chemical exposure typical of closed greenhouses (including ammonia residues and elevated CO2) was also considered to have been insufficiently verified. These concerns establish the necessity for comprehensive testing under local conditions, rather than the assumption of transferability from open-field contexts.

5.2.3 Future technological directions

The vision advanced by participants challenges conventional APV configurations. It was contended by the aforementioned parties that enclosed microenvironments require photovoltaic systems capable of modulating solar interception in accordance with photosynthetic demand, phenological phases and seasonal variability. Transparent, wavelength-selective modules were identified as a priority research trajectory, coupled with the potential integration of heat-recovery mechanisms and storage systems. APV is thus conceptualised as part of a systemic redesign in which sensors, panels and climate-control infrastructures interact dynamically, rather than as the simple addition of an energy-producing layer.

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5.2.4 Economic assets

While economic returns do not constitute the primary operational mission of a university greenhouse, participants emphasised that financial rationality must be incorporated into APV's strategic evaluation. In order to be scalable and transferable to Austrian farming, which is characterised predominantly by small-scale production, the technology must prove affordable and efficient under realistic investment constraints. In this view, the Vienna case is significant in its connection between scientific advancement and practical applicability. It anticipates the conditions under which experimental insights may enable economically viable adoption in the wider agricultural landscape.

5.2.5 Compatibility with controlled-environment agriculture

The most significant concern expressed by participants pertains to the maintenance of experimental integrity. The acceptance of APV is contingent upon its ability to maintain stable baselines for measurement, to avoid structural interference with instrumentation, and to guarantee that light distribution and airflow regimes remain compatible with sensitive crop trials. This underscores a pivotal divergence between the Austrian and German–Italian contexts: within Vienna, APV acceptance is predicated on its capacity to function as a research-validating technology, as opposed to merely a production-supporting one.

Analytical dimension	**Interpretation by participants**	**Conditions for acceptability**
Research integration	APV as a means to enhance experimental infrastructure and knowledge production	Preservation of data accuracy and stable reference conditions
Technical uncertainty	Microclimate disturbance and accelerated material wear inside closed greenhouses	Validation under local environmental stress conditions
Technological development	Priority for transparent and spectrally-selective PV solutions	Co-design of panels and climate-control technologies
Institutional value	Reinforces university positioning in sustainable innovation	Strategic planning and sustained funding commitments
Knowledge transfer potential	Bridge between scientific testing and small-farm applicability	Evidence-based demonstration of scalability

Table 32 Themes emerging from the Vienna world cafe

The tendencies summarised in Table 32 indicate that Austrian stakeholders view agrivoltaics primarily through the lens of scientific functionality rather than agricultural productivity. Their assessment highlights a demand for technical validation and methodological coherence before any broader transfer to real-world farming contexts can be considered. Overall, the insights emerging in Vienna expand the evaluative

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framework of APV by positioning research reliability and knowledge generation as central determinants of acceptability.

5.3 Discussion of results

The Wien world café of 4 February 2025 introduces an analytical vantage point that is not registered in the other national contexts investigated. In the previous experience of world cafés in Italy and Germany, farmers' perceptions of agrivoltaics (APV) are influenced by considerations of practical feasibility, economic implications and risk exposure. In contrast, Austrian participants, predominantly scientists and technical specialists, approached the technology as an interdisciplinary research object, situated at the intersection of plant physiology, energy systems engineering and environmental control. Consequently, their evaluation was not driven by immediate concerns of operational viability, but rather by an epistemic agenda centred on experimentation, observation and iterative system optimisation.

This orientation gave rise to a distinct form of critical scrutiny. Participants examined the potential of APV to enhance the precision of light management strategies within greenhouses, facilitating precise calibration of irradiance and spectral composition. Furthermore, it was emphasised that the integration of photovoltaic structures within confined microclimates necessitates a re-examination of ecological and biochemical interactions, which remain inadequately understood. This encompasses humidity dynamics, gas exchange, and stress-response monitoring. It is argued that APV should not merely coexist with the existing functions of a greenhouse, but rather prompt a reconsideration of architectural, technological and methodological configurations. This would effectively result in a redesign of how small-scale controlled-environment systems operate.

Furthermore, participants of the Vienna world café emphasised that such an intervention must ensure the scientific validity of experiments. It is important to note that university greenhouses are primarily concerned with the generation of data as opposed to the production of commodities. Consequently, any disruption caused by APV, whether it pertains to the microclimate stability or the calibration of sensors, has the potential to compromise the reliability of the trials. It is therefore considered a potential catalyst for advancing precision agronomy, on the condition that it enhances the reproducibility of results and the capacity to generate high-quality knowledge.

These insights have the potential to shift the conceptual locus of APV. The Vienna World Café is not defined exclusively as a novel agricultural technology; rather, it is revealed to be a significant research-driven innovation pathway. The Austrian case demonstrates that before APV can become an instrument of productive transformation, it must first succeed as a credible tool within scientific infrastructures, where its effects can be measured, validated and translated into principles of scalable application. In this sense, Vienna adds an upstream dimension to the broader participatory exercise: it captures the conditions under which agrivoltaics innovation can be rendered both intelligible and transferable across diverse agricultural settings.

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5.4. Conclusions

5.4.1 Strategic Conclusions

The Austrian World Café posits the notion that agrivoltaics possesses considerable potential in the realm of reshaping controlled-environment agriculture. This assertion is predicated on the premise that agrivoltaics can transform the role of university greenhouses, thereby transitioning them from being energy-dependent infrastructures to experimental platforms with the capacity to produce a portion of the energy they consume. This transition, however, is not driven by immediate economic incentives or gains in production; rather, it is driven by the prospect of establishing a more circular, self-sustaining research environment. In this paradigm, energy flows become both the subject of investigation and a resource for scientific activity.

The strategic value of APV in this context is not solely attributed to its capacity to generate electricity; rather, it is the potential to enhance the conditions under which knowledge is produced that is of significance. The participants emphasised the necessity of preserving the integrity of experiments in the process of scientific integration, as even minor alterations in light distribution, heat retention, or airflow have the potential to compromise the validity of longitudinal studies and compromise the reproducibility of data. Consequently, the implementation of APV necessitates meticulous anticipation of microclimatic ramifications and the refinement of monitoring systems endowed with the capacity to discern even the most imperceptible environmental variations over time. Consequently, the technology must be further refined within the research environment prior to any consideration of its transfer to commercial farms.

Should these conditions not be met, APV may be perceived as premature, particularly in settings where scientific credibility and methodological precision constitute non-negotiable foundations for decision-making. In other words, APV must first succeed epistemically before it can succeed operationally in Austria. It is only through systematic demonstration, cross-disciplinary validation and the establishment of evidence-based protocols that APV will be regarded not as a disturbance to controlled experiments, but as a strategic asset in advancing agronomic innovation and climate-responsive agricultural technologies. A summary of the nexus between strategic factors, core requirements and operational implication is presented in Table 33.

Strategic factors	Core requirement	Implication
Scientific validity	Precise microclimate and data accuracy	Redesign of systems for controlled trials
Technical compatibility	Lightweight and transparent PV solutions	Technology co-evolves with research needs
Institutional support	Stable funding and long-term planning	APV positioned as strategic infrastructure
Knowledge advancement	Integration with research agendas	APV informs next-generation digital agronomy

Table 33 Strategic dimensions and core requirements from participants to the Austrian world café

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The strategic dimensions summarised in Table 33 highlight that acceptance of APV within Austrian controlled-environment agriculture is fundamentally conditional. In lieu of supposing the rationales of commercial scalability, participants accentuated that technological integration ought to serve to buttress scientific precision and institutional continuity. The table illustrates that APV becomes strategically meaningful only when it contributes directly to research integrity, infrastructural foresight and the long-term advancement of agronomic knowledge.

5.4.2 General Reflections

Notwithstanding its minor deviation in target groups, the Vienna World Café exemplifies the necessity for sustained, transparent, and mutual recognition-based cooperation in the translation of agrivoltaics into research-oriented settings, which is the primary objective of this REGACE Project task.

In contrast to contexts where adoption is contingent on economic resilience or productivity enhancement, the Austrian case prioritises scientific credibility as the pivotal factor in the assessment process. The technology must therefore be incorporated through procedures that preserve experimental rigour and allow researchers to maintain high levels of control over environmental variables. In this sense, APV is not merely regarded as an infrastructural enhancement; rather, it is perceived as a catalyst for re-evaluating methodological practices, encompassing the concurrent management of light, energy and biological responses within confined systems.

The reflections collected indicate that co-design is essential to this transition. Researchers asserted that APV solutions must evolve through iterative and dialogical processes, in which technological parameters are continuously aligned with the epistemic requirements of controlled-environment agriculture. The emphasis on reproducible observations, validated monitoring systems and minimal disturbance to experimental baselines suggests that innovation must respect the delicate equilibrium on which scientific inquiry depends. Successful integration is therefore less a matter of installing new hardware and more a matter of constructing a robust relational framework linking designers, plant scientists and environmental engineers.

In conclusion, the Austrian world café experience establishes APV within a more extensive conceptualisation of innovation. This is not regarded as an artefact to be utilised, but rather as an emerging configuration that remodels the manner in which knowledge, infrastructure and sustainability ambitions intersect. In this sense, the adoption of APV in Austria will be driven not by market imperatives, but by the gradual establishment of trust in APV as a research-enabling technology capable of both meeting and advancing the methodological standards that govern experimental agriculture. Upon attaining this alignment, APV has the potential to transition from its current state as a speculative promise to a credible and durable component of scientific infrastructure. This transition will generate insights that will, over time, inform future applications beyond the university setting.

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6. 5th WORLD CAFÉ IN GREECE (VOLOS)

University of Thessaly Greenhouses — 10 February 2025

6.1. General overview

The 5th World Café, which was hosted within the REGACE framework, was convened on 10 February 2025 at the experimental greenhouse complex of the University of Thessaly in Volos. The coordination of the initiative was undertaken by Professor Nikolaos Katsoulas and Professor Chrysssoula Papaioannou of the University of Thessaly, with scientific supervision provided by Professor Andrea Volterrani and Dr. Maria Cristina Antonucci of the University of Rome Tor Vergata and the National Research Council. The operational support and thematic note-taking were provided by Dr. Anna Argyropoulou, Dr. Theodora Gheorgopoulou (University of Thessaly).

The event was attended by 10 participants, including practitioners active in greenhouse farming in Thessaly and nearby regions.

The agenda was structured around the following phases:

1. Presentation of the REGACE agrivoltaics system and its technical features;
2. Guided visit to the University lab and discussion of the experimental crops;
3. Open Space session to collect initial reactions regarding opportunities, risks, and possible developments; focus on extreme weather conditions and financial sustainability;
4. Thematic World Café tables focusing on each dimension;
5. Collective synthesis through a Fishbowl discussion.

Figure 18 The fifth World Café in Greece

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The discussions emerging indicate that Greek farmers view agrivoltaics as a potentially valuable diversification strategy in a context marked by rising energy prices and increasing climatic stress on greenhouse crops. Participants expressed clear interest in on-site energy generation as a means to improve cost stability and operational resilience. However, this interest remains conditional. Widespread adoption will depend on the demonstrated reliability of the technology, streamlined administrative procedures, and financial models that are realistically accessible to greenhouse operators. This revealed a pragmatic openness of the participants: APV is regarded as a credible option only if it can tangibly support the core priorities of Greek protected agriculture—economic security, climate resilience, and maintaining crop performance.

6.2 Emerging tendencies

The discussion was characterised by active engagement and a robust analytical approach. A reciprocal process of translation was observed, whereby experimental data were interpreted through the lens of operational experience, while farming concerns informed the scientific prioritisation of APV research questions.

6.2.1 Opportunities

Participants regarded APV as a pragmatic approach to enhance energy autonomy, particularly during summer months when greenhouse cooling demands are at their zenith and electricity costs are at their peak. It has been hypothesised by several farmers that the adoption of renewable energy sources in agricultural practices may enhance the environmental credibility of farming operations and facilitate the attainment of a competitive advantage in markets where sustainability attributes are becoming increasingly sought after. Furthermore, local energy communities were regarded as a potentially viable model for shared benefits, particularly in regions characterised by fragmented land tenure.

6.2.2 Risks and operational constraints

The primary concerns addressed pertained to the compatibility of APV with the prevalent high-light crops in Greek greenhouse farming. Shading effects were considered to be potentially detrimental unless managed dynamically, while structural elements could hinder essential farm tasks such as pruning, harvesting and equipment handling. The most significant risk identified was that of heat accumulation; the presence of additional overhead structures has the potential to compromise microclimate performance during heatwaves, a recurring phenomenon in Greece.

6.2.3 Future developments and research expectations

It was posited by participants that further testing was required in order to facilitate a more complete understanding of yield responses, with particular reference to conditions during the summer months. The combined APV–CO_2 compartment was regarded as a promising innovation with the potential to offset shading-related reductions in photosynthesis. Farmers requested transparent communication of seasonal monitoring results to guide investment decisions based on evidence. The tendencies summarised in

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Table 34 offer an initial structuring of perceptions collected during the Greek World Café, highlighting the key areas in which agrivoltaics intersects with current priorities in protected farming.

Analytical dimension	**Insights**	**Illustrative stakeholder perspective**
Opportunities	Strengthened energy autonomy and climate resilience	"Any step that reduces dependence on the grid improves our future."
Risks	Shading challenges and increased heat load	"Panels must help with heat — not add to the problem."
Future Developments	Interest in APV–CO_2 synergies and long-term monitoring	"We want to see how the dual setup performs through the summer."

Table 34 Tendencies emerging from the Greek World Café in Volos, 10 feb. 2025

These observations suggest that expectations regarding APV in Greece are predominantly driven by considerations of energy security and climate resilience, as opposed to speculative market opportunities. Concerns regarding shading and heat accumulation demonstrate that climatic performance remains a pivotal criterion for technological acceptance within Mediterranean greenhouse environments. The explicit request for long-term monitoring demonstrates that the adoption of these measures is contingent on reliable, context-specific evidence, rather than short-term promises or extrapolated assumptions.

Figure 19 Greek World Café discussions

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6.3 Discussion of Results

The Volos World Café of 10 February 2025 serves to enhance the comparative framework developed within the REGACE project by introducing a perspective that is firmly rooted in the unique context of Mediterranean farming. In this particular context, agrivoltaics is not regarded as a marginal optimisation or technological upgrade, but rather as a potential response to systemic pressures that threaten economic stability and crop viability. Farmers evaluated innovation through the dual lenses of environmental exposure and operational feasibility, emphasising that innovation cannot be disentangled from the practical conditions in which greenhouses operate under increasingly extreme weather patterns.

The comparison with other national contexts clarifies this positioning: while German discussions concentrated on regulatory predictability and institutional assurances, and Austrian experts emphasised experimental control and methodological robustness, Greek farmers prioritised the mitigation of heat stress and protection against market volatility. This suggests that the primary criterion for evaluating APV is its ability to maintain the physiological performance of crops during periods of peak radiation, when overheating already constitutes a significant constraint on productivity. Achieving energy autonomy is predicated on the integration of technology to create cultivation environments that are cooler, more stable and controllable.

In this theoretical framework, APV is conceptualised less as an engine of economic expansion and more as a risk-mitigating mechanism. The value of the technology is intrinsically linked to its potential to reconcile adverse environmental conditions with the financial fragility of a sector operating under narrow margins and increasingly unpredictable climatic cycles. It is important to note that the dominant stance among farmers is not one of resistance or uncritical enthusiasm. Conversely, farmers have exhibited a propensity to adopt innovative practices while underscoring the imperative for empirical validation prior to undertaking any significant investment. Their approach is characterised by pragmatic logic, whereby technological progress is considered favourable, provided that it is deemed conducive to safeguarding the fundamental parameters of production, namely crop health, the continuity of yield, and the manageability of operational complexity. The materials from the Greek world café in Volos posit APV as a form of adaptive resilience, the legitimacy of which is contingent on its demonstrated ability to reduce exposure rather than amplify vulnerability. This interpretation serves to expand the REGACE perception model by revealing how agrivoltaics is assessed not solely according to its energy output, but according to its contribution to maintaining the very conditions that enable agricultural viability in a warming Mediterranean climate.

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Figure 20 Materials Greek World Café

6.4. Conclusions

6.4.1 Strategic Conclusions

The Greek World Café, held in Volos on 10 February 2025, demonstrated that agrivoltaics (APV) is interpreted within a framework shaped by climatic exposure and economic vulnerability. In a sector increasingly confronted by prolonged heatwaves, rising energy expenses and structurally thin profit margins, APV is valued primarily for its potential to support adaptive resilience. Participants recognised that the direct production of electricity at the point of agricultural demand had the potential to moderate market volatility while enhancing autonomy in the management of cooling systems and climate-control infrastructures. It was also acknowledged that the integration of renewable energy sources could enhance the environmental performance of greenhouse-based agricultural practices in Greece, thereby aligning production models with national and European sustainability objectives.

However, this interest is subject to a series of thresholds that must be met before the adoption of such a measure becomes a viable proposition. Farmers emphasised that technology must first demonstrate capacity to preserve crop quality under high-radiation stress conditions, while avoiding operational complications or additional labour requirements. The magnitude of investment was considered a significant barrier,

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particularly for small and medium-sized enterprises; therefore, incentives and risk-sharing instruments were viewed as essential preconditions. Furthermore, regulatory clarity surrounding authorisations, grid access, and energy pricing schemes was identified as critical to reducing uncertainty and enabling informed decision-making.

The resulting stance is one of cautious readiness: innovation is appreciated when it strengthens rather than destabilises the productive core of agricultural activity. In this regard, APV becomes strategically meaningful only when its performance is validated by context-specific evidence and when governance, financing and technical support evolve in parallel with technology deployment. The priorities articulated during the Volos session are summarised in Table 35.

Priority area	Required measures
Thermal and Crop Protection	Dynamic shading and enhanced ventilation
Financial Feasibility	Grants, low-interest loans, stable remuneration
Regulatory Simplification	Clear procedures for permits and grid access
Operational Confidence	Maintenance services and farmer training
Evidence-Based Demonstration	Longitudinal field data and seasonal trials

Table 35 Strategic Priorities for APV Adoption in Greek Greenhouse Farming

The elements highlighted in Table 35 indicate that the success of APV in the Greek context is contingent not solely on technological potential, but on the establishment of complementary structures that enable farmers to assess and adopt innovation without undue exposure to risk.

6.4.2 General Reflections

The Greek World Café serves to corroborate the notion that the alignment between technological innovation and agricultural practice is never automatic. Farmers articulated a clear expectation that their insights, grounded in seasonal experience and embodied knowledge of crop responses, must inform every stage of APV development. From this standpoint, they are not merely passive recipients of externally designed solutions; rather, they are pivotal contributors to the validation, adaptation and contextualisation of emerging technologies. This participatory role assumes particular significance in climates such as the Mediterranean, where decision-making must continuously respond to volatile environmental pressures.

A broader implication emerges: innovation gains legitimacy only when it is supported by governance structures that anticipate the operational consequences of technological change. Farmers emphasised the necessity for institutional arrangements that would serve to reduce uncertainty and distribute risks more equitably across the value chain. Trust in APV is not predicated solely on technical promises or energy performance, but rather on clear accountability, reliable service provision and long-term commitments from the actors promoting the transition. In summary, it is imperative that technological

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development is accompanied by the necessary assurances to facilitate its judicious incorporation.

Within the conceptual framework under consideration, APV is perceived less as a ready-made solution than as an evolving socio-technical assemblage. The trajectory of its adoption is contingent upon achieving a delicate balance between innovation and agricultural continuity. It is imperative that energy gains do not come at the expense of agronomic stability, nor can digital sophistication overshadow the pragmatic constraints of production rhythms and labour organisation. Farmers conveyed a form of conditional optimism, signifying their readiness to engage in transformation processes, contingent upon the preservation of the fundamental rationale underpinning greenhouse farming, as opposed to its disruption.

The Greek case ultimately contributes more than a set of specific requirements; it provides a normative orientation for evaluating dual-use systems in climate-exposed regions. The acceptance of APV is contingent upon its capacity to enhance resilience in areas of heightened vulnerability, namely in the domains of heat management, cost predictability, and the safeguarding of yields. When these criteria are met, agrivoltaics has the potential to transition from its current experimental status to a credible component of a broader strategy for climate-adaptive farming in Greece. This strategy would enable farmers to not only adapt to change but also to actively shape its direction.

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7. 6th WORLD CAFÉ IN ITALY

Pontinia, Fattoria Solidale del Circeo Greenhouses - 12 September 2025

7.1 General overview

The sixth World Café within the REGACE programme was convened on 12 September 2025 at Fattoria Solidale del Circeo, Pontinia (Lazio). The initiative involved 10 participants, representing farmers of the area of Latium region.

Coordination and scientific oversight were provided by Marco Serra (Mycro Working) and Marco Berardo di Stefano (Fattoria Solidale del Circeo).

The agenda followed a structured sequence:

1. Presentation of results concerning agrivoltaics (APV) productivity in greenhouse environments;
2. Site visit and observation of panels installed in the pilot greenhouse;
3. Open Space session focused on the identification of impressions, doubts, expectations;
4. Shared lunch acting as informal bridge between the two methodological phases;
5. Thematic World Café discussion organised around energy, agriculture, and cost factors;
6. Collective closing synthesis (afternoon session)

The operational structure ensured that participants could directly observe the functioning of the technology before engaging in group deliberation. All intervening actors demonstrated prior familiarity with agricultural production and, in many cases, pre-existing awareness of renewable energy technologies — thus enabling a discussion grounded in operational rather than merely conceptual considerations.

Figure 21 The sixth World Café in Italy

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The general tone of work was characterised by active interest and cooperative engagement, with both technical questions and strategic reflections arising continuously during the exchanges.

7.2. Emerging tendencies

Discussions generated substantial contributions across the three analytical dimensions utilised throughout the work—opportunities, critical issues, and future developments. This structuring reflects the iterative methodology adopted across REGACE, in which stakeholder reasoning is progressively reformulated into synthetic knowledge for socio-technical governance. The Italian data presented here have been reconstructed directly from the clusters developed during the group sessions and documented within the uploaded project materials.

7.2.1 Opportunities

Participants conceptualised agrivoltaics not as a marginal add-on but as a strategic instrument of economic and environmental resilience, capable of supporting the continuity of protected agriculture under increasingly unstable production conditions. The following opportunity domains were foregrounded:

Strengthened income diversification — APV was perceived as a stabilising mechanism, allowing electricity generation to compensate for seasonal variability in crop revenues. This diversification was aligned with a broader desire to reinforce the economic viability of greenhouses facing drought events and rising operational costs.

Synergies between agricultural and energy production — Participants recognised the potential for APV to increase overall system productivity if shading dynamics, crop selection, and greenhouse configuration were technically harmonised. Agronomic stability paired with renewable energy generation could enable a dual-value chain logic, including electrification of machinery and accelerated adoption of precision farming technologies.

Energy independence as strategic protection — The generation of electricity on-site was framed as a safeguard against market volatility and future energy crises. Greater autonomy from external suppliers was interpreted as a means to sustain cooling systems, irrigation, and storage infrastructure during heatwaves and peak-cost periods. Energy resilience was viewed as an essential prerequisite for environmental resilience.

Overall, opportunity perceptions were grounded in pragmatic operational calculus: APV is valued where it reinforces existing agricultural capacities, rather than reconfiguring them around energy priorities.

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Figure 22 Location of World Café in Italy: Fattoria Solidale del Circeo, Pontinia (Lazio)

7.2.2 Critical considerations and risks

The barriers identified by participants converged strongly on the interdependence of economic and operational conditions, reflecting a rational, risk-averse stance typical of greenhouse-based agriculture:

Investment constraints — High capital expenditure (CAPEX) remains the principal adoption barrier, particularly for small and medium-sized farms where liquidity is limited and debt exposure is already significant. Farmers emphasised that without targeted incentives, financing mechanisms, and risk-sharing instruments, adoption would remain inaccessible to most operators.

Competence and operational burdens — Although not the central point of resistance, participants highlighted knowledge gaps relating to energy system management, maintenance routines, and monitoring of dual-use infrastructures. Increased operational complexity was considered acceptable only if mitigated through training and reliable technical support systems.

Technological and environmental uncertainties — Concerns regarding structural durability, recycling at end-of-life, and potential negative impacts on microclimate performance were cited as factors that could erode both productivity and long-term trust.

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These risk perceptions indicate that farmers are not opposed to APV per se, but will only adopt solutions where economic feasibility, agronomic integrity, and manageable learning curves are demonstrably secured.

7.2.3 Future developments and expected research directions

Forward-looking contributions focused on the need for systemic conditions that allow APV to transition from experimental deployment to widespread implementation:

Business models enabling viable returns on investment — Farmers explicitly linked future adoption to the development of energy community models, fair pricing for self-consumption and surplus, and operational frameworks that ensure revenue predictability.

Continuous technological refinement — Further adaptation to crop-specific light needs, reduction of installation costs, integration of real-time automation and remote-management systems, and improved solutions for mounting structures in greenhouse environments were identified as priorities.

Capacity building and dissemination — Participants underscored the requirement for dedicated training infrastructures and accessible knowledge-transfer channels to reduce dependency risks and foster autonomous decision-making at farm level.

Regulatory clarity and stable incentive frameworks — Institutional simplification was viewed as decisive for de-risking investment decisions; uncertainty in authorisation procedures and commercial rules is seen as incompatible with long-term farm planning.

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Figure 23 World Café in Italy: Fattoria Solidale del Circeo

The key trends emerging from the 6th World Café are summarised in Table 36.

Analytical dimension	**Insights**	**Illustrative perspective**
Opportunities	Dual-use value and income diversification	"APV helps secure revenue when climate affects yields."
Critical issues	Elevated initial costs and knowledge gap	"Without incentives and training, we cannot risk such a step."
Future development	Sustainable business models and training	"Farmers need support to operate new systems effectively."

Table 36 Trends and tendencies emerging from the 6th world café in Italy, Pontinia – 12 Sept. 2025

These insights indicate that APV is being interpreted within Italian greenhouse farming as a strategic instrument for risk mitigation, positioned against the dual pressures of energy price volatility and increasing climatic instability. Rather than representing a pathway for speculative business expansion, technology acquires meaning insofar as it can reinforce the continuity and resilience of agricultural production systems already operating under narrow economic margins. In this regard, adoption is conditional upon the convergence of three enabling factors: credible economic protections that reduce farmers' exposure to investment risk; strengthened operational capacities that allow the technology to be managed autonomously and efficiently; and a coherent institutional architecture that provides regulatory certainty and sustained policy support. Only when

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these dimensions advance in parallel can agrivoltaics transition from experimental promise to a pragmatic and trustworthy component of the productive strategies underpinning Italian protected agriculture. These insights position APV as a strategic safeguard against current systemic threats — rather than as an opportunistic expansion instrument.

7.3 Discussion of results

The Pontinia session contributes a distinctive perspective to the comparative framework emerging across national contexts. Italian agricultural stakeholders interpret agrivoltaics through the lens of structural vulnerabilities that shape the operational landscape of protected cultivation. Two interdependent lines of discussion were repeatedly foregrounded:

1. Economic uncertainty — driven by persistently narrow profit margins, elevated and fluctuating input costs, and exposure to volatile energy market dynamics, which collectively constrain the capacity of farms to undertake long-term investment commitments.
2. Climatic disruption — characterised by increasingly frequent drought cycles, greater variability in seasonal radiation and temperature profiles, and heightened risks to production stability and crop quality.

Under these conditions, APV is valued not as a vehicle for business diversification detached from agricultural objectives, but as a mechanism capable of sustaining the continuity of production. By internalizing energy generation within the productive perimeter of the farm, technology is seen as providing a buffer against disruptions that would otherwise exacerbate operational fragility. From this standpoint, agrivoltaics is understood as a form of infrastructural reinforcement, enabling greenhouse systems to withstand pressures that exceed farmers' capacity for autonomous adaptation.

Italy's stance therefore aligns closely with the perspective expressed in the Greek context, where climate resilience and economic security emerged as the principal motivations for APV interest. However, the Italian discussion also revealed a significant emphasis on technological modernisation, particularly through the electrification of farm operations and expanded use of automation and precision agriculture. This dual aspiration — resilience and innovation — suggests that Italian farmers envision APV as a gateway to incremental technological upgrading, provided that changes do not jeopardise their primary function as food producers.

At the same time, participants were explicit in delineating non-negotiable thresholds for acceptability. Three conditions must be met to ensure the legitimacy of APV within greenhouse farming:

• Demonstrated agronomic performance under real operational conditions, avoiding trade-offs that compromise crop health or yields.

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• Simplification rather than complication of managerial routines, ensuring that new infrastructures do not introduce dependencies that undermine farmers' autonomy or increase labour burdens.

• Financial instruments designed to distribute risk equitably and prevent disproportionate exposure of small and medium-sized enterprises, which form the dominant structural profile of the sector.

These criteria collectively reflect a stance that combines pragmatic openness with protective caution. Italian agricultural actors appear prepared to engage with innovation only when it strengthens the productive rationale of greenhouse farming rather than subordinating it to external agendas centred on energy policy or technological showcase. Agricultural continuity remains the pivot around which every evaluation turns.

In this framework, APV emerges as a conditional solution: potentially transformative, but legitimate only if its benefits materialise within the agronomic and economic logics that underpin the sustainability of farm livelihoods. Failure to align technological ambition with these structural imperatives' risks relegating APV to the domain of experimental projects, disconnected from the pragmatic constraints that define decision-making at the farming level.

7.4. Conclusions

7.4.1 Strategic Conclusions

The Pontinia World Café demonstrates that agrivoltaics is perceived as a strategically significant component within Italy's ongoing transition toward greater energy autonomy and climate-responsive resilience. In a protected-agriculture sector increasingly exposed to economic volatility and environmental stressors, APV is evaluated primarily through its capacity to reduce vulnerability rather than through its potential for speculative growth. Its value proposition is framed in pragmatic terms: the ability to stabilize income streams threatened by climate-induced production losses; the capacity to secure essential energy inputs for climate control and irrigation; and the possibility of enabling gradual technological modernization without disrupting established production logics.

APV is therefore positioned not merely as an infrastructural upgrade, but as a form of adaptive reinforcement. It promises to extend farms' decision-making horizons, allowing producers to operate with greater certainty in planning, investment, and innovation. Participants acknowledged that such potential is particularly relevant in regions where greenhouse agriculture constitutes a territorial specialization and where the impacts of droughts, heatwaves, and energy price surges have already altered the conditions of viability.

However, this strategic relevance does not translate into unconditional acceptance. The discussions underscored that APV's integration into Italian farming systems remains contingent upon the simultaneous fulfilment of a set of core enabling conditions, which together define the boundaries of responsible innovation. Farmers emphasized that any transition toward dual-use systems must proceed in a manner that preserves the productive rationale of greenhouse operations and does not generate new asymmetries of risk or dependency.

In this respect, the participants articulated four decisive requirements that must be satisfied before agrivoltaics can be considered a credible and durable component of the sector's future trajectory, as presented in Table 37.

Priority area	**Required measures**
Financial feasibility	Incentives reducing financial initial exposure Favourable remuneration for self-consumption and surplus
Skills and operational confidence	Dedicated farmer training Accessible maintenance services
Environmental compatibility	Solutions avoiding soil degradation Protection of crop viability
Institutional certainty	Stable rules for permits Grid integration Asset management

Table 37 Priorities and requirements for APV full implementation according to the participants in Pontinia of Sept. 12, 2025

APV becomes actionable only when technological advancement is accompanied by the parallel evolution of financial, operational, and regulatory conditions. Isolated improvements in panel efficiency or system design are insufficient if farms remain exposed to unsustainable investment risks or face opaque authorisation procedures. In other words, the trajectory of agrivoltaics adoption depends on the coordinated alignment of innovation with institutional reliability and economic feasibility. Without such synchrony, technological potential risks remaining confined to pilot projects, unable to translate into a credible and scalable agronomic strategy.

7.4.2. General Reflections

Italian farmers express in the world cafè in Pontinia a position of conditional readiness**:** they demonstrate openness to experimentation yet require empirical validation within their own agro-climatic and business contexts before making binding investment commitments. Their stance reinforces a broader insight: innovation legitimacy arises through co-production**,** where farmers' expertise actively shapes rather than merely receives technological development.

In this perspective, APV is not an imported solution but an evolving socio-technical assemblage that must protect the agronomic rationale of greenhouse production while enhancing sustainability, autonomy, and collective value creation.

Italian farmers participating in the Pontinia World Café articulated a stance that can be described as one of conditional readiness: they are willing to engage with innovation, yet such engagement is contingent upon evidence produced within their own agro-climatic and organisational realities. Experimental openness does not equate to

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investment commitment; rather, farmers insist that technology must demonstrate reliability under the specific environmental stresses, production rhythms, and economic constraints that characterise Italian protected agriculture. This expectation signals a sophisticated understanding of risk in innovation governance: decisions are rooted not in abstract promises but in the material and temporal logics of farming practice.

Their position strongly reinforces a core insight: the legitimacy of socio-technical innovation is not granted ex ante but emerges through processes of co-production, in which the experiential knowledge of practitioners is recognised as epistemically indispensable. Farmers do not accept the role of passive adopters of pre-configured solutions; they assert their authority to influence design requirements, operational standards, and performance criteria. In doing so, they redefine the trajectory of APV as something negotiated rather than imposed.

From this perspective, agrivoltaics cannot be framed as an external technological package simply inserted into agricultural systems. It must instead be understood as an evolving socio-technical assemblage, whose success depends on its capacity to integrate with, and reinforce, the fundamental rationale of greenhouse farming. Energy generation must support, not displace, crop viability, income stability, and workable labour organization. Only when these conditions are secured can APV credibly contribute to long-term sustainability, strengthen farmers' autonomy in managing environmental and market uncertainty, and generate collective value along both agricultural and energy dimensions.

8. 7th WORLD CAFÉ IN GREECE

Volos, University of Thessaly Greenhouses — 3 October 2025

8.1. General overview

The seventh World Café organised within the REGACE framework was convened on 3 October 2025 at the experimental greenhouse complex of the University of Thessaly in Volos. Ten agricultural actors participated, divided into two discussion groups of five, representing protected-crop farms operating in the Thessalian region.

The initiative was coordinated by the local scientific team of the University of Thessaly, with the involvement of Italian project partners. The session began with a guided technical visit to the experimental infrastructures — comprising four differentiated compartments (APV system, CO_2 compartment, combined APV + CO_2 compartment, and reference section). Participants subsequently engaged with facilitated discussion tools including thematic cards and collaborative canvases.

The deliberation was structured around three core analytical domains:

1. Challenges and benefits of agrivoltaics integration;
2. Impacts on crop quality and microclimatic performance;
3. Economic conditions and requirements for credible adoption.

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Figure 24 The seventh World Café in Greece

The exchanges proceeded in a pragmatic and operationally grounded manner, reflecting a clear interest in assessing under which conditions APV can be coherently embedded within the productive logics of Mediterranean protected agriculture.

8.2. Emerging tendencies

The evidence collected has been classified into the three analytical dimensions adopted: opportunities, critical issues, and future developments.

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Figure 25 Work in World Café

8.2.1 Opportunities

Opportunity perceptions converged on the notion that agrivoltaics could reinforce the stability and resilience of greenhouse-based agriculture under tightening climatic and market constraints. Participants did not frame APV as an instrument to radically transform production models, but rather as a means to protect and consolidate existing capacities.

The first area of opportunity concerned energy autonomy. Farmers interpreted on-site electricity generation as a strategic resource to buffer cost volatility and to guarantee uninterrupted operation of climate-control systems during the most demanding phases of the production cycle. Access to stable and self-produced energy was seen as a decisive factor for managing heat stress, particularly in regions where summer conditions already push greenhouse infrastructures to their operational limits.

A second dimension related to the efficient use of space. Dual exploitation of the greenhouse structure for both cultivation and renewable energy production was perceived as a practical method for increasing value density per square metre, enhancing the economic productivity of facilities that are already capital-intensive and spatially constrained.

Third, participants recognized that locally available energy could serve as a catalyst for technological upgrading. Secure electricity supplies may unlock broader adoption of electrified machinery, precision farming systems and digital monitoring tools, enabling incremental improvements in resource efficiency and labour organization.

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Across these domains, APV was regarded as an infrastructural enhancement that could fortify the continuity of production, ensuring that farming remains viable in a context characterised by environmental exposure and market uncertainty. The technology is valued not for its novelty in itself, but for its potential to reinforce the functional core of greenhouse agriculture while opening pathways to more sustainable and controlled production systems.

Figure 26 World Café Working Group

8.2.2 Critical considerations and risks

Risk perceptions emerged predominantly in relation to economic exposure and the practical challenges of incorporating energy systems within already complex production environments. Participants were clear that adoption cannot proceed if vulnerability increases rather than diminishes.

A first and recurrent concern related to the magnitude of the initial investment. The financial burden was considered prohibitive for small and medium-sized farms unless accompanied by dedicated support instruments. In the absence of targeted incentives or risk-sharing mechanisms, a six-year return on investment was characterised as unrealistic and incompatible with the fragile liquidity conditions typical of protected agriculture.

Operational manageability represented a second axis of hesitation. Farmers expressed reservations concerning long-term durability, maintenance demands and the effort required to keep panels efficient in dust-prone environments. Structural compatibility with existing greenhouse configurations was also viewed as uncertain, particularly where retrofitting may entail interruptions in production or impose additional labour requirements.

A further limitation concerns the infrastructural capacity of the electricity grid. Participants highlighted that constraints on connection availability and unfavourable rules governing surplus-energy injection could restrict the economic value of APV and reduce the predictability of returns.

Finally, knowledge gaps about agronomic performance remain significant. The evidence base is currently limited to a narrow set of crop types and seasonal windows; farmers therefore called for longitudinal monitoring across full cultivation cycles and

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species variability to ensure that shading and microclimate effects do not compromise yield stability.

These outcomes of the world café discussion illustrate a grounded, rational approach to risk typical of greenhouse horticulture, where margins are narrow and decision-making is conditioned by continuous exposure to climatic and market uncertainty. Adoption is possible, but only when agrivoltaics demonstrably reduces — rather than exacerbates — the operational and financial precarity that farmers already navigate.

8.2.3 Future developments and expected research directions

Forward-looking discussion underscored that the feasibility of agrivoltaics as a long-term strategy depends on a parallel evolution of institutional conditions, market arrangements and technological maturity. Participants articulated that future progress should not be driven solely by advances in hardware performance but by the emergence of a supportive ecosystem that allows farms to operate APV infrastructures with predictability and autonomy.

First, collective business models were viewed as a promising avenue for managing investment risk and distributing benefits equitably. The idea of energy communities, in particular, was regarded as a way to enhance bargaining power, reduce grid-related barriers and valorise energy produced locally through self-consumption or shared distribution schemes.

Second, technological refinement remains essential. Farmers emphasised the need for solutions calibrated to different crop species and seasonal patterns, capable of maintaining productivity under heat stress while providing stable energy generation. Automation, remote control capabilities and predictive modelling were seen as enabling tools to manage complexity without intensifying labour requirements.

Third, capacity-building emerged as a prerequisite for any responsible deployment. Participants stressed that training infrastructures and operational support must accompany installations, ensuring that farmers retain control over system functioning and do not become dependent on continuous external technical intervention.

Finally, regulatory simplification was repeatedly highlighted as a decisive condition. Clear, stable procedures for authorisation, asset management and grid integration are required to reduce uncertainty and allow investment decisions to be based on reliable timelines and returns.

These orientations demonstrate that Greek farmers evaluate APV viability through a systemic lens: technology, governance and competencies must advance cohesively in order to transform agrivoltaics from a promising experiment into a secure and operational component of protected agriculture. The main trends emerging from the session are summarised in Table 38.

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Analytical dimension	Insights	Illustrative perspective
Opportunities	Local energy and production stability	"We reduce costs where we need it most."
Critical issues	Economic burden and operational uncertainty	"Without support, it is a risk we cannot take."
Future developments	Collective models and structured training	"We need tools and skills to manage the transition."

Table 38 Trends emerging from the 7th World Café in Volos, 3 October 2025

8.3. Discussion of results

The Volos session reveals a distinctive interpretive logic through which agrivoltaics is assessed and rendered meaningful by Greek greenhouse farmers. Participants framed APV not as a pathway for sectoral expansion or diversification into non-agricultural domains, but rather as a protective infrastructure capable of counterbalancing escalating climatic and market instabilities. In this perspective, innovation is evaluated against the extent to which it preserves the operational continuity of farming under adverse conditions, rather than by its potential to generate speculative revenues.

Climatic exposure plays a decisive structuring role in this assessment. Thessaly has experienced recurrent heatwaves, prolonged drought episodes, and increasing unpredictability in the timing and intensity of weather stressors. Farmers therefore anchored their reasoning to concrete scenarios in which APV would serve as a defensive mechanism: maintaining microclimatic control during critical summer peaks, sustaining irrigation when electricity prices intensify, and mitigating the economic repercussions of production volatility. This framing situates agrivoltaics within the broader struggle to preserve the physiological stability of crops under what are perceived as rapidly tightening environmental constraints.

Within this analytical horizon, the energy dimension is never evaluated as an objective in isolation. Rather, its benefit is defined in relational terms: energy autonomy is valuable insofar as it enables and secures agricultural autonomy. Participants stressed that technological integration must not diminish farmers' discretion in managing cultivation practices, nor generate new dependencies on actors external to the agricultural domain. The legitimacy of APV thus hinges on its capacity to reinforce, rather than destabilise, established knowledge systems, labour rhythms, and spatial logics that underpin protected agriculture in the region.

Moreover, despite the existence of operational concerns, scepticism is not the dominant posture. Farmers displayed a form of pragmatic curiosity — a willingness to test and to learn — grounded in an insistence that decisions must flow from trustworthy evidence derived from local experimentation. Innovation is embraced when it demonstrates tangible contributions to risk reduction; it is approached cautiously when uncertainties appear to outweigh potential benefits. This conditional openness highlights the centrality of experiential validation: agrivoltaics must prove itself in the specific agro-

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ecological conditions in which production actually occurs, rather than through abstract performance promises.

Taken together, the discussion underscores an important conceptual point: the value proposition of agrivoltaics is fundamentally situated. It is shaped by the vulnerabilities, expectations, and practices of the agricultural communities that would adopt it. In the case of Volos, APV is not perceived as a technology that transforms agriculture into something new; it is expected to fortify what agriculture already is — an endeavour that must endure climatic uncertainty while sustaining productive reliability and economic dignity. Only to the extent that APV responds to this imperative does it emerge as a credible and desirable pathway for the future of greenhouse farming in Greece.

8.4 Conclusions

8.4.1 Strategic Conclusions

The Volos World Café confirms that the strategic value of agrivoltaics is recognised only when it simultaneously sustains and strengthens those core parameters that determine the viability of protected agriculture in Greece. Farmers did not evaluate APV as a technological upgrade in isolation, but rather as a potential infrastructural response to systemic pressures that threaten the continuity of greenhouse production. In this perspective, the technology becomes meaningful when it ensures a degree of energy autonomy that tangibly supports operational reliability, particularly during periods of elevated climatic stress. A credible solution must not only supply power, but do so in a manner that directly reinforces the functioning of cooling and irrigation infrastructures that safeguard crop conditions.

Likewise, agronomic performance remains a non-negotiable condition. Any intervention overhead must maintain, and where feasible enhance, crop quality and yield stability. The technology is deemed relevant only if its microclimatic effects align positively with the cultivation requirements of species central to local markets. Economic evaluation is equally central: financial instruments must be designed proportionately to the investment capacity of small and medium-sized farms, avoiding the risk of indebtedness or dependence on speculative market dynamics. Farmers repeatedly emphasised that even technologies with strong environmental potential remain inaccessible if they exacerbate rather than mitigate economic fragility.

Institutional certainty, then, emerged as a decisive enabling factor. Predictable and transparent regulatory protocols, together with secure and fairly remunerated access to the electricity grid, were viewed as essential to eliminate procedural risk and allow farmers to make informed and responsible decisions.

These criteria illustrate that uptake is not grounded in a desire to expand into new energy markets but in a careful assessment of whether agrivoltaics can reinforce the existing rationale of production. Within this interpretive framework, the session identified four priority conditions that must be addressed for agrivoltaics to progress from experimental demonstration to credible adoption at scale within Greek protected agriculture (Table 39).

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Priority area	Required measures
Investment sustainability	Subsidies and predictable long-term returns
Operational autonomy	Accessible training and technical support
Crop and climate compatibility	Strong evidence for yield and quality performance
Regulatory certainty	Clear procedures for permits and grid integration

Table 39 Coditions for safe and rapid APV adoption in Greek farming.

The general orientation can be characterised as one of conditional readiness: farmers express a clear willingness to consider adoption, yet this openness remains contingent on the provision of robust, context-specific evidence and on the establishment of governance arrangements capable of reducing uncertainty rather than intensifying it. In the absence of such conditions, APV is perceived as premature for large-scale uptake, regardless of its technological appeal.

8.4.2 General reflections

This session confirms and deepens a central analytical finding: the effective integration of socio-technical innovations in agriculture is inseparable from the co-production of knowledge among researchers, technology developers, and the farmers who ultimately sustain production systems. Innovation does not acquire legitimacy merely by demonstrating technical feasibility; it must establish relevance and credibility within the practical and economic realities through which farmers negotiate uncertainty on a daily basis.

Greek farmers explicitly rejected the notion of agrivoltaics as a technology to be received and implemented "as is." Instead, they asserted a proactive role in shaping APV's design logic, operational modalities, and agronomic performance thresholds. Their expectations make clear that experiential knowledge derived from crop management, labour organisation, and microclimatic variability must inform every phase of APV development. In their view, the transition to dual-use infrastructures must not reconfigure agricultural production around the needs of energy generation; rather, it must reinforce existing agronomic rationalities while opening pathways to smarter resource governance.

APV is therefore conceptualised in this context as an evolving socio-technical assemblage, whose acceptability rests on a delicate equilibrium:

- it must protect and sustain the core function of greenhouses — the stable production of market-relevant crops — and
- simultaneously deliver measurable improvements in environmental performance, operational autonomy, and resilience to systemic risks.

Only when these conditions converge does APV move beyond the domain of experimental demonstration and become a credible lever of climate-adaptive transformation for Greek protected agriculture, supporting continuity today while enabling a managed transition toward future-proof cultivation systems.

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9. 8th WORLD CAFÉ in GERMANY

Berlin (Humboldt-Universität Zu Berlin Campus) — 14 october 2025

9.1 General overview

The 8th World Café within the REGACE programme was held on 14 October 2025 at the campus of Humboldt-Universität zu Berlin. Due to unforeseen constraints, participation by external farmers proved unfeasible. The session was therefore conducted with a broad campus-based community of practitioners, including gardeners, horticultural trainees, students, and professionals with extensive experience in protected cultivation systems. This group, diverse in age and gender representation, constituted the largest and most heterogeneous participant cohort among the World Cafés implemented to date.

Discussions were facilitated by project staff through three thematic stations structured around the core analytical dimensions. Participants used prompt cards and guided queries to articulate responses, and results were subsequently clustered and ranked according to the frequency of citations.

The conversation was characterised by high engagement and a combination of empirical reasoning and reflective consideration of future implications. Even in the absence of commercial farm owners, contributions reflected practical familiarity with greenhouse production constraints and labour environments.

Figure 27 The eighth World Café in Germany

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9.2 Emerging tendencies

Outputs of the discussion have been organised according to the planned structure: opportunities, critical issues, and future developments.

9.2.1 Opportunities

Participants identified opportunities predominantly within the realm of enhanced spatial and resource efficiency. Their reflections did not portray agrivoltaics as a drastic restructuring of horticultural practice, but rather as a strategic augmentation of existing systems. The first perceived advantage concerned spatial optimisation: by allowing protected surfaces to fulfil both agricultural and energy functions simultaneously, APV was seen as a means to intensify the value generated per square metre. This is particularly relevant in high-cost, space-constrained production environments where the economic rationale of greenhouse farming depends on maximising output within tightly delimited areas.

A second area of opportunity related to the management of seasonal light surpluses. During periods of intense summer irradiation, farmers currently face heat accumulation that undermines crop performance without yielding any compensatory benefit. In this context, participants noted that agrivoltaics could help convert excess radiation into usable energy while limiting microclimate stress, thereby turning a constraint into a productive asset.

Improved resource efficiency represented a third domain of potential benefit. By moderating internal temperature fluctuations and controlling evapotranspiration dynamics, APV may contribute to reduced irrigation frequency and lower dependence on energy-intensive cooling infrastructures, thus improving environmental performance and operational economy.

Additionally, participants noted that greenhouse-integrated photovoltaic structures could impose a lighter mechanical load compared to traditional rooftop systems. Reduced exposure to wind stress and extreme weather impacts was seen as a potential contributor to long-term durability and lower risk of structural damage.

Taken together, these reflections position agrivoltaics as an instrument capable of reinforcing operational efficiency when its design is carefully attuned to the physical constraints of greenhouse systems and the seasonal variability of solar resources. For participants, the relevance of APV lies not in altering the foundational logic of protected cultivation, but in enabling more intelligent and sustainable use of the environmental inputs that greenhouses already strive to control.

9.2.2 Critical considerations and risks

Concerns expressed during the Berlin session focused predominantly on operational vulnerabilities, the feasibility of long-term investment, and safeguarding the integrity of product quality. Participants approached agrivoltaics through a cautious evaluative

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lens, grounded in the recognition that protected horticulture allows little tolerance for performance disruptions.

A central preoccupation concerned exposure to economic risk. Attendees questioned whether the benefits generated through additional electricity production would be sufficient to offset potential reductions in crop yield or declines in the aesthetic and commercial value of produce. They emphasised that predictable and credible amortisation trajectories are indispensable: without clear guarantees on returns, APV cannot be considered a responsible investment choice for businesses already operating under financial fragility.

Productivity uncertainty was likewise foregrounded. As many greenhouse crops rely heavily on optimal light conditions for uniform growth, flavour development and market-grade visual standards, participants expressed apprehension that shading could introduce unevenness in crop maturation or reduce quality indicators that directly influence sales prices. The possibility of having to compensate for productivity losses through increased labour or input adjustments further heightened concern.

Safety and labour organisation introduced another dimension of operational risk. The integration of electrical equipment within greenhouses may require specialised installation and servicing personnel. Participants noted that unfamiliar maintenance tasks could impose additional labour burdens or even introduce hazards for workers accustomed to purely agricultural routines.

Finally, questions of technical compatibility were raised. Given the diversity of greenhouse typologies — differing in structure, height, ventilation systems and crop layouts — participants stressed that APV solutions must be modular and flexible. A technology that requires major retrofitting or reconfiguration of production spaces risks undermining the delicate spatial and organisational balance that greenhouses rely upon. These concerns collectively reflect a risk-aware and pragmatic stance: the performance stability of crops remains the paramount criterion against which any innovation is judged. APV may offer new advantages, but adoption will proceed only if energy gains do not come at the expense of production reliability or introduce new forms of operational fragility.

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Figure 28 Working in the World Café

9.2.3 Installation, maintenance, and technological longevity

Future adoption was also associated with expectations regarding the long-term durability of APV infrastructures and the overall performance of the systems across their operational lifespan. Participants expressed concern that greenhouse environments — characterised by continuous exposure to humidity, temperature fluctuations and elevated UV radiation — may accelerate material deterioration. The risk that structural or functional components could degrade more rapidly under such conditions was seen as requiring robust testing and transparent guarantees from technology providers.

Maintenance considerations represented a second area of reflection. There was a shared assumption that, due to their placement within a protected environment, agrivoltaics installations might demand less frequent servicing than open-field photovoltaic systems. However, participants also noted that any increase in maintenance frequency, or the need for specialised interventions, would compromise labour efficiency and elevate operational costs, making the technology less attractive.

Uncertainty regarding the long-term behaviour of photovoltaic efficiency further contributed to a cautious attitude. The possibility of a progressive decline in energy output — insufficiently quantified or poorly communicated — was considered a potential threat to the economic credibility of APV investments. Participants insisted on clear life-cycle data to evaluate whether expected performance aligns with the financial commitments required.

Finally, the discussion returned to the role of public support mechanisms. Incentives and dedicated funding frameworks were identified as essential not only to reduce upfront financial exposure but also to provide confidence that the broader institutional system recognises and supports the risks undertaken by early adopters.

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Across these points, the conversation revealed an underlying principle: technological gains must not be purchased at the expense of production security. Agrivoltaics will be judged viable only when energy benefits accrue without introducing new fragilities into systems already operating at narrow thresholds of agronomic and economic stability.

All the analytical dimensions and insights from the 8th world cafè in Berlin are presented in Table 40.

Analytical dimension	Insights	Illustrative perspective
Opportunities	Efficient land and resource use; lower infrastructure burden	"We could finally make better use of light that currently harms production."
Critical issues	Risk to yield quality and uncertain financial return	"If energy gains do not balance crop losses, it becomes pointless."
Operational development	Durability, maintenance, and adaptable designs needed	"Systems must fit our structures, not require us to rebuild them."

Table 40 Tendencies Emerging from the 8th World Café in Berlin, 14 Oct. 2025

Table 40 captures the dialectical nature of stakeholder reasoning: agrivoltaics is viewed simultaneously as an innovation of promise and of constraint. While participants recognise its potential to transform land productivity and resource efficiency, they remain sceptical of its economic predictability and technical fit within existing farming infrastructures. The insights reveal a pragmatic vision of innovation—one that must reconcile technological novelty with the lived realities of cultivation, maintenance, and market uncertainty.

9.3 Discussion of results

The Berlin 8th World Café demonstrates that the acceptability of agrivoltaics is fundamentally conditioned by its capacity to protect the functional integrity of greenhouse production systems, while simultaneously offering tangible improvements in efficiency, energy stability and resource governance. Participants acknowledged the infrastructural potential of APV but consistently stressed that such potential acquires value only when it mitigates rather than multiplies the vulnerabilities inherent to protected horticulture. In other words, the introduction of dual-use infrastructures must contribute to stabilizing production instead of exposing it to new forms of operational or financial uncertainty.

This pronounced sensitivity to risk is not incidental. It reflects a structural feature of greenhouse agriculture: the operational margin for error is intrinsically limited, and any disturbance in crop performance rapidly translates into economic precarity. Participants therefore evaluated APV through a logic of precaution, prioritising damage avoidance over hypothetical gains. The technology is perceived as legitimate only if it

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demonstrably sustains or reinforces existing cultivation routines, enabling producers to maintain control over microclimates, labour organisation and product quality.

The discussions also drew attention to the high degree of optimisation that characterises greenhouse environments. These systems represent carefully balanced agro-ecological and organisational configurations, where light distribution, ventilation, irrigation rhythms and spatial arrangements are interdependent variables refined through practice over time. Even marginal shifts in shading, working space or physiological stress can destabilise this equilibrium. As such, energy generation cannot become an overriding design principle: its integration must be supported by rigorous evidence that crop responses remain within thresholds compatible with commercial viability.

Despite these reservations, the stance expressed in Berlin is not one of resistance. Participants conveyed a willingness to explore innovative models, provided that the performance relationship between energy production and agricultural functionality is validated under operational conditions. Adoption is therefore conditional, rooted in empirical demonstration and grounded in the pragmatic objective of preserving production continuity. APV is considered a credible pathway only when it confirms, through measurable outcomes, that its benefits outweigh the infrastructural and agronomic complexities it may introduce.

9.4 Conclusions

9.4.1 Strategic Conclusions

Agrivoltaics emerges from this session as an innovation regarded with interest, yet approached through a careful and conditional lens. Participants recognised the potential contribution of APV to more efficient resource governance and to building resilience against energy-market volatility. However, they consistently framed this potential in terms of protection and stabilisation: the technology is seen as strategically meaningful only when it reinforces the reliability of production systems that are already finely tuned to withstand climatic and economic stress.

Adoption is therefore contingent upon a set of prerequisites that define the boundary between responsible innovation and unacceptable exposure to risk. First, farmers and technicians require financial predictability: any deployment must be accompanied by amortisation periods consistent with the narrow financial margins of greenhouse horticulture, and shield producers from excessive debt exposure. Second, there must be clear, context-specific evidence demonstrating that crop yields and product quality are not negatively affected by shading or altered light spectra. Agronomic assurance constitutes a non-negotiable condition.

Third, technological solutions must be adaptable to the morphological and operational diversity of greenhouse structures, without imposing redesign costs or introducing additional labour burdens. Greenhouses are highly optimised spaces, and even minor spatial disruptions may undermine the productivity gains that APV intends to deliver. Finally, system durability must be proportionate to the scale of investment: long-term performance under humidity, radiation and ventilation stresses needs to be demonstrated to avoid premature degradation or escalation of maintenance costs.

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When these requirements are met, agrivoltaics can accompany a gradual and controlled transition toward more sustainable energy practices in protected horticulture. It can do so while preserving the operational foundations on which production continuity and farmers' economic security depend. Conversely, if these enabling conditions remain unresolved, APV is likely to remain a promising but untrusted experimental solution rather than a viable trajectory for sectoral transformation.

9.4.2 General Reflections

The insights gathered in Berlin reinforce the principle that agrivoltaics can only achieve legitimacy when its development is closely aligned with the operational logic of greenhouse agriculture. Participants made clear that the integration of energy infrastructures must respect, rather than reconfigure, the subtle equilibrium that greenhouses are designed to maintain: the regulation of microclimates, the physiological needs of sensitive crops, and the rhythms and spatial constraints of labour. In such contexts, even minor deviations in light distribution or workflow organisation can have immediate repercussions for product quantity, appearance and market value. This explains why technological promise alone is insufficient to motivate adoption; what matters is the demonstrable capacity of APV systems to sustain the agro-ecological balance on which economic viability depends.

Moreover, the Berlin discussion suggests that agrivoltaics is not understood as a disruptive innovation, but as a potential infrastructural enhancement—an additional layer that should remain functionally subordinate to agricultural objectives. Its relevance is therefore assessed primarily in defensive terms: APV must contribute to safeguarding productivity and product quality under conditions of climate stress and economic precarity. Energy generation is valued insofar as it strengthens farmers' capacity to control their production environment and mitigate external uncertainties, not as a means to diversify into unrelated sectors.

Agrivoltaics is considered promising only when it reinforces the foundational mission of greenhouse cultivation: the provision of reliable, predictable and high-quality yields despite increasingly challenging environmental dynamics. When the technology demonstrably contributes to this protective function—maintaining physiological stability of crops, preserving established working practices, and reducing exposure to volatile energy markets—it can evolve into a credible and desirable component of future horticultural systems in Europe. If, however, it introduces additional fragility into production environments already operating at the margins, its acceptability will remain limited and conditional.

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10. Cross-Country Comparative Synthesis of the Eight World Cafés

Themes, risks, and future pathways for agrivoltaics in Europe

10.1 Introduction and Methodological Framing

Within the framework of work package – Socio-technical Integration and Participatory Evaluation, this task aimed to examine how stakeholders across diverse European contexts perceive, negotiate, and co-design the future of agrivoltaics (APV). The eight World Cafés conducted between February 2024 and October 2025—in Italy (Pontinia), Germany (Watzkendorf and Berlin), Austria (Vienna), and Greece (Volos), followed by a cross-country synthesis dialogue—constitute the empirical core of this participatory exercise.

The methodology, combining site visits with technical explanations, Open Space discussions, and Fishbowl collective syntheses, enabled participants to relate technical prototypes to their own operational, regulatory, and climatic realities. This comparative synthesis consolidates those insights into an integrated interpretation of themes, risks, and forward trajectories consistent with the objectives: (1) to identify conditions for socially legitimate innovation; (2) to trace convergences and divergences across local contexts; and (3) to extract governance lessons applicable to EU-level policy on energy-agriculture integration.

10.2 Comparative Thematic Convergences and Divergences

Across the eight sessions, three major thematic axes emerged: economic feasibility, operational integration, and institutional and environmental governance. Although framed differently across contexts, these dimensions collectively describe how agrivoltaics moves from experiment to credible practice.

Italian participants (Pontinia) consistently emphasised economic realism and policy stability. APV was perceived as a potential equaliser for small farms provided that investment risks are shared through predictable incentives and cooperative ownership. German participants (Watzkendorf, Berlin) introduced a more technical and procedural reasoning, centring on microclimate management, data governance, and liability. Austrian stakeholders, drawn primarily from research institutions, reframed APV as a scientific infrastructure for testing plant–energy interactions, thus adding an epistemic layer absent elsewhere.
Greek farmers (Volos) viewed APV chiefly as a climate-adaptation mechanism, contingent on its capacity to mitigate heat stress and safeguard yield stability under extreme conditions.

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The comparative analysis indicates that while all actors perceive APV as a legitimate pathway toward sustainable agriculture, the entry point of legitimacy differs: economic for Italy, regulatory for Germany, epistemic for Austria, and climatic for Greece.

Country Sessions	Core Opportunities	Principal Risks Constraints	Institutional / Governance Gaps
Italy	Diversified income, community energy, local resilience	High upfront cost, uncertain payback, training deficit	Fragmented incentive schemes; weak integration of energy & rural-policy instruments
Germany	On-site generation, automation, precision control	Regulatory opacity, liability, thermal imbalance	Unclear data ownership; complex authorisation pathways
Austria	Research infrastructure, sensor integration, spectral control	Microclimate disturbance, material corrosion	Lack of funding continuity for applied trials
Greece	Energy autonomy, heat mitigation, cooperative models	Shading excess, cost barriers, heat accumulation	Limited administrative capacity; unpredictable incentives
Cross-country synthesis	Shared vision of dual-use land and adaptive sustainability	Economic exposure and institutional fragmentation	Need for harmonised EU framework for agrivoltaics

Table 41 Themes, riks, opportunities emerging from the 8 world cafés

Table 41 summarises the thematic convergence around opportunity, risk, and governance domains identified.

The table reveals that economic predictability and institutional coherence constitute the common denominators of stakeholder confidence. Yet, divergence persists in how each country balances technological ambition with agronomic realism. This diversity confirms the premise that participatory deliberation is indispensable for calibrating innovation to heterogeneous territorial conditions.

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10.3 Risks and Enabling Conditions across Contexts

The perception of risk evolved markedly across the eight World Cafés. Early sessions framed it primarily in financial terms—capital costs, credit exposure, and uncertain payback horizons—whereas later ones articulated systemic risk, encompassing operational complexity, legal ambiguity, and environmental side-effects.

In Italy and Greece, risk discourses intertwined with climate adaptation: overheating, water stress, and continuity of production cycles. Farmers feared that poorly calibrated modules might compromise microclimatic balance and undermine crop value. German discussions introduced institutional risk, notably liability in mixed energy-agriculture environments and dependence on proprietary software for energy management. In Austria, risk was reinterpreted as methodological uncertainty: the possibility that APV structures distort experimental baselines and compromise research validity.

Despite these variations, four enabling conditions consistently emerged:

1. Transparent and stable incentive mechanisms ensuring predictable economic returns.
2. Accessible training and service infrastructures reducing operational dependence.
3. Adaptive design and environmental monitoring guaranteeing agronomic compatibility.
4. Regulatory clarity and data governance frameworks safeguarding autonomy and accountability.

Together, these constitute what the team defines as the ecosystem of credibility—the socio-institutional fabric within which technological promise becomes investable practice.

10.4 Cross-National Governance Patterns and Socio-Technical Implications

This demonstrates that governance—not technology—is the decisive factor shaping the trajectory of agrivoltaics. Where policy frameworks provide continuity and recognisable procedures (as in Germany's energy sector), stakeholders focus on optimisation; where frameworks are fragmented (Italy, Greece), discussion gravitates toward feasibility and fairness. Austria, positioned at the research frontier, exemplifies the role of knowledge institutions as intermediaries capable of translating experimental reliability into policy guidance.

Across all sessions, three governance gaps were recurrent:

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- Regulatory fragmentation between agricultural and energy domains, leading to duplicated procedures.
- Absence of data-sharing standards, leaving farmers uncertain about rights over performance metrics.
- Weak mediation structures, such as local advisory bodies or energy-agriculture agencies.

The synthesis session recommended establishing regional innovation observatories—multi-actor hubs capable of aggregating data from pilots, disseminating evidence, and informing both CAP reforms and national energy strategies. Such intermediaries would concretise the vision of participatory governance as an ongoing infrastructure rather than a project-bounded exercise.

Dimension	**Cross-country convergence**	**Distinctive national emphases**	**Strategic implications for objectives**
Economic & Financial	Demand for stable incentives, risk-sharing, community models	Italy & Greece stress grants / low-interest loans; Germany emphasises cost-benefit realism	Align EU funding (Farming, Horizon Europe) with long-term remuneration schemes for dual-use farms.
Technical & Environmental	Integration of shading control, irrigation, and storage	Germany – automation; Greece – heat mitigation; Austria – spectral optimisation	Promote open-standard, adaptive designs validated under diverse climatic zones.
Operational Capacity	Training and maintenance ecosystems	Italy – full-service packages; Germany – retrofit support; Greece – technician proximity	Develop EU-wide vocational curricula on APV operation within Green Deal skills agenda.

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Dimension	Cross-country convergence	Distinctive national emphases	Strategic implications for objectives
Institutional & Legal	Simplified authorisations and data rights	Germany – liability frameworks; Italy – permits; Austria – research ethics	Draft model regulatory templates bridging energy and agriculture codes.
Cultural & Participatory	Co-design and trust-building as adoption preconditions	Austria – scientific co-creation; Greece – peer learning; Italy – community energy	Institutionalise participatory platforms within rural development programmes.

Table 42 Strategic orientations and future pathways for agrivoltaics across the 8 world cafés

Table 42 maps how locally situated deliberations emerging from world cafés crystallise into distinct yet interlinked strategic orientations across the participating countries. In doing so, it elucidates a scalar transition from empirical dialogue to policy architecture, showing how the participatory framework may operate not only as a consultative tool but as a mechanism for translating experiential knowledge into multi-level governance design.

10.5 Future developments and strategic recommendations emerging from the 8 world cafés

The synthesis of the eight World Cafés provides a panoramic understanding of how agrivoltaics evolves when refracted through the diversity of European agricultural, regulatory, and climatic contexts. From this cross-country dialogue, four interdependent trajectories emerge, revealing the gradual maturation of agrivoltaics from experimental curiosity to a structured policy domain.

The first trajectory concerns the movement from demonstration to institutionalisation. Across all sessions, participants agreed that agrivoltaics must no longer be conceived as a peripheral innovation or an isolated pilot activity but as a recognised component of Europe's agricultural and energy infrastructure. The transition requires embedding APV within the planning instruments of rural development and energy transition—ranging from national recovery plans to local spatial zoning strategies. This implies a conceptual and administrative shift: from temporary research sites to stable, multi-

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purpose installations that are monitored, regulated, and financed with the same continuity as traditional agricultural systems. Only by securing this institutional anchoring can agrivoltaics escape the volatility that often accompanies prototype-driven projects and become a credible axis of long-term sustainability policy.

The second trajectory signals a movement from technology to governance innovation. What the World Cafés repeatedly highlighted is that technical refinement alone cannot guarantee adoption. The decisive bottlenecks lie instead in the coordination of multiple governance layers: authorisation regimes, grid access rules, incentive frameworks, and data governance. Farmers, researchers, and institutional actors collectively recognised that innovation falters when it encounters inconsistent procedures and overlapping jurisdictions. A harmonised regulatory ecosystem encompassing transparent authorisation protocols, interoperable data standards, and predictable remuneration models therefore becomes essential. The governance challenge is not merely administrative but epistemic—it concerns the construction of a coherent field of practice in which agricultural and energy policies, often historically separate, are made to converge through institutional learning.

A third trajectory unfolds from stakeholder dialogue to capacity building. Throughout the participatory sessions, it became clear that farmers' willingness to adopt new technologies depends less on rhetorical advocacy than on continuous accompaniment and access to reliable expertise. The world cafés revealed an appetite for structured learning environments—places where experimentation, advisory support, and peer exchange can reinforce one another. The establishment of permanent training consortia is envisaged, bringing together universities, cooperatives, and technology providers under a shared mandate for competence development. Such consortia would not only transfer operational knowledge but also sustain the deliberative culture fostered through the participatory process, transforming short-term engagement into a durable infrastructure of trust. This capacity-building dimension exemplifies the social side of innovation: technology acquires legitimacy only when the people who must operate it are empowered to understand, adapt, and govern it collectively.

Finally, a fourth trajectory emerges from national pilots to European coherence. The eight World Cafés demonstrated that while local diversity is an asset, excessive fragmentation risks diluting the transformative potential of agrivoltaics. The absence of unified metrics for evaluating APV performance, disparate national incentive schemes, and divergent authorisation pathways all limit the scalability of the technology. Participants from all countries emphasised the necessity for a coherent European framework that defines agrivoltaics within the sustainability metrics of the Common Agricultural Policy, while aligning it with the research and innovation programmes of Horizon Europe. Such coherence would enable comparability of incentives, the standardisation of monitoring criteria, and the creation of a shared knowledge base for policy learning. It would also articulate agrivoltaics as a cross-cutting instrument of the

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Green Deal—an intersection between food, energy, and climate strategies that transcends national silos.

These four trajectories sketch a developmental arc that mirrors the deeper logic of participatory innovation: technological progress acquires meaning only within a robust social and institutional architecture. The lessons emerging from the eight World Cafés point toward an evolutionary path in which agrivoltaics ceases to be a technical fix and becomes instead a kind of social contract—a negotiated balance between productivity, environmental stewardship, and equity.

At its most fundamental level, this synthesis underlines a simple but profound principle: innovation acceptance precedes tech diffusion. Technical performance, however advanced, remains inert without the social credibility and institutional continuity that render it trustworthy and actionable. According to the perceptions of the farmers and experts involved into the participatory pathway, the future of agrivoltaics in Europe will depend on the capacity to integrate governance innovation with technological excellence, ensuring that the promise of dual-use land evolves into a durable and participatory foundation for the continent's green transformation.

10.6 Concluding Remarks and Policy-Relevant Insights

The eight World Cafés collectively position agrivoltaics as a boundary innovation: a liminal field in which the frontiers between energy transition and agricultural continuity, between technological rationality and social negotiation, are continuously redrawn. This hybridity is not a peripheral feature—it is the very essence of the innovation's potential and its fragility. Agrivoltaics, as revealed through the participatory process, inhabits a contested space where the paradigms of productivity, sustainability, and governance must be reconciled rather than merely juxtaposed. What emerges from the synthesis is not a univocal model but a dynamic ecology of experimentation, a system whose legitimacy depends on its capacity to integrate heterogeneous logics—economic, agronomic, environmental, and institutional—into a shared horizon of action.

The participatory methodology applied throughout the project has proven instrumental in translating a mosaic of local perceptions into a coherent European narrative. By convening farmers, researchers, technicians, and policymakers around tangible installations and shared uncertainties, the World Cafés transformed individual experiences into collective intelligence. This cumulative process illustrates that innovation, when conducted through deliberation, becomes more than a technical trajectory: it becomes a mode of governance, a form of epistemic diplomacy capable of bridging asymmetries of knowledge and power. In this sense, the project has not merely collected opinions about agrivoltaics—it has generated a social grammar for thinking about transitions that are both technological and civic.

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A first and unequivocal conclusion concerns economic credibility as the universal precondition for adoption. Across all national contexts, farmers did not question the desirability of energy self-sufficiency or the ethical value of sustainability; rather, they interrogated the feasibility of participation in this transition under the conditions imposed by market volatility and policy uncertainty. The lesson is clear: innovation cannot rely on the moral authority of the green transition alone. Its endurance depends on the predictability of returns, the equity of access, and the continuity of institutional support. Incentive schemes, remuneration mechanisms, and public–private partnerships must therefore be designed not as transient stimuli but as structural assurances—signals of long-term commitment by the institutions promoting change. In this respect, the cafés revealed a recurrent anxiety about the precarity of European agricultural enterprises: where margins are narrow and credit exposure high, uncertainty functions not as an opportunity for innovation but as a deterrent. Economic credibility, therefore, is inseparable from institutional reliability. Without stable governance architectures, even the most advanced technologies remain suspended in the rhetoric of potentiality.

A second transversal insight concerns technological acceptability, which emerges not from innovation's sophistication but from its fit with environmental and operational realities. Participants in every country reiterated that technology succeeds when it simplifies rather than complicates the daily practices of cultivation. Systems perceived as complex, intrusive, or climatically rigid encounter immediate resistance, regardless of their technical merits. In Mediterranean regions, where heat accumulation already constitutes a structural constraint, the adaptability of agrivoltaics to extreme weather conditions determines its credibility more than its energy yield. In central and northern Europe, conversely, the focus shifts to integration within existing greenhouse architectures, maintenance logistics, and the durability of components under high humidity. These divergent priorities nonetheless converge on a shared criterion: operational coherence. Agrivoltaics must not merely coexist with agriculture; it must reinforce it. Only when technology responds to the biophysical and temporal rhythms of cultivation—light cycles, humidity, crop phenology—does it become part of a productive continuum rather than an external imposition.

The third conclusion points to participatory governance as the decisive vector linking pilot success to policy uptake. The World Cafés made visible that innovation diffuses not through mandates but through trust. Structured dialogue, transparent data sharing, and iterative feedback loops create the conditions under which stakeholders perceive themselves as co-authors rather than subjects of transition. Participation, in this sense, is not a procedural embellishment; it is a system's operating condition. Where dialogue is absent, misunderstandings multiply, and technological misalignment follows. Where participatory infrastructures are strong, collective responsibility compensates for uncertainty, and governance becomes anticipatory rather than reactive. The implications extend beyond agrivoltaics: they point to a new paradigm of reflexive innovation, in which legitimacy is not granted ex ante by institutional authority but

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continuously earned through accountability and shared learning. The participatory experience thus confirms that deliberation is not ancillary to innovation—it is the infrastructure through which innovation becomes intelligible, contestable, and ultimately sustainable.

The cumulative evidence also reveals an emerging pattern of European complementarity. Italian and Greek contexts foregrounded vulnerability to climatic extremes and financial exposure, framing agrivoltaics as an instrument of adaptive resilience. The German cases, both in Watzkendorf and Berlin, privileged procedural precision and legal clarity, treating innovation as a problem of institutional engineering. Austria, with its research-driven approach, reframed agrivoltaics as an epistemic device for refining controlled-environment agriculture. These contrasts are not contradictions but facets of a single European experiment: they demonstrate that agrivoltaics functions as a diagnostic lens for the broader transition toward sustainable production systems. Its meaning varies, but its purpose converges—to render the cohabitation of energy and agriculture both credible and just.

What unites these perspectives is the recognition that agrivoltaics is not a technology in search of a problem, but a framework for reorganising the relations between humans, infrastructures, and ecologies. It redefines the very grammar of land use by introducing duality as a guiding principle: land is no longer consumed by one function but shared by many. This conceptual shift carries profound implications. It challenges the extractive logic of traditional resource management and proposes instead a symbiotic logic in which productivity and protection are co-dependent. Yet, as the World Cafés attest, this transition will not unfold automatically. It demands institutional creativity, continuous experimentation, and governance systems capable of learning at the same speed as technology evolves.

The synthesis discussions repeatedly returned to the issue of scale. Participants distinguished between the local viability of prototypes and the systemic coherence required for national or European deployment. Small-scale demonstrations generate enthusiasm but cannot substitute for long-term evidence under diverse agronomic and climatic conditions. Conversely, large-scale rollouts risk losing the participatory density that gives innovation its legitimacy. The challenge, therefore, lies in constructing a scalable participation—a governance architecture capable of retaining inclusivity while expanding reach. This is perhaps the most demanding lesson of the participatory process: that sustainability is not achieved by replication alone but by the recursive translation of local learning into institutional design.

Another critical dimension concerns knowledge governance. The issue of data ownership and accessibility surfaced repeatedly in the German and Austrian cafés, where participants warned against new asymmetries between farmers and technology providers. Agrivoltaics, if governed through proprietary software and opaque algorithms, risks reproducing the very dependencies it claims to alleviate. Conversely,

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open standards, shared databases, and public monitoring systems can transform it into a democratic infrastructure for knowledge generation. This insight extends the notion of participatory governance from social inclusion to epistemic justice: ensuring that the capacity to interpret, manage, and benefit from data remains distributed among all actors involved.

In synthesising all these perspectives, the final analysis of the participatory cycle articulated a vision of agrivoltaics as a co-produced system—technically sound, economically inclusive, environmentally adaptive, and institutionally coherent. Co-production here is not a metaphor but a methodological principle: it signifies that the design, operation, and governance of APV must evolve together, each reinforcing the other's legitimacy. When this balance is achieved, agrivoltaics becomes more than a technological add-on; it becomes a mediator of Europe's ecological transition, capable of reconciling economic viability with environmental stewardship.

The broader implication is that Europe's path to sustainable transformation will be determined less by its capacity to invent than by its capacity to coordinate invention. Agrivoltaics is an exemplary case through which to observe this shift—from innovation as competition to innovation as composition, from isolated ingenuity to collective authorship. In this regard, the participatory experience does not simply document an emerging sector; it prefigures a new governance rationality for sustainability transitions. It demonstrates that the infrastructures of deliberation, data transparency, and mutual accountability are not peripheral supports but the constitutive elements of a viable innovation ecosystem.

Analytical dimensions, lessons learned from the 8 world cafés. Potential implications and APV transformative potentials are presented in Table 43.

Analytical Dimension	**Core EU countries Lesson**	**Structural Implication**	**Transformative Potential**
Economic Credibility	Viability depends on institutional reliability rather than market spontaneity. Stable, predictable frameworks transform risk into investable opportunity.	Create long-term incentive architectures linking CAP, Horizon Europe, and regional energy schemes.	Establish agrivoltaics as a pillar of economic resilience in rural Europe.
Technological Acceptability	Success lies in ecological and operational fit.	Advance modular, adaptive systems designed through	Reinforce agriculture's ecological integrity

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Analytical Dimension	Core EU countries Lesson	Structural Implication	Transformative Potential
	Technologies must adapt to local climatic and agronomic rhythms, not impose generic models.	site-specific co-engineering.	while producing renewable energy.
Participatory Governance	Legitimacy arises from shared decision-making, transparent data, and cumulative learning.	Institutionalise participatory observatories and open-data infrastructures across Member States.	Convert participation from consultation into a permanent instrument of governance.
Knowledge and Data Justice	Control of information determines power in innovation ecosystems.	Ensure open standards and public ownership of agrivoltaic monitoring data.	Democratise the epistemic foundations of the green transition.
Scale and Coherence	Small-scale pilots inspire trust; systemic coordination ensures endurance.	Design multi-level governance linking local experiments to EU strategic frameworks.	Translate local learning into continental coherence for climate-adaptive farming.

Table 43 Synthesis of Cross-European Insights on Agrivoltaics

Table 43 distils the strategic lessons emerging from the eight World Cafés into five analytical dimensions that define the evolving European trajectory of agrivoltaics. It illustrates how local deliberations, empirical challenges, and governance experiments converge into a continental architecture of transformation—where economic credibility, technological adaptability, participatory governance, epistemic justice, and systemic coherence operate as interlocking conditions of legitimacy.

The synthesis reveals that the future of agrivoltaics in Europe will depend on maintaining a triadic equilibrium: economic realism, operational coherence, and participatory governance. None of these pillars is self-sufficient in isolation; only their alignment forms the trihedral structure through which agrivoltaics can endure as both a technological and a civic achievement. When balanced, these 3 pillars may transform agrivoltaics, according to the analysis of the participatory sessions, from an

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experimental frontier into a durable instrument of ecological transition—an integrated system where innovation is not imposed upon territories but co-produced within them.

In this perspective, these 3 dimensions embody the essence of Europe's dual-use landscapes: spaces where productivity and stewardship are recomibined, where knowledge becomes a shared commons, and where energy and agriculture converge as the twin infrastructures of a just and intelligent transition.

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Chapter 4 – Discussion and Communication of the Results

The dissemination and communication of the results produced have represented a central dimension of the REGACE project, both in terms of fostering knowledge exchange among specialists and in promoting the visibility and academic impact of the research conducted. Over the 30-month duration of the project, tthe implemented a carefully structured dissemination strategy combining international conference participation, scholarly publications, and visual communication through posters. This multi-pronged approach ensured that the methodological innovations, empirical findings, and theoretical contributions of the work reached relevant audiences in participatory research, citizen science, and qualitative methodologies.

A primary mechanism for discussion and communication was the active participation of REGACE researchers in international conferences. During the project period, team members contributed to four major conferences held in Denver, Rabat, Kaunas, and Porto. These events served not only as venues for presenting the project's activities but also as forums for methodological reflection, debate, and the comparative analysis of participatory approaches. The participation at these conferences is summarized in Table 44, which details the scientific associations, dates, research staff involved, and the titles of the presentations.

Scientific Association / Conference	Date	Research Staff	Title of Paper / Presentation
World Agrivoltaics Conference, Denver	11-13 July 2024	Volterrani Andrea, Serra Marco, Antonucci Maria Cristina	Transforming Risk Perception and Fostering Cooperatively the Agri-PhotoVoltaics Technology With Farmers in Five Countries: A Sociological Perspective From the REGACE Project
ESA – European Sociological	27-30 August 2024	Volterrani Andrea, Antonucci Maria Cristina	Reversing Risk Perception and Co-constructing Agri-

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Association Conference, Porto			photovoltaics Technology with Farmers: A Sociological Approach Based on the REGACE Project
5th ISA Forum of Sociology, Rabat	6-11 July 2025	Volterrani Andrea, Antonucci Maria Cristina, Serra Marco	Co-Creation in Climate Research: The Experience of the Horizon REGACE Project
ESA RN12 "Environment and Society & Energy and Society" Joint Conference, Kaunas	25 September 2025	Volterrani Andrea, Antonucci Maria Cristina	Building Community Trust in Sustainable Tech: The REGACE Project's Model for Inclusive Agricultural Innovation

Table 44 Conference Participation Activities

Table 44 illustrates the breadth of scholarly engagement and the strategic targeting of specialized venues where discourses on participatory innovation, citizen science, and sociological perspectives on technological adoption converge. These conferences enabled researchers to present and critically discuss the design, implementation, and evaluation of participatory methodologies, including in-depth interviews, focus groups, Open Space Technology, World Café sessions, and Fishbowl discussions, each embedded within the living lab framework. The living labs served as experimental, real-world sites where participatory methods could be tested, refined, and empirically evaluated, offering insights into the interaction between scientific knowledge, community perceptions, and technology adoption processes.

The academic value of these conferences was manifold. First, they facilitated immediate feedback from peer scholars and practitioners, allowing researchers to engage in a dialogic process that informed subsequent fieldwork within the living labs. Second, the presentation of the outcomes within a comparative international context allowed researchers to examine the translatability and adaptability of participatory techniques across diverse social, cultural, and environmental settings. Third, these engagements contributed to the consolidation of methodological rigor, reinforcing the

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iterative linkages between empirical observation, methodological reflection, and scholarly communication.

Beyond conference participation, the researchers undertook a rigorous publication program to ensure the sustained dissemination of knowledge. Over the project period, four major contributions were produced in the form of peer-reviewed journal articles, book chapters, and conference proceedings, accompanied by a poster presentation. These publications not only documented empirical findings but also provided theoretically informed analyses that situated the project's participatory and qualitative approaches within broader scholarly debates. Table 45 summarizes these publications.

Journal / Book	Authors	Title	Link to Electronic Resources
Agrivoltaics World Conference Proceedings 2024	Antonucci Maria Cristina, Volterrani Andrea, Serra Marco, Cornaro Cristina, Petitta Marcello, Bovesecchi Gianluigi	Transforming Risk Perception and Fostering Cooperatively the Agri-PhotoVoltaics Technology With Farmers in Five Countries: A Sociological Perspective From the REGACE Project	https://doi.org/10.52825/agripv.v3i.1386
Culture della Sostenibilità	Volterrani Andrea, Antonucci Maria Cristina	Innovazione tecnologica e partecipazione: prospettive sociologiche sul ruolo delle tecniche partecipative nell'adozione di pannelli fotovoltaici in agricoltura	https://doi.org/10.7402/CDS.35.8
Research in Social Movements, Conflict and	Volterrani Andrea, Antonucci Maria Cristina	Sociological Perspectives on Disruptive Innovation: The Role	https://doi.org/10.52825/agripv.v3i.1386

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Change, N. 49 (forthcoming)		of Co-Design in Agriphotovoltaics Adoption Among Farmers	

Table 45 Further Conference Participation Activities

Table 45 shows the strategic alignment of publication outputs with the objectives. Conference proceedings allowed for rapid dissemination and iterative feedback, while book chapters facilitated in-depth exposition of methodological and theoretical frameworks. Peer-reviewed journal articles, in turn, ensured high academic visibility, credibility, and engagement with a broader scholarly audience. The poster complemented these textual outputs by visually summarizing participatory processes, empirical insights, and methodological innovations, rendering the complex array of activities accessible to diverse audiences. Collectively, these outputs reflect a deliberate, multi-modal approach to scholarly communication, where different formats serve complementary functions within a coherent dissemination strategy.

A critical feature of the communication strategy lies in the integration of dissemination with the iterative operation of living labs. Conferences and publications were not merely endpoints for sharing results; they functioned as integral elements of the research cycle. Feedback obtained through scholarly interactions informed subsequent design and implementation of participatory sessions, including the refinement of interview protocols, facilitation techniques in World Café and Fishbowl sessions, and the calibration of focus group methodologies. This cyclical interaction between fieldwork, reflection, and dissemination fostered an evidence-based approach to method development, ensuring that the living labs operated as dynamic sites of experimentation where both empirical and theoretical insights could be continuously generated, tested, and communicated.

Moreover, the dissemination activities contributed significantly to the creation of an epistemic community around participatory research within environmental and technological innovation. By presenting findings at international conferences and publishing in peer-reviewed venues, researchers established connections with peers engaged in citizen science, co-production of knowledge, and sociological analyses of technology adoption. These engagements facilitated methodological exchange, identification of collaborative research opportunities, and the comparative study of participatory techniques in diverse contexts. The systematic documentation of activities in Tables 1 and 2 ensures transparency, reproducibility, and the potential for future scholarly engagement, demonstrating a structured, high-impact approach to knowledge dissemination.

From a theoretical perspective, the dissemination strategy underscores the productive interplay between empirical research and methodological reflection. Conferences and publications enabled researchers to situate participatory techniques within broader

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debates on collective knowledge, co-design, and community engagement. They also facilitated the development of contextually grounded theoretical insights, demonstrating how qualitative methods such as in-depth interviews and participatory workshops can inform both academic inquiry and practical decision-making in environmental and technological domains.

Finally, the strategic and sustained dissemination approach adopted illustrates best practices in academic communication. By combining visibility, rigor, and engagement, the team maximized the reach and impact of its outputs while maintaining close alignment with methodological innovation. The tables provide not only a record of outputs but also a conceptual mapping of how participatory methods, living lab experimentation, and scholarly communication intersect to produce robust, transferable knowledge. Through these efforts, the work has substantially contributed to advancing understanding of participatory research, qualitative methodologies, and citizen science, ensuring that the insights generated are both academically rigorous and practically relevant.

Chapter 5 – Evaluation of Change in Mental and Social Representation of the farmers' ideas on APV

The participatory dimension of the REGACE project provides an exceptional empirical framework for studying the cognitive, affective, and behavioural transformation of farmers when confronted with innovation not as a theoretical proposal but as an embodied, operational reality. Agrivoltaic greenhouses equipped with CO_2 extraction systems represent a paradigmatic instance of boundary innovation — a technological assemblage located at the intersection of energy transition, climate adaptation, and agricultural productivity. This dual-use configuration collapses traditional distinctions between production and mitigation, forcing its observers to renegotiate established categories of understanding: what counts as "agricultural infrastructure," what constitutes "energy value," and how the logics of farming and engineering can coexist within a single ecosystem.

The empirical evidence drawn from the participatory sessions demonstrates that farmers' perceptions of this hybrid system evolved through a cumulative process of exposure, deliberation, and co-production. Perception here is understood not as a static attitude but as a dynamic configuration of cognition, emotion, and interpretation shaped through interaction with material artefacts, peers, and experts. Across diverse national contexts, three interdependent stages of perceptional change were observed: experiential immersion, structured deliberation, and co-creative projection. Each stage can be analytically described through its causal mechanisms (reasons), its phenomenological expressions (ways), and the participatory architectures that sustained it (formats). Together, these stages delineate an epistemic arc that begins with

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sensory apprehension and culminates in collective authorship — the transformation of technology from an external object into a shared horizon of innovation.

1. Experiential Immersion and Cognitive Reframing

The first contact between participants and the agrivoltaic installations was deliberately conceived as an immersive experience rather than a didactic presentation. The reason for this methodological choice rested on empirical findings from cognitive science and environmental psychology: exposure to functioning artefacts activates multimodal perception, fostering deeper memory encoding and conceptual integration. In other words, understanding is not merely learned; it is lived through embodied engagement with a technological environment.

Upon entering the greenhouse, farmers encountered a sensory atmosphere radically different from traditional cultivation settings. The filtered light, the regulated temperature, and the soft mechanical pulse of CO_2 extraction units generated what many described as an "altered ecology of perception." This immediate and corporeal experience destabilised habitual cognitive frames, prompting spontaneous acts of inquiry. Farmers touched surfaces, gauged temperatures, and visually followed the interaction between sunlight and panels. Perception shifted from distant curiosity to participatory observation.

The ways this transformation manifested were linguistic, gestural, and emotional. Participants began using comparative language — "it feels like," "it seems as if" — indicating an attempt to map the new sensory reality onto prior knowledge. This process, known in cognitive linguistics as *analogical reasoning*, allowed them to domesticate technological novelty by assimilating it to the familiar. Laughter, collective commentary, and informal exchanges punctuated the walkthroughs, signalling comfort and growing trust in the learning environment.

The formats that structured this stage — guided tours followed by accessible scientific explanations — reinforced comprehension through simultaneity: every technical point was demonstrated in real time. When engineers explained that the CO_2 extraction system optimised photosynthesis, farmers could literally observe the equipment at work. This coupling of discourse and demonstration transformed the abstract logic of the system into a visible chain of cause and effect.

Extended Q&A sessions deepened the process. Participants' questions evolved from descriptive ("How does it work?") to functional ("How often must it be maintained?") and then to strategic ("Could this reduce energy dependency on external suppliers?"). This sequential sophistication revealed a progressive recalibration of cognitive models. The reason behind this progression lies in what social epistemology defines as

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epistemic reciprocity: when knowledge is not unilaterally transmitted but dialogically negotiated, comprehension becomes co-constructed.

The perceptual outcome of this phase was a profound shift from *technological estrangement* to *situated understanding*. Farmers no longer perceived the innovation as an external imposition from scientific authority but as a system potentially coherent with their own agronomic rationality. The greenhouse was no longer simply a place of observation; it became a cognitive device — an "open laboratory" in which perception and interpretation co-evolved.

In a social science scientific standpoint, this stage demonstrates that technological literacy in agriculture might be most effectively cultivated through experiential cognition. Perception changes not because individuals are persuaded, but because they are allowed to test, sense, and inhabit the innovation. The intersection of sensory immersion, peer dialogue, and transparent explanation produced a triadic learning loop in which seeing led to questioning, questioning to comprehension, and comprehension to preliminary identification with the innovation's purpose.

2. Structured Deliberation and Pragmatic Reorientation

The second stage of the participatory process established deliberative environments in which individual impressions were stabilised, contested, and cognitively reorganised through collective reasoning. The underlying mechanism of perceptual transformation in this phase was socio-cognitive: perception acquires the status of knowledge when it is collectively articulated, normatively validated, and anchored within shared interpretive frames. Within the REGACE framework, this process was neither spontaneous nor incidental but methodically structured through a sequence of participatory formats—Open Space Technology, Clustering, World Café, and Fishbowl discussions—each designed to facilitate the conversion of experiential stimuli into rational evaluation. These formats functioned as *epistemic architectures*: they provided procedural equity, dialogic symmetry, and cognitive scaffolding through which curiosity was translated into analytical judgment.

Open space environments were the first instruments of this transformation. Participants autonomously and freely selected thematic clusters—economic feasibility, regulatory reliability, environmental coherence, operational maintenance—thus asserting epistemic agency and decentralising the locus of expertise. The self-selection mechanism was not merely logistical but epistemological: it signified a transfer of authority from the project's scientific team to the deliberating community. Once organised, the groups enacted what can be described as *collective abductive reasoning*, iteratively formulating and testing interpretive hypotheses about the innovation's performance and applicability.

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The subsequent clustering activities intensified this externalisation of cognition. Participants wrote key concerns, expectations, and insights on colour-coded sticky notes and attached them to the *talking canvas*, a large modular surface that allowed for spatial reorganisation of ideas. The *talking canvas* functioned simultaneously as a heuristic device and a gamified interface. By physically manipulating ideas—grouping, moving, or juxtaposing them—participants enacted a process of embodied cognition: abstract reasoning was grounded in tactile and visual experience. The playful dynamics of repositioning the notes produced a mild competitive energy that sustained attention and encouraged participation, particularly among less verbally assertive individuals. Through this hybrid of reasoning and play, cognition was externalised and socialised: knowledge production became a collective, visible, and iterative act.

The deliberative setting was intentionally convivial. Tables were arranged in circular configurations reminiscent of cafés, with time for food and coffee pauses always available. This spatial and sensory design was not incidental but instrumental. Social psychology and environmental cognition research demonstrate that conviviality and sensory comfort reduce power distance, enhance trust, and increase discursive openness. Within this affective ecology, the act of sharing food and conversation served as a low-threshold entry into complex reasoning. The alternation between structured discussion and informal exchanges generated a rhythm conducive to deep reflection without cognitive fatigue.

Facilitators operated as relational mediators rather than moderators. Their role was to maintain horizontal symmetry across the communicative field. They circulated among tables, paraphrased complex arguments into accessible language, and drew connections between dispersed clusters of thought. Through their affective competence—humour, attentiveness, and empathetic timing—they instantiated the principle of deliberative democracy: that all participants, regardless of technical background, must have both the time and the social permission to speak. The facilitators' soft presence transformed potential asymmetries of expertise into conditions of epistemic parity, thus ensuring that the process of knowledge formation remained inclusive and dialogically balanced.

The world café sessions amplified this dynamic through a controlled mechanism of rotation and reiteration. As participants moved from one table to another, they transmitted and reformulated prior discussions. This circulation generated a cumulative form of reasoning: each conversational sequence functioned as an iterative review of previous insights. The "talking tablecloths" covering the tables, on which participants drew diagrams or inscribed key terms, served as cognitive artefacts. They made the evolution of reasoning visible and traceable, transforming ephemeral dialogue into persistent semiotic matter. Over time, these artefacts accumulated into a complex visual syntax of deliberation—a cartography of shared comprehension that could be collectively verified and refined.

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The fishbowl discussions introduced a distinct epistemic modality: reflexive observation. By seating small groups at the centre of a larger circle of listeners, the format enacted a symbolic and procedural redistribution of communicative authority. Participants alternated between inner and outer circles, shifting from active to reflective positions. This rotation produced what Habermasian theory would describe as reciprocal turn-taking: legitimacy derived from the equitable circulation of speech acts. The spatial choreography ensured that knowledge was produced through sequential synthesis rather than contestation.

Within these deliberative ecologies, perceptual evolution was empirically detectable through discursive and behavioural indicators. Linguistic data recorded during the sessions showed an increased frequency of modal constructions ("might," "could," "should") and conditional syntax ("if... then..."), signifying a move from categorical to probabilistic reasoning. This linguistic shift indicates a transition from affective appraisal to inferential cognition. Participants also demonstrated semantic internalisation: technical terms such as "spectral response," "thermal regulation," or "microclimatic optimisation" were integrated into their active vocabulary with correct contextual application. Behaviourally, farmers exhibited higher degrees of turn-taking and mutual referencing, suggesting the emergence of *distributed cognition*—the shared processing of complex information through collective coordination.

The addition of gamified and expressive components—the sticky notes, the talking canvas, the visual clustering—acted as catalysts for engagement by converting abstract deliberation into a multimodal sensory task. Cognitive psychology suggests that such multimodality enhances memory retention and associative reasoning. The physical act of writing, moving, and visualising ideas served not only communicative but also epistemic functions: it transformed thought into gesture, thereby increasing participants' sense of agency over the cognitive process.

This stage also revealed an affective-cognitive equilibrium between innovation enthusiasm and risk awareness. Farmers articulated both their aspirations for autonomy and their apprehensions regarding financial exposure, grid dependency, and maintenance complexity. Rather than polarising the debate, the formats channelled these tensions into structured evaluation. Participants collectively reconstructed the meaning of the innovation along three analytical vectors: economic rationality (cost-benefit alignment and amortisation dynamics), environmental coherence (balance between energy efficiency and crop integrity), and operational manageability (labour, maintenance, and governance requirements).

The scientific interpretation of this phase situates it within the framework of pragmatic cognition—the capacity to reason operationally about novelty by embedding it within pre-existing repertoires of practice. The participatory methods deployed in this work provided the necessary epistemic scaffolding for this reasoning to emerge: they offered semiotic artefacts for externalisation, procedural rules for inclusion, and sensory

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affordances for engagement. Within this architecture, deliberation acted not as a mechanism of persuasion but as an instrument of inference and verification.

By the conclusion of this stage, perception had achieved a state of evaluative equilibrium. Enthusiasm persisted, but it had been reconfigured through the lens of realism and conditional feasibility. The farmers no longer perceived the agrivoltaic greenhouse as a technological spectacle; they understood it as an adaptive subsystem governed by economic, environmental, and institutional contingencies. The co-presence of conviviality, gamification, and procedural democracy enabled a form of "rationalised attention:" a sustained, evidence-based curiosity that combined critical distance with participatory commitment.

From an analytical perspective, this phase confirms that perceptual stability in participatory innovation environments depends upon the interplay of three structural conditions: cognitive anchoring (the capacity to articulate experience within shared linguistic and conceptual frames), social symmetry (the equitable distribution of discursive agency), and epistemic transparency (the collective visibility of reasoning processes). The REGACE deliberative stage exemplified the alignment of these conditions through its hybrid ecology of conviviality, play, and structured reflection. It demonstrated that perception matures not through transmission but through co-construction, not through persuasion but through verification, and not through hierarchy but through the democratic choreography of collective reasoning.

3. Co-Creative Projection and the Formation of Collective Intelligence

The final phase of perceptual evolution within the REGACE participatory framework was characterised by a discernible transition from interpretive comprehension to generative projection, prompted by participants' explicit requests to discuss and imagine future developments.

At this juncture, participants—having internalised both the operational logic and systemic constraints of the agrivoltaic greenhouse equipped with CO_2 extraction mechanisms—began to elaborate hypothetical extensions, adaptive variants, and prospective governance configurations of the technology. The underlying cognitive principle governing this transition is that of closure through projection: once an artefact has been epistemically stabilised through comprehension, cognitive energy is reoriented toward the anticipation of alternative scenarios. Competence becomes a precondition for creativity; understanding inaugurates imagination.

This stage was operationalised through the recalibration of deliberative formats—most notably the World Café and Fishbowl configurations—so as to transform evaluation into co-design. The methodological architecture was expressly forward-oriented. Tables were restructured around speculative prompts ("How might this system be adapted for small-scale cultivation?"; "In what ways could agrivoltaics contribute to

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rural energy communities?"), which functioned as semiotic stimuli for anticipatory reasoning. The objective was not to elicit consensus but to cultivate epistemic fertility: a proliferation of possible futures emerging from the intersection of empirical familiarity and imaginative extrapolation.

Perceptual transformation during this phase was empirically traceable through both linguistic and behavioural indicators. The discursive register of the participants underwent a marked shift from descriptive and observational to performative and propositional. Utterances increasingly employed the first-person plural and the conditional mood ("we could redesign," "we might combine," "we should test"), signalling a transition from spectatorship to authorship. This rhetorical evolution, supported by pragmatic markers such as gesture and collective affirmation, indicates the emergence of design thinking as a spontaneous cognitive orientation.

Concrete outputs materialised from these discursive operations: proposals for modular photovoltaic arrangements calibrated to crop-specific light tolerances; designs for decentralised micro-grids linking adjacent farms; integrated water-harvesting and energy storage systems; and suggestions for utilising surplus solar power in post-harvest refrigeration or low-emission mechanisation. Such propositions demonstrate not speculative fantasy but an emergent collective intelligence—a distributed epistemic capacity whereby diverse professional and experiential knowledges converge to generate novel system-level hypotheses.

The reason perception advanced so radically at this stage lies in the triadic convergence of epistemic confidence, relational trust, and experiential anchoring. Participants possessed sufficient technical comprehension to formulate critiques, a stable field of peer reciprocity that legitimised expression, and direct empirical grounding in the observed system to prevent abstraction. The resulting cognitive formation aligns with what contemporary science and technology studies conceptualise as co-productive imagination: the iterative negotiation of technological futures through situated reasoning among interdependent epistemic agents.

The spatial and procedural configuration of the sessions was crucial in sustaining this generative dynamic. Facilitators employed a high degree of visual epistemology—real-time synthesis of emergent ideas on large-format panels and digital displays. These visual syntheses aggregated keywords, diagrams, and conceptual relations, producing a shared cognitive landscape in which participants could recognise their contributions inscribed within the collective corpus of thought. This recursive feedback mechanism instantiated what cognitive linguistics terms distributed coherence: an emergent order of understanding produced by many minds reasoning in synchrony without the erasure of individual variance.

Within this setting, facilitators assumed the role of epistemic curators rather than pedagogical authorities. They refrained from evaluative interruption, intervening

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primarily to ensure thematic continuity, discursive equity, and semiotic clarity. Their curatorial mediation functioned as a meta-communicative regulator, preserving the internal coherence of the participatory discourse while safeguarding its open-endedness. Through this reflexive structure, the group attained what systems theory would describe as autopoietic cognition—a self-organising circulation of information in which the community itself becomes the medium of reasoning.

The cognitive content of this phase can be conceptualised as a movement from comprehension to authorship. Farmers ceased to perceive agrivoltaics as an externally imposed technological object and began to construe it as a mutable socio-technical assemblage whose optimisation required their interpretive agency. Discussions transcended the operational level to encompass regulatory and institutional considerations: energy cooperatives, licensing simplification, incentive harmonisation, and inclusion of agrivoltaic indicators within Common Agricultural Policy frameworks. The discursive field thus expanded from local functionality to systemic governance, signalling a shift from instrumental reasoning to normative reflection.

In analytic terms, this final phase demonstrates that participatory intelligence operates as a cognitive infrastructure for sustainability transitions. Co-creation embeds technological innovation within networks of symbolic meaning, reciprocal trust, and prospective rationality. Farmers' imaginative extrapolations, while not all technically realisable, functioned as heuristic instruments that disclosed latent affordances within the technology itself. Innovation, under these conditions, ceased to operate as a unidirectional transfer of knowledge; it became an iterative epistemic negotiation between the empirical and the speculative, between system performance and social expectation.

The process of facilitation further enhanced this collective cognition by rendering the temporality of thought visible. As facilitators clustered and re-presented themes in successive plenary sessions, participants could observe their own reasoning trajectories materialised and evolving. This reflexive temporality reinforced the sense of authorship: participants recognised that the epistemic field of the project was co-extensive with their own deliberations. In methodological terms, this recursive visibility functioned as an index of legitimacy—a public trace of collective reasoning that stabilised trust while sustaining epistemic dynamism.

The epistemological structure of the participatory cycle can thus be delineated as a tripartite continuum: embodied cognition (direct sensory exposure to technology), social deliberation (collective reasoning under conditions of epistemic symmetry), and anticipatory projection (the co-creative extension of comprehension into future-oriented design). Each phase produced distinct epistemic artefacts: in the first, experiential literacy; in the second, pragmatic evaluation; in the third, systemic foresight. These artefacts collectively constituted a reflexive ecology of understanding in which perception evolved into an active instrument of knowledge production.

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Within this architecture, the agrivoltaic greenhouse functioned as both a technological and cognitive dispositif: a material infrastructure for energy generation and an epistemic medium for social learning. The integration of CO_2 extraction systems amplified this duality, demonstrating the potential of technological assemblages to operate simultaneously as tools of environmental regulation and as vectors of conceptual innovation. The installation thus served as a prototype not only of agronomic adaptation but of learning-by-deliberation—a method by which technological meaning emerges through discursive praxis.

The theoretical implications extend beyond the agrivoltaics domain. The REGACE process illustrates a transferable epistemological model for embedding innovation within socio-ecological systems. First, direct exposure aligns perceptual and cognitive registers by transforming observation into embodied comprehension. Second, structured deliberation stabilises comprehension through intersubjective validation and argumentative coherence. Third, co-creative projection translates comprehension into collective authorship, embedding technology within moral, institutional, and cultural logics. In this continuum, perception is not an antecedent to innovation but its constitutive medium—the very process through which novelty acquires legitimacy and durability.

By the conclusion of the REGACE participatory trajectory, participants' perception of agrivoltaics had achieved epistemic maturity. It had become multi-scalar, empirically informed, and normatively structured. Farmers no longer conceptualised the technology as an exogenous artefact but as an extension of agrarian rationality: an adaptive ecology capable of reconciling productivity with stewardship, autonomy with interdependence, and technical modernity with ecological continuity.

The transformation observed here substantiates a central hypothesis in participatory epistemology: technological acceptance is not a behavioural derivative of persuasion but the cognitive outcome of co-production. Understanding, trust, and imagination operate as mutually conditioning variables within a single epistemic system. The intersection of experiential exposure, deliberative rationality, and collective imagination thus constitutes a model of epistemic democracy—a form of knowledge governance in which technology, cognition, and society evolve as co-extensive dimensions of a shared rational project.

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Annex 1 – Spring School Programme

REGACE PROJECT's Spring School
May 3rd-5th, 2023

Programme Partners:

University of Rome Tor Vergata

Fattoria Solidale del Circeo

Theme and Aims

The REGACE Spring School on participatory research provides an overview of research methods in qualitative and quantitative research on participatory processes and community work.

Strategies used in participatory research focus on process and capacity building. The process is intended to produce valuable and sound information and build capacity among the research participants, who will learn to analyse the information they have collected from the involved groups and decide how to apply this data.

Aimed to promote participatory research, the course briefly introduces the main theories and research approaches to participation and community engagement. We will present participatory research tools and techniques such as non-directive interviews, in-depth interviews, active listening, natural observation and specific group-based techniques, such as the Open Space Technology (OST) and the World Café.

The Spring School will create spaces to share, discuss and debate, allowing the participants to interact with each other and with the team of teaching researchers in a perspective of collaborative joint learning on the practices, the problems, and the challenges of participatory and community research.

To enhance the spirit of sharing between practitioners and academic researchers, a special focus will be on activities to facilitate interaction and collaboration among participants. These will include participatory research activities and real-life exercises.

Dates
From May 3rd to 5th, 2023
Arrival date: May 2nd

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Departure date: May 5th

Venue
The Spring School is an onsite event, where participants will meet and work together.

The venue is:
Fattoria Solidale del Circeo
Strada Lungo Ufente, 16 - Pontinia - Latina
tel. +39 0773 249698

Participants' requisites and working language

The programme is intended for an audience made of early-stage careers of qualitative researchers, community activists, and community facilitators from Italy, Greece, Austria, Germany, and Israel.

After the Spring School, the participants will be involved in the subsequent phases of the REGACE Project in their own country, helping the research group to carry out interviews to farmers and the World Café sessions.

Motivation and commitment to learning and practising in participatory research are prerequisites. A good command of **English** as a working and teaching language is also required.

Costs
Participation in the Spring School is free of charge. No participation fee will be asked to participants. Travel and accommodation costs are covered by the Italian REGACE partners.

Spring School Programme overview

Day 1 - May 3rd, 2023

9:00 am	Introduction to Spring School: Horizon Regace
9:15	Ice breaking
9:45	The non-standard qualitative interview: objectives, methods, analysis of results
10:00	The mock interview. Participants will be invited to carry out a non-standard qualitative interview
12:30	Lunch

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2:30 pm	The focus group: objectives, methods, analysis of results
3:30	The focus group simulations
5:30	Debriefing of the day
6:30	Closing of the day

Day 2 - May 4th, 2023

9:30 am	Participation facilitation methods: open space
10:30	Construction and implementation of an open space
11:30	Debriefing
12:30	Lunch
2:30 pm	Sentiment analysis
3:15	Examples of live sentiment analysis
5:00	Debriefing of the day
6:00	Closing of the day

Day 3 - May 5th, 2023

9:30 am	Participation facilitation methods: world café
10:15	Realisation of a world café
11:30	Debriefing of the spring school, calendar of meetings in the various countries, group management methods
12:30	Closing of the Spring School
1:00 pm	Lunch and departure of participants

Teaching Staff

Cristina Cornaro, Coordinator of REGACE Project Born in Rome in 1967, in 1991 she graduated with honours in Physics at La Sapienza University of Rome. In 1996, she obtained a PhD in Thermophysical Properties of Materials at the University of Rome Tor Vergata with a thesis entitled 'A sensor for measuring the temperature of planetary atmospheres'. She was awarded a two-year post-doctoral fellowship at the same university and a CNR scholarship for study abroad at the University of Minnesota, USA, where she conducted research in the field of heat transfer and fluid dynamics. Since 2001, she has been a researcher at the Faculty of Engineering at the University of Rome 'Tor Vergata' in the scientific disciplinary sector of Technical Environmental Physics. She qualified as an associate professor on 04/04/2017. He has held the chair in Technical Environmental Physics since 2003 and the course in Measurement, Monitoring and Certification Systems for the 2nd-level Master's Degree in Photovoltaic Engineering (www.masterpv.org) at the same University. His main scientific interests concern the study of thermal and fluid-dynamic phenomena, thermal measurements and indoor and outdoor environmental monitoring, and environmental well-being. Recently, his activities have focused on measuring solar radiation on the ground and monitoring the performance of solar energy conversion devices in the field of energy saving, architectural integration of photovoltaics and the development of renewable energy sources. It manages the ESTER (Solar Energy Test And Research, www.ester.uniroma2.it) laboratory financed within the framework of the Lazio Region's Organic Photovoltaics Cluster (CHOSE) project. The laboratory consists of a high-performance solar weather station and a monitoring station for photovoltaic modules of various technologies.

Andrea Volterrani, Coordinator of the Spring School. Sociologist of cultural and communication processes, associate professor at the University of Rome Tor Vergata; he is the Director of the Master in Social Communication and of the Master in Social Agriculture. He teaches Theory and Technique of Mass Communications and Sociology of Communication in several degree courses His professional interests focus on research, training and consultancy about social communication and prevention, the third sector and volunteering, new forms of mutuality and the social development of communities.

Stella Iezzi, Social statistician, associate professor at the University of Rome Tor Vergata. Within statistical research, she has an expertise in Sentiment analysis.
Maria Cristina Antonucci, researcher in social sciences at the National COuncil of Research (Consiglio Nazionale delle Ricerche - CNR), PhD in Sociology of political processes. She is an expert in participatory approaches and community-activated processes for social innovation. She has published articles, essays and volumes on non-political participation, third-sector advocacy, and gender issues.

Marco Serra, Sociologist of organisations, trainer and facilitator of participatory processes. Expert in visual methods and tools for facilitating organisational processes and learning.

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Annex 2 – Spring School Pictures

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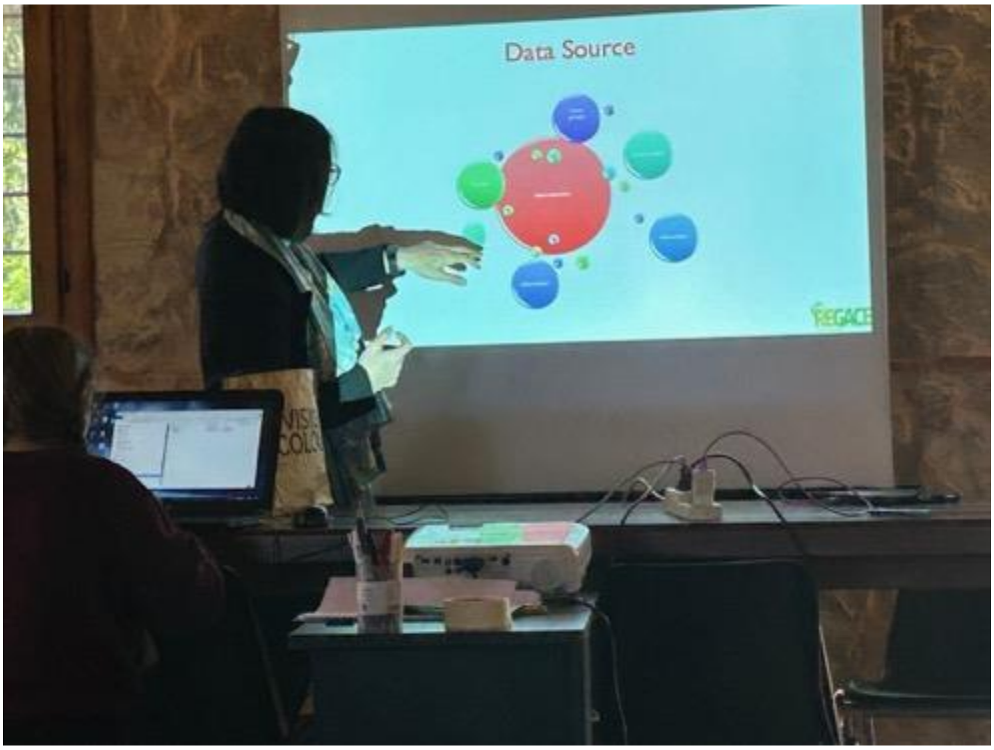

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