HarvRESt
Greener Farming with RES

D3.4

Business Model Catalogue

26/06/2026

Funded by
the European Union

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PROJECT INFORMATION

ACRONYM	HarvRESt
PROJECT NAME	Harnessing the vast potential of RES for sustainable farming
PROGRAMME	Horizon Europe
TOPIC	HORIZON-CL6-2023-CLIMATE-01-7
TYPE OF ACTION	HORIZON Research and Innovation Actions
PROJECT NUMBER	101136904
START DAY	1 January 2024
DURATION	36 months

DOCUMENT INFORMATION

TITLE	D3.4
WORK PACKAGE	WP3
TASK	T3.5
LEAD PARTNER	Engreen
CONTRIBUTORS	CKIC, HEC
DATE	26/06/2026
DISSEMINATION LEVEL	Public

DOCUMENT HISTORY

Version	Date	Changes	Responsible partner
0.1	15/06/2026	First issuance	Engreen
0.2	19/06/2026	Comments, suggestions and additions of information	Task Partners and Coordinator
0.3	22/06/2026	Final draft version	Engreen
1.0	26/06/2026	Format changes	CIRCE

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ABBREVIATIONS

AD	Anaerobic Digestion
AI	Artificial Intelligence
AVPP	Agricultural Virtual Power Plant
BESS	Battery Energy Storage System
BM	Business Model
BMI	Business Model Innovation
CAP	Common Agricultural Policy
CAPEX	Capital Expenditure
CHP	Combined Heat and Power
CO_2	Carbon Dioxide
CO_{2e}	Carbon Dioxide Equivalent
DO	Denomination of Origin
DSS	Decision Support System
DSO	Distribution System Operator
EaaS	Energy-as-a-Service
EEA	European Environment Agency
EMF	Ellen MacArthur Foundation
EMS	Energy Management System
ESCO	Energy Service Company
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GHG	Greenhouse Gas
ha	Hectare
HoReCa	Hotel/Restaurant/Catering sector
IaaP	Infrastructure-as-a-Platform
IACS	Integrated Administration and Control System
ICT	Information and Communication Technologies
ID	Identification
IPR	Intellectual Property Rights
IRENA	International Renewable Energy Agency
IRTA	Institut de Recerca i Tecnologia Agroalimentàries
KER	Key Exploitable Result
LBG	Liquid Biogas

LFP	Lithium Iron Phosphate
N / P	Nitrogen/Phosphorus
OEM	Original Equipment Manufacturer
P2P	Peer-to-Peer
PPA	Power Purchase Agreement
PV	Photovoltaic
PVT	Photovoltaic-Thermal
R&D	Research and Development
RBM	Regenerative Business Model
RE	Renewable Energy
RES	Renewable Energy Sources
SBM	Sustainable Business Model
SME	Small and Medium-sized Enterprise
TRL	Technology Readiness Level
TSO	Transmission System Operator
UPC	Universitat Politècnica de Catalunya / Barcelona Tech
VAWT	Vertical Axis Wind Turbine
VPP	Virtual Power Plant
WEF nexus	Water-Energy-Food nexus

1 EXECUTIVE SUMMARY

To meet Europe's climate goals, the farming sector must profoundly change how it creates value in rural areas. While renewable energy technologies for agriculture are technically ready, they won't be widely adopted without the right economic and social support systems. The HarvRESt project addresses this challenge by studying decentralized energy setups within farming communities. Its main goal is to build a solid data foundation for two tools: an Agricultural Virtual Power Plant, which links multiple small energy sources to act as one large power grid, and a Decision Support System. These tools are designed to help balance energy generation with food and feed production, navigating the complex relationship between water, energy, and food.

To organize the current market landscape, this study created the HarvRESt business models catalogue, aiming to explore innovative ways to integrate renewable energy into agriculture. The document lists and defines 33 real-world European business models, covering different farm sizes, farming activities, technologies, and evaluation criteria. It also includes a comparative analysis of business models developed by startups and small-to-medium enterprises in the renewable energy sector. The study analyzes these 33 configurations across four structural areas, which encompass technological types, management and ownership structures, land-use strategies, and sector-specific integration. An expert panel then scored each model across seven performance areas—including long-term resilience, how easily they can be copied elsewhere, and how attractive they are to stakeholders—to see which ones have the best potential to scale up.

The analysis highlights a promising opportunity, revealing that while a gap remains between farm-level setups and the broader energy market, farmers are highly willing to diversify into energy production, providing a strong foundation for growth. Right now, attraction from large energy companies and integration into the main power grid are still in the early stages, leaving room for further development. However, current farm energy initiatives have successfully established themselves as viable, local, self-consumption loops. Looking forward, the study shows an excellent opportunity to upgrade these isolated setups into official, organized agri-energy units.

Furthermore, clear operational trade-offs exist within the sector. Complex configurations like agrivoltaics, which combines solar panels with crops or livestock, and biogas systems offer excellent recycling of resources and long-term resilience, despite requiring higher up-front costs. On the other hand, standalone solar installations and third-party leasing frameworks provide lower entry barriers and are easier to scale up quickly in the short term.

An assessment of how easily these models can move across different countries indicates that the primary barriers to expanding agricultural energy are institutional and bureaucratic rather than technological. Deep information gaps persist, with nearly half of the surveyed market players reporting systemic uncertainty regarding available subsidies and rural governance rules. Crucially, two major friction points stall cross-sector collaboration. First, a severe time clash exists between the rapid decision-making cycles required by private investors and the slow, step-by-step bureaucratic processes typical of public administrations, which effectively paralyzes public-private partnerships. Second, centralized power grid regulations in multiple European regions actively penalize local setups by legally restricting or banning peer-to-peer energy trading among neighbors, which hurts economic profits and confines farmers to isolated operations.

The ability to move these agri-energy business models across Europe is highly unequal and depends heavily on regional differences in government efficiency. Consequently, regions with slower bureaucracy or follower markets should initially prioritize simple, commercially proven models, specifically standalone solar assets that are either farmer-owned or managed by energy service companies, as these bypass bureaucratic hurdles. Moving toward highly integrated, multi-source hybrid models and collective cooperatives remains strictly dependent on future policy changes, such as opening up the power grid and simplifying cross-sector permitting procedures. Ultimately, this catalog gives the HarvRESt Decision Support System and Agricultural Virtual Power Plant the real-world data calibration they need, ensuring a complete overview of the toolkit for decision-making and planning.

2 INTRODUCTION

The HarvRESt project aims to advance knowledge on decarbonization strategies for farms, fostering stronger synergies between the agricultural and energy sectors. The project focuses on developing a decision support system (DSS) designed to provide tailored recommendations for both farmers and policymakers. These recommendations will prioritize the optimization of renewable energy production alongside food and feed outputs within agro-communities. To achieve these objectives, the HarvRESt project adopts a holistic, multi-actor approach, addressing social, economic, environmental, technical, and regulatory dimensions of the agricultural sector. This comprehensive strategy ensures the alignment of project outcomes with the interests of key stakeholders while supporting the sustainable development of the sector. To facilitate this approach, the project's developments are structured around three interconnected pillars, each addressing critical aspects of the decarbonization process and its integration within agro-communities:

1. Social engagement and Innovative BMs, considering financial issues but also social sciences.
2. Agricultural and environmental trade-offs addressing the impact of RES technologies on agricultural production, potential trade-offs and synergies as well as the potential of ICT solutions to better identify these opportunities.
3. RES sources and smart energy systems, which addresses the modelling and design of the technological alternatives required to support the uptake and upscaling of RES production

The developments of such pillars are synergic and interconnected. In particular, the flowchart showed here on the side summarize how the workflow will be developed along the project lifespan.

To gather valuable insights, co-create solutions, and validate them, HarvRESt relies on four complementary Use Cases located in Denmark, Spain, Italy, and Norway. Furthermore, to facilitate the achievement of the project's objectives, the HarvRESt community will include a broad range of stakeholders, involving 200 agricultural and energy stakeholders and reaching over 1,500 farms as part of the initiative.

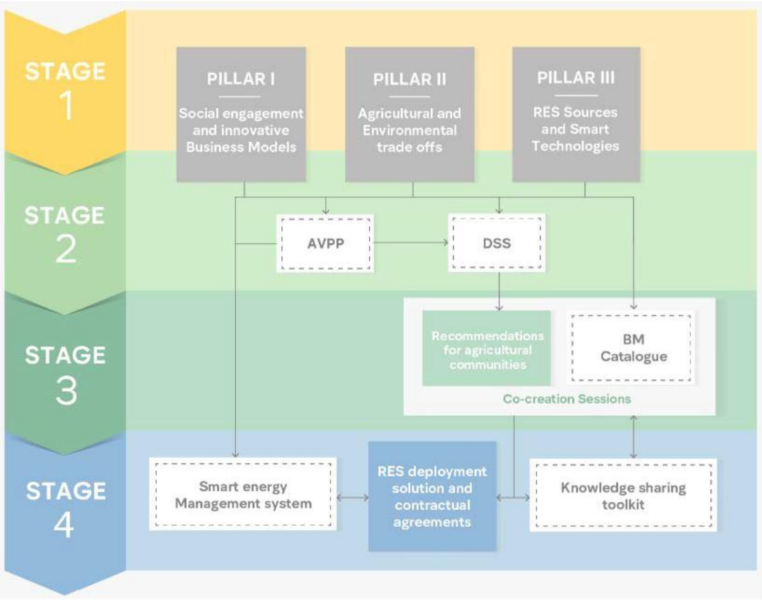

Figure 1. HarvRESt Pillars

The project workflow is organized in Work Packages (WP) as shown in Figure 1.

2.1 Structure of the deliverable

This deliverable is structured in the following way: The introductory chapter frames the purpose, scope, and objectives of [D3.4] within Work Package 3 and, in particular, its implementation under Task [T3.5] "Development of HarvRESt business models catalogue". Section 2.2 outlines the direct correlation and synergies with findings from previous tasks, while establishing how this report serves as a valuable baseline for subsequent deliverables, notably [D7.1], [D8.4], and [D8.9].

In the Methodology chapter, the multi-phase framework designed for the study is presented, detailing the overall approach based on desk research, benchmark analysis, and stakeholder engagement activities (such as surveys, interviews, and co-creation workshops).

The Business Models Catalogue chapter forms the core of the document, starting with a conceptual introduction to business model innovation and defining the key sustainable, circular, and regenerative archetypes for RES integration in agro-farms. It then details the primary user groups identified during consultations and builds a comprehensive taxonomy of 33 European business models, categorizing them across four distinct dimensions: Technology Archetype, Governance & Ownership, Land Use Strategy, and Agricultural Sector, concluded by a consolidated cross-cutting summary matrix.

The Business Models Applied in the Real Market chapter explores the socio-technical reality of the sector, offering a critical cross-national assessment of enablers and barriers across different European regions. Furthermore, it presents a multi-criteria viability evaluation conducted by an expert panel to score each model, concluding with a bridge toward the operationalization of the project's digital toolkits, specifically the Decision Support System (DSS) and the Agricultural Virtual Power Plant (AVPP).

Finally, the deliverable closes with the Conclusions chapter, which synthesizes the main empirical and policy findings, ensuring that the catalogued insights effectively calibrate the upcoming decision-making and planning frameworks of the HarvRESt project.

2.2 Relation with other tasks and deliverables

The Deliverable [D3.4] is part of the WP3 and, in particular, implements the [T3.5] Development of HarvRESt business models catalogue, having the ambition of producing a report including the list and definition of Business Models identified as relevant for HarvRESt, which will include information on various user sizes, agricultural activities, technologies, evaluation criteria, and examples, along with a comparative analysis of Business Models developed by startups and SMEs in the field of renewable energies.

Business model related outcomes of the HarvRESt project, valuable findings and insights from previous deliverables deployed within the HarvRESt project so far have been taken into consideration to (i) provide a clear background of this study and (ii) align it with the other deliverables, showing a direct correlation between input and output of each project’s task, as shown in the methodology Figure 3. Therefore, the next sections of the introduction are extracts selected from other HarvRESt deliverables for this purpose.

Moreover, this deliverable will be a valuable input for further HarvRESt’s works, in particular: [D7.1], [D8.4] and [D8.9].

3 METHODOLOGY

3.1 Overall approach

The overall approach of the study is founded on (i) **understanding of the State of the Art** of the sector of intervention and (ii) how the project can **exploit its results** so that the impact goals of the project can be achieved.

With this perspective, a full understanding of the project's market is vital, and the Engreen's tasks are focused on **three study areas: (1) the financial environment, (2) the business models, and (3) exploitation and IPR strategy.**

The overall study is performed by (i) reviewing official reports, documents, literature and (ii) involving stakeholders to gather updated information. Defining benchmarks is approached not only by studying the market in its general terms (macroeconomics, regulatory, sizing, financing, etc.), but focusing on adopted business models, which are chosen as the key tool for identifying barriers and opportunities in the reference market.

Stakeholder engagement by means of (i) stakeholder mapping, (ii) stakeholder consultation, (iii) workshops and (iv) impact boosting activities such as capacity building is a cross-cutting activity along all the Work Packages, as it represents one of the project's pillars.

The approach based on leveraging on both desk research and stakeholder engagement for a strong understanding of the sector and deep technical knowledge represents the foundation for deploying **co-created tools and models** to support, encourage and scale up the transformation of traditional solutions to market ready innovations.

To better specify the overall approach adopted in each study area:

1. The financial environment's analysis is focused on **the current financial instruments** for fostering stronger synergies between the agricultural and energy sectors. In fact, this task strongly contributes to developing a decision support system (DSS) designed to provide tailored recommendations for both farmers and policymakers. For this reason, the identification of key financial schemes able to boost this transition may accelerate in the green revolution. More in general, the understanding of such financial environment also helps in the identification of country/regional incentives, able to support the different stakeholders. By understanding these elements, it is easier to identify the types of incentives that are likely to be effective in promoting sustainable agricultural and energy practices.

2. The business models (BMs) assessment analysis is focused on **both the partners' and stakeholders' business models**, as well as on exploring new and innovative business models for integrating RES in the agricultural sector. A Preliminary BMs assessment, is based on the partners' business models. Then, a more extended BMs assessment is performed by including the stakeholders' business models. Such dual analysis focus is to both understanding of the State of the Art of the sector of intervention and how the project can exploit its results.

3. **Exploitation and IPR Strategy** starts from the parters' analysis and consultation on their businesses and engagement activities, targeting both projects' partners and external stakeholder groups. Such an approach is necessary for full understanding of the context and using them as a starting point increases the exploitability of the results identified and later characterized.

Thus, there is a synergy between the work on the BMs of partners/stakeholders, KER characterization and IPR, since these three aspects are strongly intertwined.

The Exploitation and IPR Strategy development is based on a step-by-step methodology, which has been designed to bring together the expertise and peculiarities of the Consortium partners and stakeholders from one side and the results of the project, which is divided into three main phases.

1. KER Identification phase, and draft IPR tools
2. KER Characterization phase, and preliminary IPR strategy
3. KER Roadmap development phase, and final IPR strategy

The overall methodology that is adopted to carry out the work is divided into three consequential phases:

- **Phase I:** Exploitation strategy planning, desk research and data collection, which is composed of a set of activities to assure, as outputs, the results of analysis of KERs and financial mechanisms of both energy and agricultural sectors. In brief, this phase paves the way for the Exploitation and IPR strategies, and describes the market with a focus on the financial environment.
- **Phase II:** HarvRESt Business Models assessment, which is composed of a set of activities to assure, as outputs, the KER characterization and BM catalogue. In brief, this phase fully drafts the Exploitation and IPR strategies, and describes the market with a focus on business models.
- **Phase III:** Roadmapping and valorization of HarvRESt results, which is composed of a set of activities to assure, as outputs, the knowledge sharing toolkit, partner roadmap for exploiting HarvRESt results, and recommendation catalogue for HarvREST's results replication best practice. In brief, this phase finally defines the Exploitation and IPR strategies, provides tools, guidelines and recommendations, as well as evaluates the impact of HarvRESt project's.

The methodology is summed up in the following flowchart, representing the key phases it is composed of:

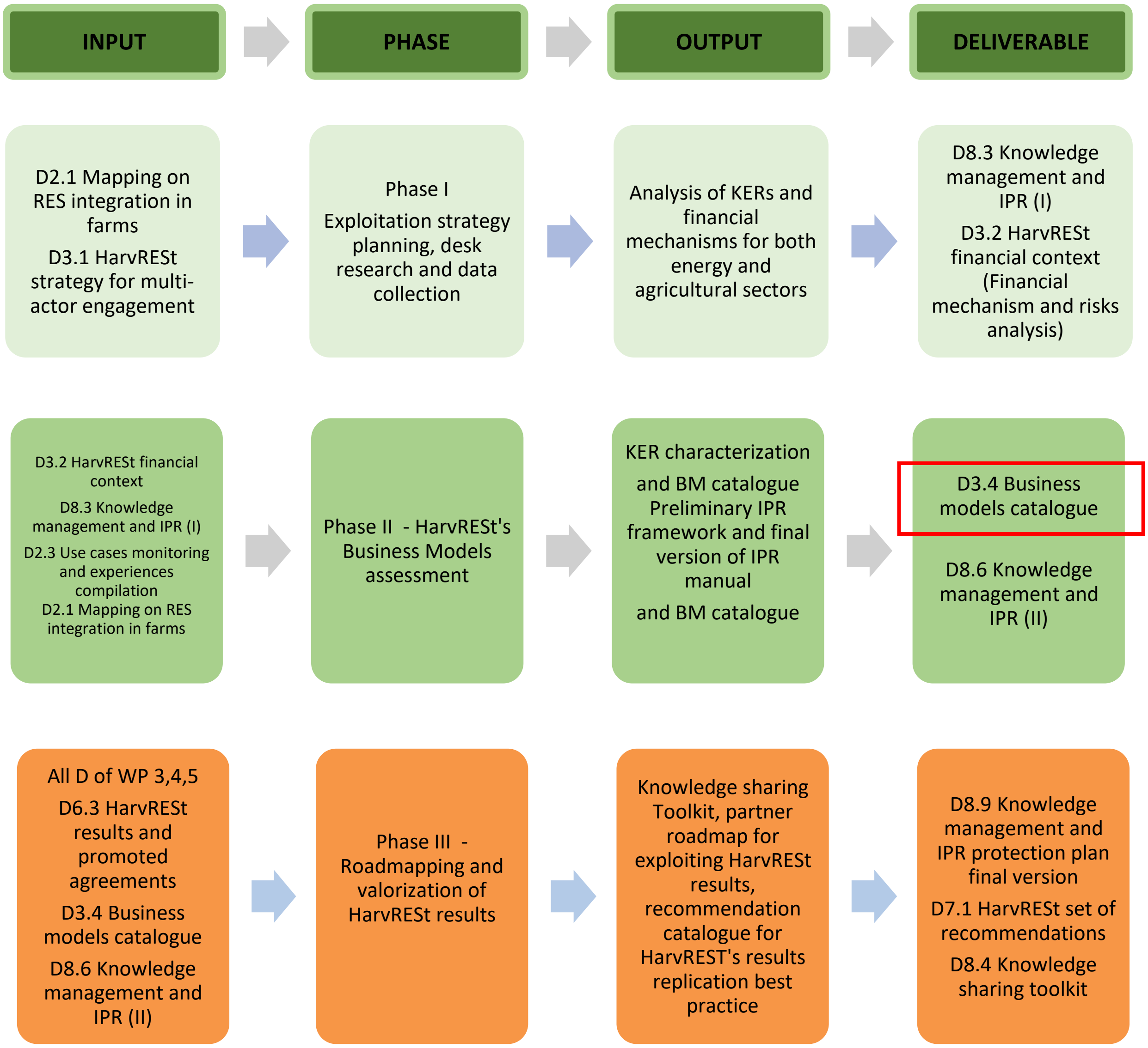

Figure 2. Methodology flowchart

3.2 Methodology for the business model catalogue

Phase II is focused on the HarvREStt Business Models assessment. In brief, this phase fully drafts the Exploitation and IPR strategies, and describes the market with a focus on business models (Figure 3).

In this phase both the business model partners and new and innovative business models for integrating RES in the agricultural sector are reviewed. The review to include new and innovative BMs to create an HarvREStt BMs catalogue.

For this work a useful input is the deliverable [D2.3] that assesses the work done with the stakeholder identified by the HarvREStt project. The phase ends by delivering [D3.4].

The second phase of EnGreen's methodology consists of the following sub-tasks:

[T3.5.a] Validation of Table of Contents for deliverables [D3.4]

[T3.5.b] Inserting relevant contents from Input Deliverables, including UCs

[T3.5.c] Benchmark analysis

[T3.5.d] Stakeholders consultation

[T3.5.e] BM categorization

[T3.5.f] Definition of matrix evaluation parameters (Pre-Assessment Criteria Matrix)

[T3.5.g] Preliminary development of the HarvRESt BM catalogue

[T3.5.h] Validation workshop

[T3.5.i] Final development of the HarvRESt BM catalogue

[T3.5.l] Final workshop with partners and stakeholders

[T3.5.m] Draft version of [D3.4]

[T3.5.n] Gathering comments from WP partners on Draf D3.4

[T3.5.o] Final version of [D3.4]

The main outputs of the second phase is a catalog of BMs focused on innovative strategies for integrating renewables into the agricultural Outputs 1 and 2 contribute to Deliverable [D8.6] and [D7.1]

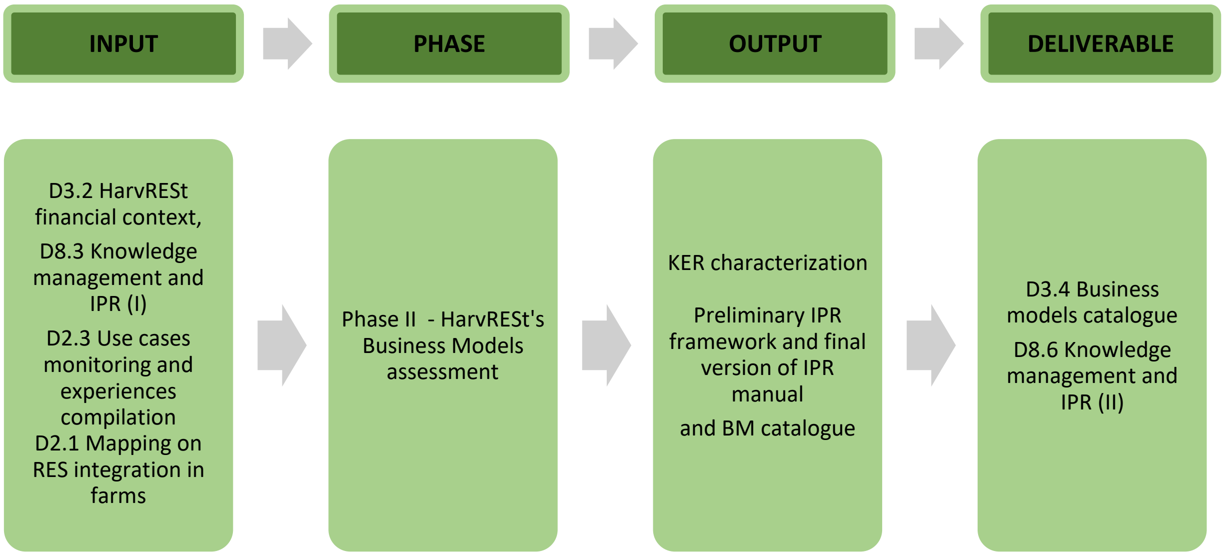

Figure 3. Phase II Methodology

3.2.1 Development of HarvREst business models catalogue

Task 3.5 aims to develop of HarvREst business models catalogue. EnGreen is the leader of the activities and the main responsible for the BM catalogue, but a major contribution is made also by CKIC, HEC partners. The catalogue, together with the CKIC analysis are the main body of the deliverable [D3.4].

The BMs catalogue aggregates in a comprehensive way the most relevant business models of the agricultural sector in order to enable an easy consultation and a better sharing of the knowledge developed during the work.

The **data collection(1)** is carried out by using the following methods:

(1a) Benchmark analysis: CKIC uses the same datasets in Task 3.3 to perform a benchmark analysis of BMS developed by start-ups and early market SME. The analysis will result in a benchmark and comparative table of different business models vis a vis RE application areas, with detailed content of BM options for the catalogue.

(1b) Stakeholder consultation (e.g. face-to-face interview or survey): Conducting a stakeholder consultation with key players directly involved in the world of agricultural sector can serve as a crucial step in narrowing down the long list, ensuring that the selected candidates align with practical insights and industry needs.

Data collected are expected to include case studies and examples from the real market, as well as potential models to be tested.

Then, **(2) data collected are analyzed** (cleaned and processed) and reported by using the BM Canvas tool, a template that outlines the key components of a business model, including customer segments, value proposition, channels, customer relationships, revenue streams, key activities, key resources, key partnerships, and cost structure.

Then, **(3) the BMs are categorized** according to a selected classification criteria with a view of an easy consultation and comparison.

Lastly, the **(4) BMs comparison is performed by evaluation criteria** for assessing the value of each BM.

A **(5) validation workshop** with consortium partners is organized for collecting inputs from partners and thus other relevant BMs in the sector, while **a (6) final workshop** with stakeholders is to present the final BM catalogue.

3.2.2 [T3.5.c] Benchmark analysis

This sub-task is done by CKIC. The methodology has been decided and they provide an initial input through this benchmark analysis.

3.2.3 [T3.5.d] Stakeholder consultation (identification of key stakeholders to be contacted, interview, highlights)

A second part of the data collection consists in a stakeholder consultation with bilater meeting (online or in presence). This will be done by identify key stakeholders to be contacted for interviews aimed at collecting highlights and opinions about the BM catalogue

Data collected are analyzed (cleaned and processed) and reported by using the BM Canvas tool, a template that outlines the key components of a business model, including customer segments, value proposition, channels, customer relationships, revenue streams, key activities, key resources, key partnerships, and cost structure.

3.2.4 [T3.5.e] BM categorization and assessment

The resulting BM identified from the data collection are categorized. This intermediate steps is needed for the final evaluation of the BMs . The BMs are described per each selected agricultural sub-sector. The report includes the following sections, which are set to disseminate results in different contexts (decision makers, developers, local entrepreneurs, etc.):

- Main reasons for supporting the solutions under analysis
- Business Model Canvas based on that developed by Alexander Osterwalder.
- Description of the BM(s)
- BM(s) sketch

- Enabling factors and recommendations for policy makers and developer

3.2.5 Definition of matrix evaluation parameters (Pre-Assessment Criteria Matrix)

Lastly, the (4) BMs comparison is performed by evaluation criteria for assessing the value of each BM. Once all the data are collected an evaluation matrix is designed by identifying key parameters which are the most effective for an evaluation of the BM identified during the data collection. In the parameters identification and the evaluation a particular focus on the solution adopted in the BMs is adopted.

3.2.6 [T3.5.h-l] Two workshops: Validation and final Workshop of the BM catalogue

A (5) validation workshop with consortium partners is organized for collecting inputs from partners and thus other relevant BMs in the sector, while a (6) final workshop with stakeholders is to present the final BM catalogue.

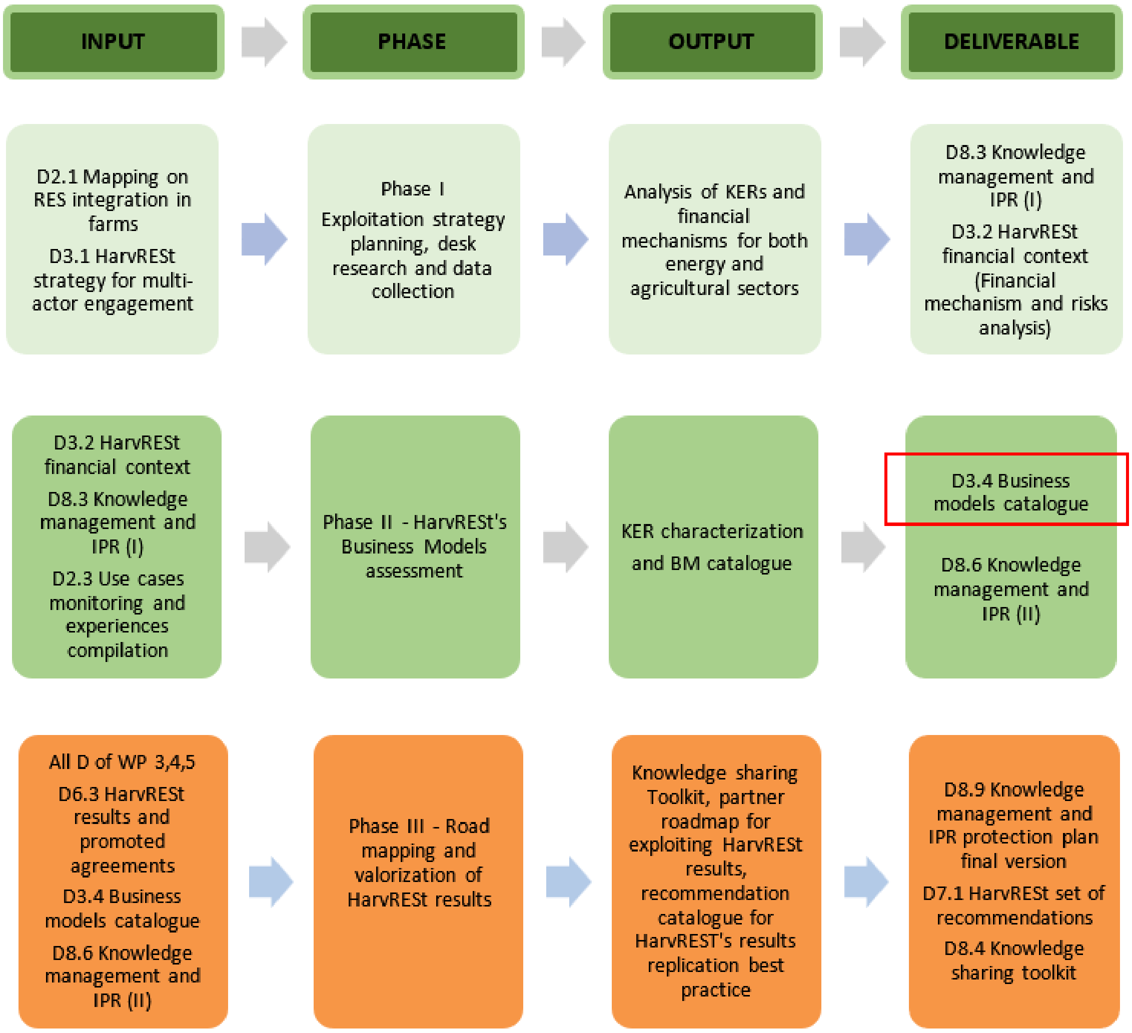

Figure 4. Methodology structure

4 BUSINESS MODELS CATALOGUE

4.1 Introduction to business models for RES in agri-farms

The agricultural sector in Europe is both a major contributor to and largely impacted by the effects of Green House Gases (GHG) on climate change. As of 2022, the sector was responsible for up to 12% of GHG emissions in the EU, at 380 million tonnes (Mt) of CO_{2e} (Mal, 2024), and 363.8 Mt CO_{2e} in 2023 (EEA, 2025).

The EU Climate Law and Green Deal aim for carbon neutrality by 2050, setting ambitious targets to reduce overall emissions by 55% as soon as 2030 (EEA, 2025), driving regulatory, policy and market change across the continent.

For agriculture, this presents new challenges and opportunities for green innovation in technology, institutions, and business models (Kemp et al., 2019; Lehmann-Ortega et al., 2022). Renewable Energy Sources (RES) for sustainable farming have been identified as instrumental in creating pathways for reducing emissions in the sector (EMF, 2013), and are the focus of this report.

Technological innovation for harnessing RES such as solar-PV, small-scale wind, biogas, or geothermal have been widely developed, while others are at varying stages of maturity, such as agrivoltaics, biomethane, micro-hydro (Section 4.1.2). But technological maturity alone does not guarantee adoption or market impact – a key component for successful innovation are business models that are able to create and capture value aligned with changing systems (Kemp et al., 2019; Teece, 2010).

4.2 Business models definitions

Broadly speaking, business models are defined as the way companies organise and structure their mechanisms to create, deliver and capture value (c.f. Osterwalder & Pigneur, 2010; Teece, 2010). Figure 5 outlines relevant business models that are oriented to the different low-carbon, sustainable and/or circular solutions included in this catalogue and Table 1 shows the definition these key business models to adapt to societal and global changes and create new market opportunities, business model innovation aims to re-imagine the purpose of a business to create and capture new value (Amit & Zott, 2012; Bocken et al., 2014). Business model mapping allows for a clear conceptualisation of structural components that make up the business, it not only gives organisational direction but can also be used as a tool for experimentation in adaptation to change (Chesbrough, 2010; Diaz Lopez et al., 2019).

Figure 5. Key Business models found in this catalogue, compiled by authors.

Table 1. Definition of business models concepts

Term	Definition
Business model (BM)	A business model describes the logic of how a firm creates, delivers, and captures value, including its value proposition, customer segments, and revenue mechanisms (Osterwalder & Pigneur, 2010; Teece, 2010).
Business model innovation (BMI)	Business model innovation refers to the reconfiguration of a firm's value creation and capture mechanisms, often involving new ways of organizing resources, partnerships, or revenue streams to generate competitive advantage (Amit & Zott, 2012; Foss & Saebi, 2016).
Sustainable business model (SBM)	A sustainable business model integrates financial, environmental and social considerations into value creation, delivery, and capture, aiming to generate long-term benefits for stakeholders, society, and the natural environment (Bocken et al., 2014; Boons & Lüdeke-Freund, 2013).
Circular economy business model (CEBM)	A circular economy business model is designed to slow, close, or narrow resource loops through strategies such as reuse, repair, remanufacturing, and recycling, thereby reducing resource inputs and waste (Bocken, 2024; Geissdoerfer et al., 2017).
Regenerative business model (RBM)	A regenerative business model aims to actively restore and enhance ecological and social systems, creating net-positive impacts rather than merely reducing harm (Hahn & Tampe, 2020; Konietzko et al., 2020; Lehmann-Ortega & Dubreil, 2025).

4.3 Business models archetypes for RES

This report analyses SBM innovation for the implementation of RES in agri-farms in Europe. In this context, value creation and capture, interactions with stakeholders (supply chains) and customers, and revenue models are fragmented across energy, food, and land, and are therefore not mono-sector actors, nor do they adhere to single regulatory systems (IRENA & FAO, 2021). Because of this, BM innovation occurs across multiple dimensions of the business.

BM archetypes help map existing and potential innovation pathways for business. Building on the work of scientific literature, Table 2 presents existing BM archetypes for sustainable business development and innovation, grouped into five overarching categories: circular, regenerative, service-oriented, scaling-up solutions, and governance and ecosystem-oriented.

Table 2. Business model architypes for RES in farming. Compiled from our research and the works of Tukker (2004), Bocken et al. (2014), Lüdeke-Freund et al. (2016), Diaz Lopez et al. (2019), Bocken (2024), Lehmann-Ortega and Dubreil (2025), Soltoff et al. (2026).

Circular	Service-oriented	Scaling-up solutions	Ecosystem-oriented	Regenerative
Closing resource loops	Functionality rather than ownership (lisencing, servicing, intellectual property)	Supporting sustainable solutions and ventures (R&D, clusters, incubators, consulting)	Collective Ownership (cooperatives, resource sharing, joint ventures, open access to information)	Regenerating local ecosystems and communities
Life extension and 'R' strategies (Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, Recover)	Service rather than product (rental, asset management)	Venture capitalism	Social Enterprise (inclusive business: connecting smaller actors to larger markets)	Slow production and consumption
Pollution control	Take-back-management (end-of-life)	Hybrid business	Physical spaces for regenerative, social, entrepreneurial connectivity and collaboration	Localisation of production and employement
Replace with natural processes and renewable energy	Encouraging sufficiency and slow consumption	Labs and experimentation	Community enablers	Creating networks of local partners
Energy and material efficiency	Educational and training services	Marketing and communications as an educational tool for culture change and solution uptake	Not-for-profit collaborative platforms	
Creating networks of industrial partnerships (industrial symbiosis)	Collaborative service platforms (optimise capacity use)	Training and workshops for skill uptake		
		Advocacy and stewardship		

"Circularity" focuses on closing material and energy flows, showcasing established circular strategies that aim to reduce the overall environmental impact of industrial processes (technical and organic), while creating economic value through cost reduction and savings (Diaz Lopez et al., 2019; EMF, 2013). For RES in farming, examples of BMs focusing on material cycling shown in this catalogue include transforming agricultural waste into energy for biogas production; self-consumption of RES produced on the farm to replace fossil fuels in business processes such as heating, cooling, lighting, irrigation or powering machinery; or selling agricultural waste to third parties for biogas production off-farm.

"Service-oriented" models create a shift in consumer-supplier relationships by offering a product-as-a-service rather than direct sale/ownership to customers (Tukker, 2004). These BMs can take many forms but ultimately require behavioural and cultural shifts around consumption patterns and product offerings, and not just technical innovation (Geissdoerfer et al., 2017 ; Hobson, 2021; Tukker, 2004). From a circularity perspective, retaining ownership of products allows businesses to better adapt to changing customer needs (Tukker, 2004) and cycle materials back into their own supply chains (EMF, 2013). In this sense, these BMs work towards a dematerialisation of the economy, where services are a way to promote sufficiency and behavioural change.

An example from this catalogue, are ESCOs (Energy Service Companies): these BMs lease farming land to produce RES - where they own, maintain and service the technology - and sell the energy at reduced prices to the farmers they lease from.

"Scaling up" includes BMs that act as supporting members to farmers and agri-actors in the development and diffusion of RES, through R&D, consulting services, finding financing for projects, offering experimentation equipment or spaces, or advocating for change and protection of actor rights (Bocken, 2024; Lüdeke-Freund et al., 2016). These BMs help support the growth and uptake of RES BMs in farming.

Within this catalogue, examples are BMs that run R&D experimentation on farms to test new technologies (agrivoltaics, smart irrigation, etc…), clusters, partnership with groups who communicate and disseminate research results and promote farms that implement RES.

"Ecosystem-oriented" highlights enabling conditions such as collective ownership models, social enterprises (involving different stakeholders), hybrid business structures, and innovation ecosystem building organisations. These types of BMs build networks of actors that help absorb the financial or infrastructural risks involved in innovation (Piterou & Coles, 2020). This catalogue showcases, a joint-venture between R&D actors, farmers and an energy management business; a not-for-profit data management tool for information sharing on manure-based biogas and tax implications; a training and educational programme for skills uptake in the sector of agrivoltaics, amongst others.

"Regenerative" BMs are emerging archetypes that are not yet widely adopted. Regenerative BMs are holistic, sector transforming and localised structures that seek to restore nature and communities as a key function of the business (Bocken, 2024; Lehmann-Ortega & Dubreil, 2025). An example from this catalogue includes an organic cooperative farm that manages protected land, manages the entire value chain of agri-production from sheep and goats (milk, cheese, etc), and has hospitality and agritourism programs to educate and share knowledge with local and international actors. The self-consumption of RES produced onsite further reduces the environmental impact of their production processes.

The business models outlined above can also be identified using the conceptual framework, developed by Pombo et al. (2018), that maps four main business model dimensions for RES, included below in Figure 6 for reference.

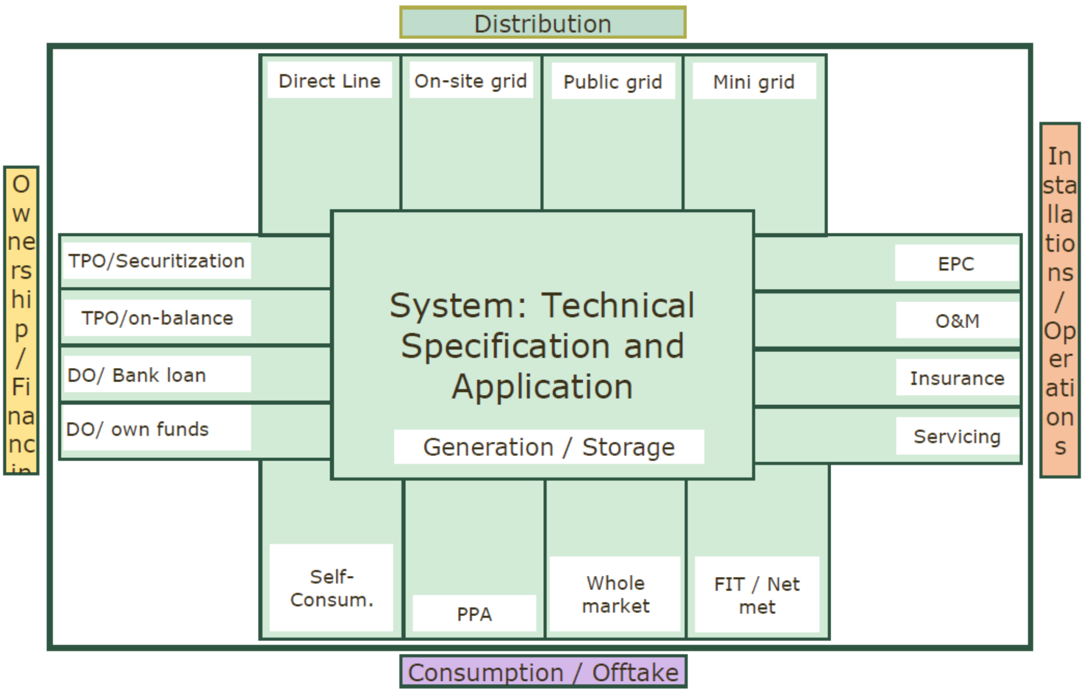

Figure 6. Four main dimensions of business models for RES (Pombo et al., 2018).

BMs operate across interconnected dimensions, and for sustainability transitions this represents systemic and multi-level processes rather than purely technological shifts (Bocken et al., 2016; Geissdoerfer et al., 2017).

4.4 Business models catalogue users

The HarvRESt Business Model Catalogue is designed as a practical reference tool for a diverse ecosystem of stakeholders involved in the deployment of Renewable Energy Sources in agricultural contexts. The evidence gathered through the HarvRESt stakeholder consultation engaged actors across the agri-sector, industry and private sector, academia and research, and civil society, confirming that the integration of RES in agriculture is a systemic process involving multiple groups with distinct roles, interests, and points of entry into the business model landscape. Six primary user groups have been identified on the basis of the consultation findings and the broader HarvRESt engagement framework.

Energy companies and technology providers are central actors in RES deployment across all four HarvRESt countries. This group encompasses energy sector companies, equipment manufacturers, technology developers, and grid operators. They use the catalogue to identify deployment contexts compatible with specific technologies, to design appropriate service and contractual models (e.g. Energy-as-a-Service, Power Purchase Agreements, lease arrangements), and to orient product development towards the technical requirements and constraints of agricultural users.

Farmers and agricultural stakeholders — including individual farmers, livestock producers, cooperatives, value chain actors, and farmers' organisations — are the primary implementers and asset owners of RES systems. The catalogue serves this group as an orientation tool, enabling users to identify business models suited to their specific sector, operational scale, ownership capacity, and land-use situation. Agricultural cooperatives additionally use it to identify community-scale models that allow members to benefit collectively from economies of scale unavailable to individual farms.

Research institutions and innovation clusters, including universities, public research organisations, agri-food research institutes, and technology clusters, use the catalogue as a structured inventory of real-world business models for comparative analysis, technology assessment, and innovation pipeline development. They are particularly interested in the Technology Archetype and Land Use Strategy dimensions, which provide the technical specificity needed to frame research questions and identify knowledge gaps.

Public authorities — national ministries, regional governments, regulatory bodies, and local administrations — use the catalogue primarily as an evidence base for policy design. By mapping existing business models across governance structures, land-use implications, and sectoral applicability, the catalogue enables policymakers to identify where regulatory or financial barriers are most acute and which support instruments are most likely to accelerate adoption, including in the context of CAP Strategic Plans and the EU Taxonomy for Sustainable Activities.

Environmental associations and energy communities — including Renewable Energy Cooperatives (RESCoops), local energy communities, and civil society organisations — use the catalogue to identify models aligned with community-ownership principles and to monitor the consistency of RES deployment with biodiversity and land-use sustainability criteria. This group is particularly active in Spain and Italy, where energy communities have grown significantly following the transposition of the Internal Market for Electricity Directive.

Investors and financial institutions, including green banks, impact investors, rural development funds, and commercial lenders, use the catalogue as a tool for risk assessment and opportunity identification. They are particularly relevant in Spain and Italy, where the financing gap for RES in agriculture is most pronounced. The Governance & Ownership dimension is of primary interest, as it distinguishes between farmer-owned, ESCO-managed, and cooperative models with different risk and bankability profiles.

4.5 Business model catalogue structure

This chapter presents a systematic catalogue of business models for Renewable Energy Sources applied to agricultural activities. The catalogue integrates evidence from four complementary sources: the HarvRESt project Use Cases (documented in D2.3), the direct stakeholder consultation survey, innovative technology cases collected from the Net Zero Insights platform through Task 3.5, and a targeted scientific literature review. Together, these sources cover 33 European business models, ranging from commercial farm-scale deployments to pilot and demonstration projects.

The catalogue is structured around four categorisation dimensions, selected on the basis of the literature review[1] and validated through the stakeholder consultation process. Each dimension captures a distinct and operationally relevant perspective on how a RES business model functions in an agricultural context. The four dimensions are:

1. **Technology Archetype** — the primary energy conversion technology or combination of technologies underpinning the business model.
2. **Governance & Ownership** — the contractual and institutional structure defining who owns, finances and operates the RES asset.
3. **Land Use Strategy** — the way in which the RES system interacts with agricultural land and productive activities.
4. **Agricultural Sector / Product** — the primary farming activity in which the business model operates, which shapes its energy demand profile and integration logic.

The following section (Section 3.4) presents first a consolidated summary table of all 33 business models, followed by the classification tables for each of the four dimensions, each preceded by a description of its sub-categories. Section 3.5 provides a cross-cutting summary matrix mapping all business models simultaneously across the four dimensions, as a quick-reference tool for practitioners and policymakers.

4.6 Categorization of business models

The following Table 3 identifies the sources of the case studies discussed.

Table 3. Business model Source Legend

Color	Source	Description
GREEN	HarvRESt Use Cases	HarvRESt use cases as extensively described in HarvRESt D2.3
BLUE	Survey on Business Models	Business models gathered with direct stakeholder survey consultation
YELLOW	Net Zero Insights	Business models collected through the Net Zero Insights platform
ORANGE	Literature	Business models included from a targeted literature review conducted to complement data collected directly through surveys and use cases

Table 4 provides a concise summary of each business model included in the catalogue, more detailed descriptions of each case are available in the Annex 2 Business Model *Compendium*.

Table 4. Business model catalogue: BM description

ID Code	Business Model Name	BM Description	Country	Source
BM01	Biogas → Biomethane with Grid Injection (Single Off-Taker)	Biogas produced from cow manure at the Noguera-Sorigué plant (Balaguer, Lleida) is upgraded to biomethane and injected into the natural gas network via a single offtaker (Axpo). The plant has four digesters treating agro-residues. Sorigué operates as the technical operator; Torre Santamaría supplies manure; BETA Tech Centre coordinates R&D. The HarvRESt Catalan Use Case runs bio-residue fertilisation field trials on 40 experimental plots at the adjacent farm.	Spain (Lleida)	HarvRESt Use Cases
BM02	Biogas Planning & Decision-Support Tool (National Scale)	Digital planning tool developed by FBCD/ConTerra using consecutively updated IACS agricultural activity data (covering ~32,000 Danish farms, 55,000 livestock production sites and 600,000 field parcels) to assess manure-based biogas potential, GHG emission impacts,	Denmark (national)	HarvRESt Use Cases

		N/P nutrient balances and CO_2 tax implications at farm-to-regional level. Serves energy companies, municipalities and agricultural advisors.		
BM03	Agrivoltaic Pilot on Vineyard: Electricity Cost Reduction + Wine-Climate Resilience	Viñedos del Río Tajo (VRT), a 430 ha mechanised brandy vineyard in Guadamur, Toledo, reconfigured its agrivoltaic systems as part of HarvRESt. The 2024 season demonstrated a ~30% reduction in evapotranspiration, a 96% reduction in hours above 40°C (severe heat stress), and ~10% electricity cost reduction. Grape yield was 28%/8% lower in morning/afternoon-shaded plots vs control; the tracker algorithm was adjusted for 2025.	Spain (Toledo)	HarvRESt Use Cases
BM04	Integrated Energy Management for Sustainable Winery (PV + BESS + Electric Machinery)	Viñas del Vero (VdV), a Somontano DO winery with 515 ha, integrates 277 kWp of PV, lithium-ion battery storage (BESS), an autonomous electric robot (Naio, 6 kW) and an electric tractor (Monarch, 52 kW). An EMS developed within HarvRESt optimises self-consumption, battery charge/discharge, forklift scheduling and real-time grid price response, achieving 84% energy self-sufficiency and saving ~20 kg CO_2/ha per Naio robot pass.	Spain (Huesca)	HarvRESt Use Cases
BM05	Triple-Action RES Transition in Italian Agrivoltaic Farming (FSDC)	Fattoria Solidale del Circeo (FSDC, 135 ha, Lazio) implements three parallel actions: (1) a catalogue of technological opportunities for farm electrification; (2) integration of agronomic practices with agrivoltaics — a 2025 sowing of mixed ryegrass + alfalfa on 80 ha under PV canopies, with CAP compatibility assessed; and (3) an educational training programme combining lectures and hands-on labs on agrivoltaics, solar irrigation and hydroponics.	Italy (Lazio)	HarvRESt Use Cases
BM06	Multi-Source RES Integration for Energy-Independent Meat Production Farm	Grønn Gårdsenergi AS (GGE, Western Norway) integrates 52.56 kWp rooftop PV, 136 kW battery storage and 20 m³ heat storage with planned additions of biomass CHP (wood chip or biogas, 50–100 kW), three novel small-scale wind turbines (Carnetic VAWT and Sine Delta bladeless prototypes) and two micro-hydro installations (~31 kW combined, ~136,000 kWh/yr). An AI-driven EMS manages all sources. Target: 100% RE self-sufficiency. GGE is founding member of the emerging 'Landkraft' cooperative.	Norway (Rogaland)	HarvRESt Use Cases
BM07	Farm-Scale Biogas CHP: Waste Intake + Self-Consumption + Grid Sale	PORGAS 2010 S.L. (Cassà de la Selva, Girona) operates an on-farm biogas plant co-located with a pig farm and an animal feed factory. Agri-food industry residues and pig slurry are co-digested; a CHP unit converts biogas into electricity and heat. Electricity is partially sold to the grid and partially self-consumed; heat replaces fossil fuels for farm heating. Revenue streams: waste gate fees + electricity sales. Financed 40% grant / 60% bank loan.	Spain (Girona)	Survey on Business Models
BM08	Biogas from Farm Waste with Circular By-products (ESCO-supported)	REMONDIS Iberia supplies organic input materials to on-farm biogas plants and, in some cases, also operates those plants. Beyond energy generation, the plants produce digestate valorised as fertiliser or compost. The value proposition combines waste management services for farms with renewable energy production and circular nutrient recovery. Ownership is hybrid (public–private).	Spain	Survey on Business Models

BM09	Integrated Waste Management, Biofertiliser Production & RE (Community Model)	Axpo describes a community ownership model for the circular valorisation of organic agri-food waste streams. The company supports farms and agri-food industries in managing residues that feed biogas plants producing both energy and biofertilisers. Key customers are manufacturing industries and transport companies seeking green credentials. >10% R&D budget. Revenue from biofertiliser sales and renewable energy production.	Spain (national)	Survey on Business Models
BM10	Self-Consumption Biogas CHP on Pig Farm (Full Energy Autonomy)	UPC Barcelona Tech studied a pig farm case where a biogas plant fed by pig manure and corn silage covers all farm energy demand (thermal and electrical) with no energy sold externally. The CHP unit with boiler saves ~473 MWh/yr of electricity and ~1,600 MWh/yr of heat, while improving digestate quality as fertiliser and reducing odours. Financing: own funds + bank loan.	Spain	Survey on Business Models
BM11	Bioenergy Cluster Facilitating New Valorisation Pathways	The Associació Clúster de la Bioenergia de Catalunya is an enabling organisation connecting farms, energy companies, researchers and public bodies to identify and test new bioenergy valorisation pathways. As a facilitator rather than an operator, the cluster generates network effects and coordinates sector knowledge sharing.	Spain (Catalonia)	Survey on Business Models
BM12	Organic Cooperative: Full Agri-Food Value Chain + PV Self-Consumption + Participatory Certification	Coop ASCA, a mountain organic livestock cooperative managing 1,320 ha (87% in protected areas) in Anversa degli Abruzzi, covers the full value chain from organic sheep/goat breeding to agritourism, catering and a didactic farm. Three phases of rooftop PV (2000, 2010, 2023) support energy self-consumption. The globally recognised 'adottaunapecora' (adopt-a-sheep) participatory certification model engages customers worldwide as co-investors in sustainability.	Italy (Abruzzo)	Survey on Business Models
BM13	Integrated Agri-Food Production with Solar Self-Consumption + Social Agriculture	Von Stillfried & Cestari Società Agricola (Pontinia & Terracina, Lazio) integrates sustainable crop cultivation, agri-food processing and social agriculture with PV energy self-consumption. The value proposition includes 20–30% energy cost reduction, diversified income from short supply chains and HoReCa channels, and social/community benefits. Financed 40% public grant, 30% equity, 30% bank loan.	Italy (Lazio)	Survey on Business Models
BM14	Experimental Agrivoltaic on Apple Orchards (Research & Knowledge Model)	IRTA (Institut de Recerca i Tecnologia Agroalimentàries) designed and monitors an experimental agrivoltaic system on a productive apple orchard at its Mollerussa experimental farm. Two PV configurations (fixed and dynamic) are tested on two Malus domestica varieties. Value: knowledge on agronomic compatibility and economic profitability, transferable to commercial fruit growers. Funded by Generalitat de Catalunya.	Spain (Lleida)	Survey on Business Models
BM15	Agrivoltaic R&D for Regional Agricultural Sector	NEIKER-BRTA (Basque public agricultural research centre) conducts R&D to generate agrivoltaic field data improving the competitiveness of the regional agri-food sector. 33% of staff time dedicated. Key opportunity: peri-urban agrivoltaic systems. Fully publicly funded; 5–10% R&D budget invested.	Spain (Basque Country)	Survey on Business Models

BM16	Farmers' Association — Advisory, Lobbying & Subsidy Facilitation for RES	ASAJA-Toledo, a farmers' organisation in Toledo province, defends members' interests and facilitates access to public funding for renewable energy investments (solar panels, irrigation modernisation, drones). Revenue from membership fees and service fees. 100% internal staff. Value to members: grant navigation and permitting support they could not access alone.	Spain (Toledo)	Survey on Business Models
BM17	Next2Sun: Vertical Bifacial PV (Fields2Sun / Fence2Sun) for Agrivoltaics	Next2Sun develops east–west oriented vertical bifacial PV systems that enable simultaneous electricity generation and agricultural production. Fields2Sun positions vertical PV module rows with wide spacing allowing machinery to operate beneath. Fence2Sun integrates bifacial modules into existing farm fence lines. The vertical design achieves ~10% higher energy yield per kWp than south-facing fixed-tilt PV and preserves ~90% of agricultural land. East–west orientation spreads production into morning and afternoon, reducing midday grid stress.	Germany	Net Zero Insights
BM18	H2arvester: Mobile Agrivoltaic System with Green Hydrogen Production	H2arvester is a portable agrivoltaics solution where lightweight solar-panel arrays are mounted on wheeled 'solar cars' that autonomously move across farmland. Electricity produced on-site is channelled into an electrolyser, producing green hydrogen and recoverable heat for storage and local use. The mobile units occupy ~10% of a hectare, leaving land available for agriculture. Currently at TRL 4–6 (demonstration/pilot phase), not yet commercially viable.	Netherlands	Net Zero Insights
BM19	GVS Solar: Mobile Off-Grid Solar Irrigation System with AI Water Management	GVS Solar provides a containerised, mobile solar-powered irrigation system (76.05 kW, 195 monocrystalline panels, 25.6 kWh LFP battery bank) suited for pivot or drip irrigation. The system integrates AI and field sensors to optimise water and energy use. It operates fully off-grid or as part of an interconnected micro-grid cluster. Relocatable in under 30 minutes, removing grid access constraints and high energy costs for remote farms.	International (Spain focus)	Net Zero Insights
BM20	Ecoways: Small-Scale Wind Turbines with Wooden Blades for Farm Self-Consumption	Ecoways develops small-scale wind turbines (WES 30/250 at 250 kW, WES 80, WES 100, WES 50, WES 20/70) targeting farms with 25,000–500,000 kWh annual needs. Turbines use larch wooden blades, mechanical pitch control, and a ring-generator (no gearbox) operating at lower wind speeds. Hybrid solutions (wind + solar PV + storage) improve self-consumption. Designed for medium wind regimes and agricultural landscapes.	Germany (international)	Net Zero Insights
BM21	MicroBiogasItalia: Small-Scale Livestock Biogas Plants (from 20 kW)	MicroBiogasItalia develops small-scale biogas plants (starting from ~20 kW) for livestock farms, converting animal manure into electricity and heat through wet or dry digestion. The company offers turnkey support: feasibility, permitting, installation, monitoring and long-term operation. Systems use manure alone (no energy crops), with reported production costs of ~0.10 €/kWh and operating costs of ~0.04 €/kWh. Also distributes BioCompostMachine for on-farm composting.	Italy	Net Zero Insights

BM22	Nenufar: Floating Covers for Slurry Pits to Capture Fugitive Biogas	Nenufar provides pneumatic floating covers for manure and digestate storage pits that capture biogas naturally produced during slurry storage. The system includes a rainwater removal pump and integrated biological desulphurisation + activated-carbon filter to treat raw biogas for safe utilisation. Compared to uncovered pits, the system captures emissions that would otherwise be released, reduces ammonia and odour, prevents rainwater dilution and increases effective storage capacity.	France	Net Zero Insights
BM23	Terrawatt: Pyrolysis + Biological Methanation Converting Green Waste to Biogas + Biochar	Terrawatt integrates pyrolysis with biological methanation to convert green waste (normally unsuitable for anaerobic digestion) into renewable energy and carbon-rich by-products. Biomass undergoes thermochemical treatment producing syngas and stable biochar; syngas is then converted by methanogenic bacteria into quality biomethane. Dual output: renewable gas + biofertiliser. Currently at industrial demonstration stage (TRL 7).	France	Net Zero Insights
BM24	Biofrigas: Container-Based Liquid Biogas (LBG) Production from Farm and Agri-Food Waste	Biofrigas provides container-based CryoSep systems that produce liquid biogas (LBG) from anaerobic digestion of farm and agri-food waste. Raw biogas is purified, upgraded to biomethane and cryogenically liquefied at ~–160 °C. LBG is significantly more transportable than raw biogas, enabling decentralised production for farms or cooperatives far from gas grids. A co-product is liquid biogenic CO_2, usable in food, industrial or greenhouse applications.	Sweden (international)	Net Zero Insights
BM25	Causeway Energies: GeoSolar Geothermal + Solar-Thermal with Heat-as-a-Service Model	Causeway Energies provides geothermal and advanced heat-pump systems (GeoSolar) coupling geothermal resources with solar-thermal or hybrid PVT panels for year-round heat supply. The GeoBattery concept captures and stores surplus/waste heat for reuse in winter peak-demand periods. Seasonal thermal storage is particularly relevant for farms with refrigeration, processing or greenhouse heating. Business model innovation: Heat-as-a-Service financing reduces upfront CAPEX for farmers and SMEs.	Ireland (international)	Net Zero Insights
BM26	Greenwell: Repurposed Abandoned Oil & Gas Wells as Geothermal Heat Sources for Farms	Greenwell converts abandoned oil and gas wells into geothermal heat sources for nearby agricultural or horticultural facilities. A closed-loop heat-exchange system is installed inside the plugged wellbore; cool fluid circulates down and returns as heated fluid. This avoids high drilling costs that are the main barrier to geothermal adoption. Delivery model: Greenwell converts wells at their own risk and leases the heated infrastructure to customers at a flat rate. Supported by Climate KIC and Interreg Central Europe; first commercial deployment targeted 2025.	United Kingdom (EU-wide)	Net Zero Insights
BM27	M-TEC: Integrated On-Farm Energy Management (PV + Heat + Battery Storage)	M-TEC provides an integrated on-farm energy management platform combining solar PV, heat generation and electricity storage (46 kWh battery, 18 kW output). A central M-TEC control application coordinates PV generation, heat pumps and power-to-heat devices in real time to maximise self-consumption and energy self-sufficiency. Unlike stand-alone components, the integrated platform significantly improves system efficiency and economic returns.	Austria (international)	Net Zero Insights

BM28	Tadus E Traktoren: High-Power Electric Tractor with Swappable Battery System	Tadus is developing the T16.20 electric tractor (160 hp / near-production prototype) with a swappable 200 kW battery system and a multi-motor drivetrain. Pre-series of 5 units planned for first customers in 2026. Compared to diesel tractors, up to 75% lower operating costs when paired with self-generated electricity. The swappable battery addresses downtime limitations of early electric tractors. Targets the mid-power segment (>100 hp) where electric options remain scarce.	Germany	Net Zero Insights
BM29	Community Biogas Cooperative: Shared Manure → Energy + Digestate	Multiple farms pool manure and organic residues to supply a central community biogas plant. Members share investment costs (CAPEX), receive revenues from energy sold, and receive digestate returned as fertiliser. Governance is collective. Well established in German and Danish biogas clusters. Key references: Raven & Gregersen (2007) Energy Policy; Rosenbloom et al. (2020) Energy Research & Social Science.	Denmark / Germany	Literature
BM30	Agrivoltaic ESCO / Lease Model for Farms	An energy company installs agrivoltaic panels on farmland under a lease agreement. The farmer receives land rent and discounted electricity; the company sells surplus electricity to the grid. Reduces farmer CAPEX to zero while transferring long-term value to the ESCO. Key references: Weselek et al. (2021) Agronomy for Sustainable Development; Dinesh & Pearce (2016) Renewable & Sustainable Energy Reviews.	EU (France, Germany)	Literature
BM31	Small-Scale Run-of-River Micro-Hydro – ESCO Model	An energy company installs and operates micro-hydro turbines on farms with water rights, leasing the water resource from the farmer. The farmer receives royalties or land rent; the company sells electricity. Provides passive income with no CAPEX for the farmer. Key references: Paish (2002) Proceedings of the ICE – Energy; Bracken et al. (2014) Renewable Energy.	EU (Alpine regions)	Literature
BM32	Community Wind Cooperative for Agricultural Areas	Groups of farmers and local community members co-invest in wind turbines, sharing costs and revenues. Well established in Denmark, Germany and the Netherlands. Key references: Huybrechts & Mertens (2014) Annals of Public & Cooperative Economics; Bauwens et al. (2016) Renewable & Sustainable Energy Reviews.	EU (Denmark, Germany, Netherlands)	Literature
BM33	Green Hydrogen from Farm RES for Agricultural Machinery	Excess renewable electricity from farm PV or wind is used to produce green hydrogen via electrolysis. Hydrogen powers fuel-cell tractors or is sold to local mobility hubs, providing zero-emission farm machinery fuel and a secondary revenue stream. Key references: Sgobbi et al. (2016) International Journal of Hydrogen Energy; Rodriguez et al. (2022) Renewable Energy.	EU (pilot projects)	Literature

The business models listed in the table above are further analysed in the following sections according to the four proposed categorisation dimensions.

4.7 Categorization by technology archetype

This defines how specific energy properties and digital strategies create distinct operational and business logic (Table 5).

- **Biogas & Biomethane:** Biochemical-Circular model; transforms residues into baseload energy, grid-injected gas, and circular fertilizers.
- **Biomass (Solid):** Thermal-Centric model; prioritizes heat-as-a-product via direct combustion or gasification for facility heating and crop drying.
- **Hydroelectric:** Constant-Load model; delivers continuous power or mechanical drive using run-of-river or low-head water sources.
- **Wind Power:** Kinetic-Mechanical model; utilizes decentralized turbines for off-grid power and water extraction without complex inverters.
- **Hydrogen:** Decarbonized-Vector model; acts as a clean energy carrier for heavy-duty field operations or carbon-free fertilizer production.
- **Solar & Agrivoltaics:** Photovoltaic-Agronomic model; integrates panels with crops to reduce irrigation needs and protect against weather stress.
- **Mixed RES & Smart Mgmt:** Systemic-Integration model; combines hybrid sources and intelligent EMS to optimize storage, peak-shaving, and autonomous machinery.
- **Advisory & Planning Tools:** Digital-Strategic model; leverages Big Data, GIS, and DSS to optimize regional energy planning and nutrient cycles.

Table 5. Business model catalogue: Technology Archetype

Technology Category	ID Code	Business Model Name	Country	Source
Biogas & Biomethane	BM01	Biogas → Biomethane with Grid Injection (Single Off-Taker)	Spain (Lleida)	HarvRESt Use Cases
	BM02	Biogas Planning & Decision-Support Tool (National Scale)	Denmark (national)	HarvRESt Use Cases
	BM07	Farm-Scale Biogas CHP: Waste Intake + Self-Consumption + Grid Sale	Spain (Girona)	Survey on Business Models
	BM08	Biogas from Farm Waste with Circular By-products (ESCO-supported)	Spain	Survey on Business Models
	BM09	Integrated Waste Management, Biofertiliser Production & RE (Community Model)	Spain (national)	Survey on Business Models

	BM10	Self-Consumption Biogas CHP on Pig Farm (Full Energy Autonomy)	Spain	Survey on Business Models
	BM11	Bioenergy Cluster Facilitating New Valorisation Pathways	Spain (Catalonia)	Survey on Business Models
	BM21	MicroBiogasItalia: Small-Scale Livestock Biogas Plants (from 20 kW)	Italy	Net Zero Insights
	BM22	Nenufar: Floating Covers for Slurry Pits to Capture Fugitive Biogas	France	Net Zero Insights
	BM23	Terrawatt: Pyrolysis + Biological Methanation Converting Green Waste to Biogas + Biochar	France	Net Zero Insights
	BM24	Biofrigas: Container-Based Liquid Biogas (LBG) Production from Farm and Agri-Food Waste	Sweden (international)	Net Zero Insights
	BM29	Community Biogas Cooperative: Shared Manure → Energy + Digestate	Denmark / Germany	Literature
Biomass (Solid)	BM06	Multi-Source RES Integration for Energy-Independent Meat Production Farm	Norway (Rogaland)	HarvRESt Use Cases
	BM12	Organic Cooperative: Full Agri-Food Value Chain + PV Self-Consumption + Participatory Certification	Italy (Abruzzo)	Survey on Business Models
Solar & agrivoltaics	BM03	Agrivoltaic Pilot on Vineyard: Electricity Cost Reduction + Wine-Climate Resilience	Spain (Toledo)	HarvRESt Use Cases
	BM05	Triple-Action RES Transition in Italian Agrivoltaic Farming (FSDC)	Italy (Lazio)	HarvRESt Use Cases
	BM13	Integrated Agri-Food Production with Solar Self-Consumption + Social Agriculture	Italy (Lazio)	Survey on Business Models
	BM14	Experimental Agrivoltaic on Apple Orchards (Research & Knowledge Model)	Spain (Lleida)	Survey on Business Models
	BM15	Agrivoltaic R&D for Regional Agricultural Sector	Spain (Basque Country)	Survey on Business Models
	BM17	Next2Sun: Vertical Bifacial PV (Fields2Sun / Fence2Sun) for Agrivoltaics	Germany	Net Zero Insights

	BM18	H2arvester: Mobile Agrivoltaic System with Green Hydrogen Production	Netherlands	Net Zero Insights
	BM19	GVS Solar: Mobile Off-Grid Solar Irrigation System with AI Water Management	International (Spain focus)	Net Zero Insights
	BM30	Agrivoltaic ESCO / Lease Model for Farms	EU (France, Germany)	Literature
Mixed RES & Smart Mgmt	BM04	Integrated Energy Management for Sustainable Winery (PV + BESS + Electric Machinery)	Spain (Huesca)	HarvREStUse Cases
	BM06	Multi-Source RES Integration for Energy-Independent Meat Production Farm	Norway (Rogaland)	HarvRESt Use Cases
	BM25	Causeway Energies: GeoSolar Geothermal + Solar-Thermal with Heat-as-a-Service Model	Ireland (international)	Net Zero Insights
	BM26	Greenwell: Repurposed Abandoned Oil & Gas Wells as Geothermal Heat Sources for Farms	United Kingdom (EU-wide)	Net Zero Insights
	BM27	M-TEC: Integrated On-Farm Energy Management (PV + Heat + Battery Storage)	Austria (international)	Net Zero Insights
	BM28	Tadus E Traktoren: High-Power Electric Tractor with Swappable Battery System	Germany	Net Zero Insights
Hydroelectric	BM06	Multi-Source RES Integration for Energy-Independent Meat Production Farm	Norway (Rogaland)	HarvRESt Use Cases
	BM31	Small-Scale Run-of-River Micro-Hydro – ESCO Model	EU (Austria, Switzerland, Norway)	Literature
Wind Power	BM06	Multi-Source RES Integration for Energy-Independent Meat Production Farm	Norway (Rogaland)	HarvRESt Use Cases
	BM20	Ecoways: Small-Scale Wind Turbines with Wooden Blades for Farm Self-Consumption	Germany (international)	Net Zero Insights
	BM32	Community Wind Cooperative for Agricultural Areas	EU (Denmark, Germany, Netherlands)	Literature

Hydrogen	BM18	H2arvester: Mobile Agrivoltaic System with Green Hydrogen Production	Netherlands	Net Zero Insights
	BM33	Green Hydrogen from Farm RES for Agricultural Machinery	EU (pilot projects)	Literature
Advisory & Planning Tools	BM16	Farmers' Association — Advisory, Lobbying & Subsidy Facilitation for RES	Spain (Toledo)	Survey on Business Models

4.8 Categorization by Governance & Ownership

This defines the relationship between the farmer, the technology provider, and the community (Table 6).

- **Farmer-Owned (Independent):** The farmer owns and operates the RES asset directly; high CAPEX exposure but maximum long-term revenue retention.
- **Third-Party Managed (Lease/ESCO):** An Energy Service Company installs and owns the equipment; the farmer provides land or feedstock and purchases cheaper energy.
- **Community/Cooperative:** Multiple farms pool resources to co-own and co-operate a shared RES plant, sharing investment risk and energy revenues.

Table 6. Business model catalogue: Governance and Ownership

Ownership Category	ID Code	Business Model Name	Country	Source
Farmer-Owned / Independent	BM03	Agrivoltaic Pilot on Vineyard: Electricity Cost Reduction + Wine-Climate Resilience	Spain (Toledo)	HarvRESt Use Cases
	BM04	Integrated Energy Management for Sustainable Winery (PV + BESS + Electric Machinery)	Spain (Huesca)	HarvRESt Use Cases
	BM06	Multi-Source RES Integration for Energy-Independent Meat Production Farm	Norway (Rogaland)	HarvRESt Use Cases
	BM07	Farm-Scale Biogas CHP: Waste Intake + Self-Consumption + Grid Sale	Spain(Girona)	Survey on Business Models
	BM10	Self-Consumption Biogas CHP on Pig Farm (Full Energy Autonomy)	Spain	Survey on Business Models
	BM13	Integrated Agri-Food Production with Solar Self-Consumption + Social Agriculture	Italy (Lazio)	Survey on Business Models
	BM17	Next2Sun: Vertical Bifacial PV (Fields2Sun / Fence2Sun) for Agrivoltaics	Germany	Net Zero Insights
	BM19	GVS Solar: Mobile Off-Grid Solar Irrigation System with AI Water Management	International (Spain focus)	Net Zero Insights
	BM20	Ecoways: Small-Scale Wind Turbines with Wooden Blades for Farm Self-Consumption	Germany (international)	Net Zero Insights

	BM21	MicroBiogasItalia: Small-Scale Livestock Biogas Plants (from 20 kW)	Italy	Net Zero Insights
	BM22	Nenufar: Floating Covers for Slurry Pits to Capture Fugitive Biogas	France	Net Zero Insights
	BM23	Terrawatt: Pyrolysis + Biological Methanation Converting Green Waste to Biogas + Biochar	France	Net Zero Insights
	BM24	Biofrigas: Container-Based Liquid Biogas (LBG) Production from Farm and Agri-Food Waste	Sweden (international)	Net Zero Insights
	BM27	M-TEC: Integrated On-Farm Energy Management (PV + Heat + Battery Storage)	Austria (international)	Net Zero Insights
	BM28	Tadus E Traktoren: High-Power Electric Tractor with Swappable Battery System	Germany	Net Zero Insights
	BM33	Green Hydrogen from Farm RES for Agricultural Machinery	EU (pilot projects)	Literature
Third-Party Managed (ESCO / Lease)	BM01	Biogas → Biomethane with Grid Injection (Single Off-Taker)	Spain (Lleida)	HarvRESt Use Cases
	BM08	Biogas from Farm Waste with Circular By-products (ESCO-supported)	Spain	Survey on Business Models
	BM25	Causeway Energies: GeoSolar Geothermal + Solar-Thermal with Heat-as-a-Service Model	Ireland (international)	Net Zero Insights
	BM26	Greenwell: Repurposed Abandoned Oil & Gas Wells as Geothermal Heat Sources for Farms	United Kingdom (EU-wide)	Net Zero Insights
	BM30	Agrivoltaic ESCO / Lease Model for Farms	EU (France, Germany)	Literature
	BM31	Small-Scale Run-of-River Micro-Hydro – ESCO Model	EU (Austria, Switzerland, Norway)	Literature
Community / Cooperative	BM02	Biogas Planning & Decision-Support Tool (National Scale)	Denmark (national)	HarvRESt Use Cases
	BM05	Triple-Action RES Transition in Italian Agrivoltaic Farming (FSDC)	Italy (Lazio)	HarvRESt Use Cases

	BM06	Multi-Source RES Integration for Energy-Independent Meat Production Farm	Norway (Rogaland)	HarvRESt Use Cases
	BM09	Integrated Waste Management, Biofertiliser Production & RE (Community Model)	Spain (national)	Survey on Business Models
	BM11	Bioenergy Cluster Facilitating New Valorisation Pathways	Spain (Catalonia)	Survey on Business Models
	BM12	Organic Cooperative: Full Agri-Food Value Chain + PV Self-Consumption + Participatory Certification	Italy (Abruzzo)	Survey on Business Models
	BM14	Experimental Agrivoltaic on Apple Orchards (Research & Knowledge Model)	Spain (Lleida)	Survey on Business Models
	BM15	Agrivoltaic R&D for Regional Agricultural Sector	Spain (Basque Country)	Survey on Business Models
	BM16	Farmers' Association — Advisory, Lobbying & Subsidy Facilitation for RES	Spain (Toledo)	Survey on Business Models
	BM18	H2arvester: Mobile Agrivoltaic System with Green Hydrogen Production	Netherlands	Net Zero Insights
	BM29	Community Biogas Cooperative: Shared Manure → Energy + Digestate	Denmark / Germany	Literature
	BM32	Community Wind Cooperative for Agricultural Areas	EU (Denmark, Germany, Netherlands)	Literature

4.9 Categorization by Land Use Strategy

This defines how the RES system interacts physically with agricultural land and productive activities (Table 7).

- **Dual-Use / Agrivoltaic Integration:** PV panels are co-located on cultivated land to simultaneously generate electricity and deliver agronomic co-benefits such as reduced heat stress and lower evapotranspiration.
- **On-Farm Infrastructure (No Land Competition):** The RES system is installed on non-cultivated surfaces (rooftops, yards, fences) or exploits ambient resources (wind, subsurface heat) without removing productive land from agricultural use.
- **Waste & Residue Valorisation (Off-Field):** Energy is generated entirely from organic residue flows — manure, slurry, agro-industrial by-products — already produced on-farm; no land is reallocated to energy purposes.
- **Water-Linked / Riparian:** The system exploits a hydraulic resource — river flow, lake head, or groundwater — associated with the farm holding, without occupying any cultivated surface.
- **Mobile / Relocatable Systems:** The RES unit is engineered for physical mobility, allowing redeployment across parcels or integration into crop rotations without permanent land-use trade-offs.
- **Digital / No Physical Footprint:** Value is created entirely through data processing, advisory services, or stakeholder facilitation; no physical infrastructure occupies agricultural land.

Table 7. Business model catalogue: Land use Strategy

Land Use Strategy	ID Code	Business Model Name	Country	Source
Dual-Use / Agrivoltaic Integration	BM03	Agrivoltaic Pilot on Vineyard: Electricity Cost Reduction + Wine-Climate Resilience	Spain (Toledo)	HarvRESt Use Cases
	BM04	Integrated Energy Management for Sustainable Winery (PV + BESS + Electric Machinery)	Spain (Huesca)	HarvRESt Use Cases
	BM05	Triple-Action RES Transition in Italian Agrivoltaic Farming (FSDC)	Italy (Lazio)	HarvRESt Use Cases
	BM14	Experimental Agrivoltaic on Apple Orchards (Research & Knowledge Model)	Spain (Lleida)	Survey on Business Models

	BM15	Agrivoltaic R&D for Regional Agricultural Sector	Spain (Basque Country)	Survey on Business Models
	BM17	Next2Sun: Vertical Bifacial PV (Fields2Sun / Fence2Sun) for Agrivoltaics	Germany	Net Zero Insights
	BM18	H2arvester: Mobile Agrivoltaic System with Green Hydrogen Production	Netherlands	Net Zero Insights
	BM30	Agrivoltaic ESCO / Lease Model for Farms	EU (France, Germany)	Literature
On-Farm Infrastructure (No Land Competition)	BM06	Multi-Source RES Integration for Energy-Independent Meat Production Farm	Norway (Rogaland)	HarvRESt Use Cases
	BM07	Farm-Scale Biogas CHP: Waste Intake + Self-Consumption + Grid Sale	Spain (Girona)	Survey on Business Models
	BM10	Self-Consumption Biogas CHP on Pig Farm (Full Energy Autonomy)	Spain	Survey on Business Models
	BM12	Organic Cooperative: Full Agri-Food Value Chain + PV Self-Consumption + Participatory Certification	Italy (Abruzzo)	Survey on Business Models
	BM13	Integrated Agri-Food Production with Solar Self-Consumption + Social Agriculture	Italy (Lazio)	Survey on Business Models
	BM20	Ecoways: Small-Scale Wind Turbines with Wooden Blades for Farm Self-Consumption	Germany (international)	Net Zero Insights
	BM21	MicroBiogasItalia: Small-Scale Livestock Biogas Plants (from 20 kW)	Italy	Net Zero Insights
	BM22	Nenufar: Floating Covers for Slurry Pits to Capture Fugitive Biogas	France	Net Zero Insights
	BM27	M-TEC: Integrated On-Farm Energy Management (PV + Heat + Battery Storage)	Austria (international)	Net Zero Insights
	BM28	Tadus E Traktoren: High-Power Electric Tractor with Swappable Battery System	Germany	Net Zero Insights
	BM25	Causeway Energies: GeoSolar Geothermal + Solar-Thermal with Heat-as-a-Service Model	Ireland (international)	Net Zero Insights
	BM26	Greenwell: Repurposed Abandoned Oil & Gas Wells as Geothermal Heat Sources for Farms	United Kingdom (EU-wide)	Net Zero Insights

	BM32	Community Wind Cooperative for Agricultural Areas	EU (Denmark, Germany, Netherlands)	Literature
	BM33	Green Hydrogen from Farm RES for Agricultural Machinery	EU (pilot projects)	Literature
Waste & Residue Valorisation (Off-Field)	BM01	Biogas → Biomethane with Grid Injection (Single Off-Taker)	Spain (Lleida)	HarvRESt Use Cases
	BM08	Biogas from Farm Waste with Circular By-products (ESCO-supported)	Spain	Survey on Business Models
	BM09	Integrated Waste Management, Biofertiliser Production & RE (Community Model)	Spain (national)	Survey on Business Models
	BM22	Nenufar: Floating Covers for Slurry Pits to Capture Fugitive Biogas	France	Net Zero Insights
	BM23	Terrawatt: Pyrolysis + Biological Methanation Converting Green Waste to Biogas + Biochar	France	Net Zero Insights
	BM24	Biofrigas: Container-Based Liquid Biogas (LBG) Production from Farm and Agri-Food Waste	Sweden (international)	Net Zero Insights
	BM29	Community Biogas Cooperative: Shared Manure → Energy + Digestate	Denmark / Germany	Literature
Water-Linked / Riparian	BM06	Multi-Source RES Integration for Energy-Independent Meat Production Farm	Norway (Rogaland)	HarvRESt Use Cases
	BM31	Small-Scale Run-of-River Micro-Hydro – ESCO Model	EU (Austria, Switzerland, Norway)	Literature
Mobile / Relocatable Systems	BM18	H2arvester: Mobile Agrivoltaic System with Green Hydrogen Production	Netherlands	Net Zero Insights
	BM19	GVS Solar: Mobile Off-Grid Solar Irrigation System with AI Water Management	International (Spain focus)	Net Zero Insights
	BM02	Biogas Planning & Decision-Support Tool (National Scale)	Denmark (national)	HarvRESt Use Cases

Digital / No Physical Footprint	BM11	Bioenergy Cluster Facilitating New Valorisation Pathways	Spain (Catalonia)	Survey on Business Models
	BM16	Farmers' Association — Advisory, Lobbying & Subsidy Facilitation for RES	Spain (Toledo)	Survey on Business Models

4.10 Categorization by Agricultural Sector / Product

This defines the primary farming sector in which the business model operates, shaping its energy demand profile and integration logic (Table 8).

- **Cereals & Arable Crops:** Annual herbaceous crops (maize, wheat, barley, rapeseed) on open arable land; energy integration targets irrigation, drying, and crop residue valorisation.
- **Viticulture & Wine / Spirits:** Grapevine cultivation for wine or distillate production; energy integration focuses on self-consumption, vineyard climate resilience, and cellar decarbonisation.
- **Fruit & Orchard Crops:** Permanent tree crops (apple, almond, olive, stone fruits); agrivoltaic and precision energy systems are evaluated for microclimate, water savings, and product quality effects.
- **Livestock — Intensive / Monogastric:** High-density pig or poultry farming generating large manure and slurry volumes; primary candidates for small-scale biogas and slurry-capture solutions.
- **Livestock — Extensive / Ruminants:** Cattle, sheep, or goat rearing in extensive settings, often with on-farm dairy or meat transformation; favours mixed RES strategies and circular nutrient management.
- **Mixed Farming (Crop + Livestock):** Operations combining significant crop and animal production without a dominant activity; energy strategies must address multiple and concurrent demand profiles.
- **Horticulture & Protected Crops:** Intensive vegetable production, greenhouses, and irrigated specialty crops with high continuous energy and water demands; targets grid-independent irrigation and thermal supply.
- **Agro-Food Processing & Value Chain:** The primary actor is an agro-industrial operator whose model is built around residue transformation; energy generation is embedded in an industrial rather than a farm management logic.
- **Multi-Sector / Generic (Technology or Advisory Provider):** The actor operates across multiple farming sectors simultaneously; the agricultural product is not a differentiating variable for the business model logic.

Table 8. Business model catalogue: Agricultural Sector

Agricultural Product	ID Code	Business Model Name	Country	Source
Cereals & Arable Crops	BM01	Biogas → Biomethane with Grid Injection (Single Off-Taker)	Spain (Lleida)	HarvREST Use Cases
	BM10	Self-Consumption Biogas CHP on Pig Farm (Full Energy Autonomy)	Spain	Survey on Business Models
	BM17	Next2Sun: Vertical Bifacial PV (Fields2Sun / Fence2Sun) for Agrivoltaics	Germany	Net Zero Insights
Viticulture & Wine / Spirits	BM03	Agrivoltaic Pilot on Vineyard: Electricity Cost Reduction + Wine-Climate Resilience	Spain (Toledo)	HarvREST Use Cases
	BM04	Integrated Energy Management for Sustainable Winery (PV + BESS + Electric Machinery)	Spain (Huesca)	HarvREST Use Cases
Fruit & Orchard Crops	BM12	Organic Cooperative: Full Agri-Food Value Chain + PV Self-Consumption + Participatory Certification	Italy (Abruzzo)	Survey on Business Models
	BM14	Experimental Agrivoltaic on Apple Orchards (Research & Knowledge Model)	Spain (Lleida)	Survey on Business Models
Livestock — Intensive / Monogastric	BM07	Farm-Scale Biogas CHP: Waste Intake + Self-Consumption + Grid Sale	Spain (Girona)	Survey on Business Models
	BM10	Self-Consumption Biogas CHP on Pig Farm (Full Energy Autonomy)	Spain	Survey on Business Models
	BM21	MicroBiogasItalia: Small-Scale Livestock Biogas Plants (from 20 kW)	Italy	Net Zero Insights
	BM22	Nenufar: Floating Covers for Slurry Pits to Capture Fugitive Biogas	France	Net Zero Insights
Livestock — Extensive / Ruminants	BM01	Biogas → Biomethane with Grid Injection (Single Off-Taker)	Spain (Lleida)	HarvREST Use Cases
	BM06	Multi-Source RES Integration for Energy-Independent Meat Production Farm	Norway (Rogaland)	HarvREST Use Cases
	BM12	Organic Cooperative: Full Agri-Food Value Chain + PV Self-Consumption + Participatory Certification	Italy (Abruzzo)	Survey on Business Models

	BM29	Community Biogas Cooperative: Shared Manure → Energy + Digestate	Denmark / Germany	Literature
Mixed Farming (Crop + Livestock)	BM05	Triple-Action RES Transition in Italian Agrivoltaic Farming (FSDC)	Italy (Lazio)	HarvRESt Use Cases
	BM06	Multi-Source RES Integration for Energy-Independent Meat Production Farm	Norway (Rogaland)	HarvRESt Use Cases
	BM13	Integrated Agri-Food Production with Solar Self-Consumption + Social Agriculture	Italy (Lazio)	Survey on Business Models
Horticulture & Protected Crops	BM19	GVS Solar: Mobile Off-Grid Solar Irrigation System with AI Water Management	International (Spain focus)	Net Zero Insights
	BM25	Causeway Energies: GeoSolar Geothermal + Solar-Thermal with Heat-as-a-Service Model	Ireland (international)	Net Zero Insights
	BM26	Greenwell: Repurposed Abandoned Oil & Gas Wells as Geothermal Heat Sources for Farms	United Kingdom (EU-wide)	Net Zero Insights
Agro-Food Processing & Value Chain	BM08	Biogas from Farm Waste with Circular By-products (ESCO-supported)	Spain	Survey on Business Models
	BM09	Integrated Waste Management, Biofertiliser Production & RE (Community Model)	Spain (national)	Survey on Business Models
	BM23	Terrawatt: Pyrolysis + Biological Methanation Converting Green Waste to Biogas + Biochar	France	Net Zero Insights
	BM24	Biofrigas: Container-Based Liquid Biogas (LBG) Production from Farm and Agri-Food Waste	Sweden (international)	Net Zero Insights
Multi-Sector / Generic (Technology or Advisory)	BM02	Biogas Planning & Decision-Support Tool (National Scale)	Denmark (national)	HarvRESt Use Cases
	BM11	Bioenergy Cluster Facilitating New Valorisation Pathways	Spain (Catalonia)	Survey on Business Models
	BM15	Agrivoltaic R&D for Regional Agricultural Sector	Spain (Basque Country)	Survey on Business Models
	BM16	Farmers' Association — Advisory, Lobbying & Subsidy Facilitation for RES	Spain (Toledo)	Survey on Business Models

	BM17	Next2Sun: Vertical Bifacial PV (Fields2Sun / Fence2Sun) for Agrivoltaics	Germany	Net Zero Insights
	BM18	H2arvester: Mobile Agrivoltaic System with Green Hydrogen Production	Netherlands	Net Zero Insights
	BM19	GVS Solar: Mobile Off-Grid Solar Irrigation System with AI Water Management	International (Spain focus)	Net Zero Insights
	BM20	Ecoways: Small-Scale Wind Turbines with Wooden Blades for Farm Self-Consumption	Germany (international)	Net Zero Insights
	BM27	M-TEC: Integrated On-Farm Energy Management (PV + Heat + Battery Storage)	Austria (international)	Net Zero Insights
	BM28	Tadus E Traktoren: High-Power Electric Tractor with Swappable Battery System	Germany	Net Zero Insights
	BM30	Agrivoltaic ESCO / Lease Model for Farms	EU (France, Germany)	Literature
	BM31	Small-Scale Run-of-River Micro-Hydro – ESCO Model	EU (Austria, Switzerland, Norway)	Literature
	BM32	Community Wind Cooperative for Agricultural Areas	EU (Denmark, Germany, Netherlands)	Literature
	BM33	Green Hydrogen from Farm RES for Agricultural Machinery	EU (pilot projects)	Literature

4.11 Summary matrix

The following matrix (Table 9) provides a consolidated cross-view of all 33 business models catalogued in Section 3.4, mapped simultaneously across the four categorisation dimensions: Technology Archetype, Governance & Ownership, Land Use Strategy, and Agricultural Sector. This matrix serves as a quick-reference tool enabling users to identify, compare and select business models according to their specific operational context.

Table 9. Business model catalogue: Summary Matrix

ID Code	Business Model Name	Technology	Governance & Ownership	Land Use Strategy	Agricultural Product
BM01	Biogas → Biomethane with Grid Injection (Single Off-Taker)	Biogas & Biomethane	Third-Party Managed (ESCO / Lease)	Waste & Residue Valorisation (Off-Field)	Cereals & Arable Crops, Livestock — Extensive / Ruminants
BM02	Biogas Planning & Decision-Support Tool (National Scale)	Biogas & Biomethane	Community / Cooperative	Digital / No Physical Footprint	Multi-Sector / Generic (Technology or Advisory)
BM03	Agrivoltaic Pilot on Vineyard: Electricity Cost Reduction + Wine-Climate Resilience	Solar & Agrivoltaics	Farmer-Owned / Independent	Dual-Use / Agrivoltaic Integration	Viticulture & Wine / Spirits
BM04	Integrated Energy Management for Sustainable Winery (PV + BESS + Electric Machinery)	Mixed RES & Smart Mgmt	Farmer-Owned / Independent	Dual-Use / Agrivoltaic Integration	Viticulture & Wine / Spirits
BM05	Triple-Action RES Transition in Italian Agrivoltaic Farming (FSDC)	Solar & Agrivoltaics	Community / Cooperative	Dual-Use / Agrivoltaic Integration	Mixed Farming (Crop + Livestock)
BM06	Multi-Source RES Integration for Energy-Independent Meat Production Farm	Biomass (Solid), Mixed RES & Smart Mgmt, Hydroelectric, Wind Power	Farmer-Owned / Independent, Community / Cooperative	On-Farm Infrastructure (No Land Competition), Water-Linked / Riparian	Livestock — Extensive / Ruminants, Mixed Farming (Crop + Livestock)
BM07	Farm-Scale Biogas CHP: Waste Intake + Self-Consumption + Grid Sale	Biogas & Biomethane	Farmer-Owned / Independent	On-Farm Infrastructure (No Land Competition)	Livestock — Intensive / Monogastric
BM08	Biogas from Farm Waste with Circular By-products (ESCO-supported)	Biogas & Biomethane	Third-Party Managed (ESCO / Lease)	Waste & Residue Valorisation (Off-Field)	Agro-Food Processing & Value Chain
BM09	Integrated Waste Management, Biofertiliser Production & RE (Community Model)	Biogas & Biomethane	Community / Cooperative	Waste & Residue Valorisation (Off-Field)	Agro-Food Processing & Value Chain

BM10	Self-Consumption Biogas CHP on Pig Farm (Full Energy Autonomy)	Biogas & Biomethane	Farmer-Owned / Independent	On-Farm Infrastructure (No Land Competition)	Cereals & Arable Crops, Livestock — Intensive / Monogastric
BM11	Bioenergy Cluster Facilitating New Valorisation Pathways	Biogas & Biomethane	Community / Cooperative	Digital / No Physical Footprint	Multi-Sector / Generic (Technology or Advisory)
BM12	Organic Cooperative: Full Agri-Food Value Chain + PV Self-Consumption + Participatory Certification	Biomass (Solid)	Community / Cooperative	On-Farm Infrastructure (No Land Competition)	Fruit & Orchard Crops, Livestock — Extensive / Ruminants
BM13	Integrated Agri-Food Production with Solar Self-Consumption + Social Agriculture	Solar & Agrivoltaics	Farmer-Owned / Independent	On-Farm Infrastructure (No Land Competition)	Mixed Farming (Crop + Livestock)
BM14	Experimental Agrivoltaic on Apple Orchards (Research & Knowledge Model)	Solar & Agrivoltaics	Community / Cooperative	Dual-Use / Agrivoltaic Integration	Fruit & Orchard Crops
BM15	Agrivoltaic R&D for Regional Agricultural Sector	Solar & Agrivoltaics	Community / Cooperative	Dual-Use / Agrivoltaic Integration	Multi-Sector / Generic (Technology or Advisory)
BM16	Farmers' Association — Advisory, Lobbying & Subsidy Facilitation for RES	Advisory & Planning Tools	Community / Cooperative	Digital / No Physical Footprint	Multi-Sector / Generic (Technology or Advisory)
BM17	Next2Sun: Vertical Bifacial PV (Fields2Sun / Fence2Sun) for Agrivoltaics	Solar & Agrivoltaics	Farmer-Owned / Independent	Dual-Use / Agrivoltaic Integration	Cereals & Arable Crops, Multi-Sector / Generic (Technology or Advisory)
BM18	H2arvester: Mobile Agrivoltaic System with Green Hydrogen Production	Solar & Agrivoltaics, Hydrogen	Community / Cooperative	Dual-Use / Agrivoltaic Integration, Mobile / Relocatable Systems	Multi-Sector / Generic (Technology or Advisory)
BM19	GVS Solar: Mobile Off-Grid Solar Irrigation System with AI Water Management	Solar & Agrivoltaics	Farmer-Owned / Independent	Mobile / Relocatable Systems	Horticulture & Protected Crops, Multi-Sector / Generic (Technology or Advisory)
BM20	Ecoways: Small-Scale Wind Turbines with Wooden Blades for Farm Self-Consumption	Wind Power	Farmer-Owned / Independent	On-Farm Infrastructure (No Land Competition)	Multi-Sector / Generic (Technology or Advisory)
BM21	MicroBiogasItalia: Small-Scale Livestock Biogas Plants (from 20 kW)	Biogas & Biomethane	Farmer-Owned / Independent	On-Farm Infrastructure (No Land Competition)	Livestock — Intensive / Monogastric

BM22	Nenufar: Floating Covers for Slurry Pits to Capture Fugitive Biogas	Biogas & Biomethane	Farmer-Owned / Independent	On-Farm Infrastructure (No Land Competition), Waste & Residue Valorisation (Off-Field)	Livestock — Intensive / Monogastric
BM23	Terrawatt: Pyrolysis + Biological Methanation Converting Green Waste to Biogas + Biochar	Biogas & Biomethane	Farmer-Owned / Independent	Waste & Residue Valorisation (Off-Field)	Agro-Food Processing & Value Chain
BM24	Biofrigas: Container-Based Liquid Biogas (LBG) Production from Farm and Agri-Food Waste	Biogas & Biomethane	Farmer-Owned / Independent	Waste & Residue Valorisation (Off-Field)	Agro-Food Processing & Value Chain
BM25	Causeway Energies: GeoSolar Geothermal + Solar-Thermal with Heat-as-a-Service Model	Mixed RES & Smart Mgmt	Third-Party Managed (ESCO / Lease)	On-Farm Infrastructure (No Land Competition)	Horticulture & Protected Crops
BM26	Greenwell: Repurposed Abandoned Oil & Gas Wells as Geothermal Heat Sources for Farms	Mixed RES & Smart Mgmt	Third-Party Managed (ESCO / Lease)	On-Farm Infrastructure (No Land Competition)	Horticulture & Protected Crops
BM27	M-TEC: Integrated On-Farm Energy Management (PV + Heat + Battery Storage)	Mixed RES & Smart Mgmt	Farmer-Owned / Independent	On-Farm Infrastructure (No Land Competition)	Multi-Sector / Generic (Technology or Advisory)
BM28	Tadus E Traktoren: High-Power Electric Tractor with Swappable Battery System	Mixed RES & Smart Mgmt	Farmer-Owned / Independent	On-Farm Infrastructure (No Land Competition)	Multi-Sector / Generic (Technology or Advisory)
BM29	Community Biogas Cooperative: Shared Manure → Energy + Digestate	Biogas & Biomethane	Community / Cooperative	Waste & Residue Valorisation (Off-Field)	Livestock — Extensive / Ruminants
BM30	Agrivoltaic ESCO / Lease Model for Farms	Solar & Agrivoltaics	Third-Party Managed (ESCO / Lease)	Dual-Use / Agrivoltaic Integration	Multi-Sector / Generic (Technology or Advisory)
BM31	Small-Scale Run-of-River Micro-Hydro – ESCO Model	Hydroelectric	Third-Party Managed (ESCO / Lease)	Water-Linked / Riparian	Multi-Sector / Generic (Technology or Advisory)
BM32	Community Wind Cooperative for Agricultural Areas	Wind Power	Community / Cooperative	On-Farm Infrastructure (No Land Competition)	Multi-Sector / Generic (Technology or Advisory)
BM33	Green Hydrogen from Farm RES for Agricultural Machinery	Hydrogen	Farmer-Owned / Independent	On-Farm Infrastructure (No Land Competition)	Multi-Sector / Generic (Technology or Advisory)

5 BUSINESS MODELS APPLIED IN THE REAL MARKET

5.1 Dimensions of the socio-technical context for BMs in RES for farming

The deployment and scaling of RES in agri-farms is consistently characterised in the literature by needing a strong alignment between regulation, market, organisational, behavioural, and technological contexts, ensuring coherence across the broader socio-technical system in which they are deployed. Figure 7 outlines the structure of analysis used in this next section (Bocken et al., 2016; Diaz Lopez et al., 2019; Lüdeke-Freund et al., 2018; Lüdeke-Freund et al., 2016).

Figure 7. Dimensions of the socio-technical context for BMs in RES for farming (Diaz Lopez et al., 2009; Montalvo, 2002).

While technological solutions for on-farm energy generation have matured significantly in recent years, their widespread adoption remains strongly mediated by policy and regulatory frameworks (or the lack of them), administrative procedures (burdening or agile), public and private financing (available or restricted), infrastructure (sufficient or constrained) and technological and organisational capabilities (including new skills and competences, or the lack thereof). This results in a context where business model feasibility is often determined less by technical capability than by regulatory alignment and institutional support (IRENA & FAO, 2021).

Several factors can constitute enablers and barriers that act in favour or against the diffusion of RES more broadly (Diaz Lopez et al., 2009; Hadjimanolis, 2003; Montalvo, 2002) also affecting the uptake of associated BMs. A similar pattern can be observed in the agrifood sector. Respondents to the HarvRESt stakeholder survey in Annex 1 noted the factors shown in Table 10 as main barriers for implementation of RES in farms.

Table 10. Barriers as seen through the results of the HarvRESt survey (Annex 1).

Barrier category	% of respondents who face this barrier or believe this is a key barrier
Regulation & administration	83% complex permitting, 78% administrative, 61% bureaucracy
Finance and markets	43% financial barriers : high upfront costs, 35% funding access
Infrastructure and operations	57% report grid connection constraints 65% fragmented responsibilities; lack of coordination platforms between stakeholders in governance
Organisational capabilities: Skills, awareness and acceptance	31% lack of expertise and trained personnel 13–17% Cooperation difficulties 44% unsure about funding 52% unsure about policy strategies, incentives and support schemes 30% Landscape conflicts / social acceptance challenges

The following section presents the key enablers and barriers of each of these dimensions in the context of RES for farming in Europe today, by analysing the administrative and regulatory context, the financial reality, technological readiness levels of each RES included in the catalogue, infrastructural gaps and enablers, and finally organisational capabilities such as skills and knowledge - In an effort to give an overview of the socio-technical system present in Europe today.

5.1.1 Regulation: Administrative and regulatory context

As noted, public support and enabling regulatory environments are fundamental for scaling RES in SBMs. Many EU-level strategies exist for the development of sustainable farming, RES implementation, and more specifically for RES in farming, with many overlapping frameworks. Table 11 Table 11 below gives an overview of the regulations, policies and financing instruments in place today[2]. Many of these stem from European Green Deal (2019) which set extensive and cross-sectoral strategic goals for a green transition.

EU legal and policy instruments are presented in Table 11 in the form of a matrix linking policy type and application areas, and a final category for assessing whether regulation or policy influence BM innovations. This highlights the inherently cross-cutting nature of EU governance.

[2] The EU-level regulatory landscape outlined in Table 11, fails to capture the complexity and specificity of laws and strategies in place at the national and regional levels. Some EU countries have specific regulations, policies or financial mechanisms to encourage RES for sustainable farming that are not covered in Table 11. EU National Climate and Energy plans across member states include many of those strategies – however, these have not been included in this brief review.

Table 11. Regulatory, policy and financing mechanisms for RES in farming at EU-level, compiled by authors from Wall and O'Shea (2025), (European Commission, 2026a), (European Commission, 2026b), (European Commission, 2026c), (République Française, 2026).

Policy / Instrument	Type	Function	Sustainable farming	RES	RES in farming	BM innovation
Common Agricultural Policy (CAP) 2023–2027 (Reg. EU 2021/2115) Including Eco-schemes & Agri-environmental and climate measures (AECC/AECMs)	Regulation + financing	Income support, rural investment, sustainability transition, incentives for climate-friendly farming practices (agroecology, carbon farming, efficiency)	✓		✓	✓
Renewable Energy Directive (RED II / RED III)	Regulation	Binding renewable energy targets, permitting frameworks, sector integration (incl. heating, fuels, hydrogen)		✓	✓	✓
EU Emissions Trading System (ETS)	Regulation (market mechanism)	Carbon pricing to incentivise low-carbon and renewable investments		✓	✓	
European Green Deal (2019)	Strategy	Overarching framework for climate neutrality, resource efficiency and sustainability transition	✓	✓	✓	
Biodiversity Strategy (2020)	Policy strategy	Protect ecosystems, soils and biodiversity in agricultural landscapes	✓		✓	
Fit for 55 package	Policy + legislative package	Align EU climate/energy laws with 2030 targets (decarbonisation, electrification)		✓	✓	
REPowerEU Plan	Policy strategy	Accelerate renewable deployment and decentralisation, reduce fossil dependency		✓	✓	
Circular Economy Action Plan (including the Ecodesign for Sustainable Products Regulation)	Policy strategy	Accelerate the development of circular economy across industry and consumption patterns, including a focus on sustainable products and technologies and	✓	✓		✓

		circular business models.				
Farm to Fork Strategy (2020)	Policy strategy	Transform food systems toward sustainability and lower emissions	✓		✓	
LEADER programme	Financing (community-based)	Support local innovation, rural entrepreneurship and community energy projects	✓	✓	✓	
Horizon Europe	Financing (R&D)	Innovation in agriculture, bioeconomy and renewable energy technologies	✓	✓	✓	✓
LIFE Programme	Financing	Environmental and climate action pilot projects (incl. land use and energy)	✓	✓	✓	
Cohesion Policy funds: European Agricultural Fund for Rural Development European Regional Development Fund European Social Fund	Financing	* Support for organic farming, protection of biodiversity, investment in the agri-food and forestry sectors. * Infrastructure investment, including decentralised renewable energy systems and aid to small and medium businesses. * Employment and skills development, social inclusion, sustainable rural economy development.	✓	✓	✓	

The presence of EU-level regulations and policies allow for institutional support of RES in farming today. However, strategies such as the Green Deal, REPowerEU, and the CAP operate with partially overlapping but not fully integrated objectives, creating inconsistencies in how agri-energy systems are supported or constrained (Alves et al., 2026). This is marked by a misalignment between energy and agricultural frameworks, rooted in the dual use of land for both food and energy production (Alves et al., 2026; Boros et al., 2025; Chatzipanagi et al., 2023).

More concretely, in the case of emerging technologies such as agrivoltaics, interview insights from Spain (Annex 4) reveal that legal, long-term classifications for land hosting photovoltaic infrastructure remain ambiguous. Without clarity, agrivoltaics projects may be treated as land-use conversion rather than multifunctional agriculture. This creates financial and administrative uncertainty for farmers, particularly in relation to eligibility for CAP direct payments or permitting procedures (Chatzipanagi et al., 2023; Chatzipanagi et al., 2022; Mehta et al., 2025).

For the latter, farmers must navigate cross-sector processes, that are often sequential rather than in parallel (Okodoi & Kisiangani, 2024). Because of this, permitting timelines can stretch over multiple years – up to 6 years in Spain based on interview evidence (Annex 2). This disproportionately affects decentralised and small-scale installations, which lack the organisational capacity of large energy developers (Alves et al., 2026; Okodoi & Kisiangani, 2024).

More details on the data collected from the HarvRESt survey can be found in Section 5.2.

5.1.2 Finance and markets

While many RES projects still have high entry and capital expenditure costs (CAPEX), generally, solar-PV, small-scale wind, and modern bioenergy systems have become increasingly accessible, with well-established supply chains and proven performance in rural areas (IEA, 2025; Mwangi et al., 2025).

While there exists increasing public financing opportunities, as seen in Table 11, that act as key enablers of RES uptake for farming, the sector is strongly shaped by a dependence on public support mechanisms include investment subsidies, feed-in tariffs, and innovation grants (IRENA & FAO, 2021; Karanjikar et al., 2024). This is reflected in the survey results with grants being the most valued (61%) and most used (48%) method of financing. These continue to influence the economic viability of many projects, as the dependence reflects both the capital-intensive nature of RES technologies and the still-evolving market conditions for green energy in agriculture. Additionally, reliance on policy incentives and financing can create project vulnerability to shifting political priorities (Karanjikar et al., 2024).

On the other hand, the emergence of innovative ownership models can alleviate and share financial risk, such as co-ownership (coops), third-party ownership (ESCOs), partnerships, or joint ventures (Piterou & Coles, 2020), as is seen in this catalogue (Annex 1 & 4).

5.1.3 Technology: Technological Readiness Levels

Technology for RES are largely mature and adopted within the renewable energy market. Table 12 gives an overview and analyses the most prevalent technologies included in this Catalogue. The categorisation is based on Technology Readiness Levels (TRL) (Mankins, 2004) found in literature and underlined by our own research. This framing is used to analyse system innovation pathways and deployment potential (Huang et al., 2025; Nguyen et al., 2017), and include:

- Mature (TRL 7-9): Technologies are fully commercialised and deployed at scale; systems are proven in real operational environments.
- Semi-mature (TRL 5-6): Technologies are demonstrated and validated in relevant or real environments, but still undergoing scaling, cost reduction, and system integration before widespread adoption.
- Emerging (1-4): Technologies are at early-stage R&D, including basic principles (TRL 1–2), laboratory validation (TRL 3), and small-scale prototypes tested in controlled environments (TRL 4).

Table 12. Technological Readiness Levels of RES used in farming based on the research of this report.

Maturity level	Technologies	Description
Mature and widely deployable (TRL 7-9)	**PV**	Solar PV is described as a "global cornerstone of electricity generation" with more than 2.2 TW installed capacity and rapid deployment across multiple countries (IEA-PVPS, 2025).
	Biogas, Combined Heat and Power (CHP)	Biogas (including CHP use) is already widely deployed, with strong policy support and expected global growth of approximately 22% by 2030. It is used commercially for electricity and heat production (IEA, 2025).
	Small wind	Small wind turbines are established technologies within distributed energy systems. Though still improving in efficiency, they are part of current energy transition infrastructures (Bianchini et al., 2022).
	Geothermal	Geothermal has been a source of renewable energy for over 100 years, has mature technologies, but has not played a major role in the global energy mix. Today, new technologies are emerging that could scale its' use (IEA, 2024).
	EMS (energy management systems)	Energy management systems are widely implemented and assessed through established maturity models (e.g., ISO 50001-based frameworks), they show advanced deployment (Monteiro et al., 2022).
	Energy storage	Several storage technologies, such as Li-ion batteries, pumped hydro, are classified as fully mature and commercial, while others are still emerging (see below) (Gagne, 2024; Nguyen et al., 2017).
Semi-mature/ scaling	**Agrivoltaics**	Agrivoltaics is a relatively new but rapidly growing field, with proven potential but remaining technical, economic, and policy challenges for large-scale deployment (Gomez-Casanovas et al., 2023; Zahrawi & Mousaad Aly, 2024).
	Biomethane upgrading	Biomethane is expanding quickly, with increasing policy support and infrastructure integration, but still requires scaling to reach its full potential (Wall & O'Shea, 2025).
	Electric machinery	Electrification of machinery in agriculture and industry is progressing but still faces cost, infrastructure, adoption and policy barriers (IEA, 2025).
Emerging/ experimental	**Hydrogen production**	Hydrogen technologies such as electrolysis and pyrolysis are considered critical but still developing, requiring further investment and innovation for large-scale commercialisation (Abdullah Mezaal et al., 2024; Elistratov & Terekhov, 2026)
	Mobile agrivoltaics	Advanced or mobile agrivoltaics systems remain experimental, with ongoing research addressing design, land-use, and operational uncertainties (Zahrawi & Mousaad Aly, 2024).

Table 12 indicates that a majority of the technologies available today for RES in farming are mature, with more emerging as the sector grows. Incoming technologies, such as agrivoltaics or biomethane upgrading, are being built on existing and mature systems such as solar or biogas, facilitating their uptake into the market. As regulations, infrastructure and institutions shift for mature technologies, this also paves the way for emerging ones. What can be said to be lacking, are mature business models.

5.1.4 Infrastructure and operations

Constraints on grid access and energy export, also constitute a challenge for RES scalability in agri-farming, as it limits the economic viability of distributed RES business models (Okodoi & Kisiangani, 2024). Countries across the EU have different policies and requirements for access to the energy grid. Literature (Chatzipanagi et al., 2023; Okodoi & Kisiangani, 2024) and interview evidence from Norway and Spain (Annex 4) highlight both physical and institutional barriers, including saturated grid capacity, high connection fees, and restricted opportunities for local energy sharing (section 5.2).

These findings are consistent with broader research on decentralised renewable energy systems, which identifies grid integration and market access as critical determinants of business model feasibility (Alves et al., 2026; Piterou & Coles, 2020; Wainer et al., 2022). Without adequate infrastructure and regulatory provisions for decentralised energy exchange, farmers are often limited to self-consumption models, reducing potential revenue diversification. This trend was identified in the HarvRESt survey, where private ownership represented a dominating model for 39% of actors, and can be seen as a key barrier to energy community development in Europe (European Court of Auditors, 2026).

5.1.5 Organisational capabilities: Skills and access to information and awareness

Information gaps remain a critical, barrier to the deployment of renewable energy systems in European agricultural contexts (IRENA & FAO, 2021; Piterou & Coles, 2020). Survey evidence confirms the scale of this issue, with 44% of respondents reporting uncertainty regarding the availability of funding programmes and 52% unsure whether relevant strategic plans exist (Annex 1), indicating a substantial disconnect between policy provision and end-user awareness. More on this in section 5.2.

An ICLEI report (Okodoi & Kisiangani, 2024) notes that effective renewable energy deployment depends on “raising local awareness […] and building capacities” among stakeholders. They state that the combination of low awareness of funding opportunities, limited understanding of policy frameworks, and weak dissemination of strategic plans creates a structural barrier, where available instruments exist but are not utilised, leading to underinvestment and slowing the energy transition (Mwangi et al., 2025; Okodoi & Kisiangani, 2024).

This can also be said for the development of essential skills to install, operate and maintain RES on farms. If training and educational programs are not in place and accessible, this limits the possible uptake of RES, even when financial and regulatory support exists (Diaz Lopez et al., 2009; Montalvo, 2002).

Taken together, (sections 5.1.1 to 5.1.5) these factors define a regulatory and technological context in which many RES solutions are technically viable, yet only selectively deployable. Business model innovation in this domain is therefore closely tied to the evolution of policy frameworks, infrastructure systems, and regulatory alignment across sectors. The following section further supports these insights through HarvRESt data collection and processing.

5.2 Critical assessment Across Contexts and Regions

This section draws on primary data gathered through the HarvRESt stakeholder consultation survey Data Analysis (Annex 1), complemented by evidence from three additional expert interviews conducted specifically to probe cross-national transferability and regulatory positioning. Together, these two layers of evidence — 23 survey respondents from the main consultation and 3 targeted expert interviews —

are used to evaluate how business models catalogued in Section 3 can be adapted to different regulatory contexts and international settings.

The analysis is structured around the six thematic sections of the survey — Energy Sector (Section A), Financing (Section B), Public-Private Partnerships (Section C), Regulatory Landscape (Section D), Governance and Institutions (Section E), and Energy Systems and Technologies (Section F) — and examines, for each thematic area, whether the aggregate tendency observed across the full sample is consistently reflected in each national context, or whether meaningful divergences emerge that have implications for replicability.

The main HarvRESt survey reached 23 respondents, predominantly from Spain (n=16, 70%) and Italy (n=5, 22%), with one respondent from Denmark and one unattributed. This geographic concentration reflects the project consortium's primary operational territories. The 3 additional interviews included one respondent from Spain, Norway and Germany. The three additional expert interviews were conducted as a gap analysis to deepen the dimension of the transferability assessment across nations from a policymaker's point of view (Table 13).

Table 13. Number of respondents for every section and country

Country	n	Source / Profile	Energy Sector	Financing	Public-Private Partnerships	Regulatory Landscape	Governance and Institutions	Energy Systems and Technologies
Spain	16	Main survey	16	16	15	16	15	15
Spain	1	Expert interview with policymaker	1	1	1	1	1	—
Italy	5	Main survey	5	5	5	5	4	5
Denmark	1	Main survey	1	—	—	—	—	—
Norway	1	Expert interview with policymaker	1	1	—	1	1	1
Germany	1	Expert interview with policymaker	1	1	—	1	1	—

5.2.1 Energy Sector: Priorities, Adoption Drivers and Barriers

Renewable Energy Sources (RES) are the dominant energy priority across the full sample (74% of respondents), followed by the Agricultural Value Chain (48%) and Waste Recovery (35%). Economic profit is the leading adoption factor (70%), ahead of energy availability (52%) and environmental protection (43%). On the obstacle side, administrative procedures dominate overwhelmingly (78%), compounded by bureaucratic barriers (61%), financial barriers (43%), and lack of policy incentives (35%). Technical aspects rank as the most critical barrier on average (avg. rank 2.14), ahead of legal (2.73) and financial (2.77) dimensions.

Spain confirms the aggregate picture: RES leads (75%), with administrative procedures cited by 88% of respondents, above the overall average, reinforcing that administrative friction is most acute in this context. Italy mirrors RES prioritisation (80%) but diverges on obstacles: technological limitations emerge as a co-primary barrier (60% of Italian respondents vs. 17% overall), reflecting the country's lower deployment rate. Norway's municipal expert highlights a more integrated, multi-vector priority hierarchy (EVs, district optimisation, RES and the agricultural value chain treated as equally weighted) with barriers perceived as interlocking rather than individually dominant.

RES adoption intent is near-universal across all contexts, but the obstacle profile diverges systematically: administrative and bureaucratic barriers dominate in Spain; technological unreadiness constrains Italy; and farmer time scarcity, identified by the German expert as the single most important barrier, ranked above legal, financial and technical dimensions, is an invisible transaction cost almost usually absent from standard survey instruments. Business models requiring minimal administrative footprint on the farmer's side show the highest cross-context transferability.

5.2.2 Regulation: Universal Bottlenecks, Contextual Intensity

Complex permitting is the single most cited regulatory obstacle across the full sample (83%), and the most critical in the barrier ranking: 13 out of 22 respondents rank it as their number one regulatory priority (avg. rank 1.62). Grid connection issues (57%) and lack of incentives (52%) follow at distance. Strategic RES plans are unclear to most respondents: 52% answer 'Not Sure' and only 26% confirm the existence of a strategic framework in their context, a finding replicated by both Spanish and German expert interviewees, neither of whom could confirm an integrated national RES strategy. The Norwegian expert adds a dimension absent from the quantitative survey: the regional energy network monopoly that prevents local energy sharing between neighbours, directly blocking community and prosumer models even where technical and financial conditions are met.

Spain and Italy share permitting and grid connection as their top two regulatory obstacles, with Spain registering higher urgency (permit rank 1.50 vs. 2.25 in Italy). Italy's agrivoltaic regulatory framework has advanced since the 2022 MITE guidelines and the PNRR programme, but implementation-level complexity persists, particularly for small operators without legal support. In Norway, the network monopoly barrier is particularly relevant to HarvRESt models: any business model relying on local energy exchange (community biogas, cooperative PV, peer-to-peer trading) requires grid access reform to be replicable in similar regulatory environments.

Permitting complexity is confirmed as the universal regulatory bottleneck across all five countries represented. Its form differs: procedural fragmentation in Spain (permit rank avg. 1.50, highest urgency in the dataset), administrative overload in Germany (rank 1, approval timelines of 4–5 years documented), and network monopoly rules in Norway blocking cooperative energy sharing. Business models with the lowest permitting footprint (rooftop PV self-consumption and ESCO models where the third party handles authorisations) show the greatest regulatory transferability. A one-stop-shop permitting mechanism, as called for under RED III, is the single most impactful enabling policy for cross-context replication.

5.2.3 Finance and markets: Instruments, Effectiveness and Information Gaps

Grants are the most valued financing instrument (61%) and the most used (48%). Tax incentives rank second in both effectiveness (52%) and use (35%). A profound information gap shapes the landscape: 44% of respondents are unsure whether relevant funding exists in their context. Carbon financing and results-based financing are perceived as moderately effective (30% and 26%) but dramatically underused (13% each). The Norwegian expert diverges from the aggregate, identifying tax incentives as more effective than grants in a mature market context. The German expert's most salient observation is historical: biogas has been financially supported in Germany for decades, but 'less so now than 20 years ago', a subsidy erosion trajectory that is a direct cautionary signal for Southern European markets now entering the biogas deployment phase.

Spain presents the richest but most fragmented financing landscape: multiple national programs exist across two ministries (ecological transition and agriculture), yet the solar sector expert still answers 'Not Sure' on the existence of integrated strategic plans — instruments exist, but navigability does not. Italy shows lower financing awareness overall, with greater openness to equity and results-based instruments, consistent with its cooperative business traditions. Norway benefits from a layered municipal-national system (Bionova, Enova, Klimasats, local ENOK funds), with energy price volatility identified as the primary barrier to long-term contractual agreements. Germany's civil society perspective favours outcome-conditioned instruments that can integrate biodiversity criteria alongside energy performance.

Financing uncertainty is as significant a barrier to replication as regulatory complexity. Tax incentives offer the most context-neutral entry point across all national systems surveyed. Results-based financing holds the greatest untapped potential for models with measurable environmental co-benefits. The German biogas trajectory illustrates the fragility of subsidy-dependent business models over time: follower markets should build for subsidy phase-out from the outset.

5.2.4 Technology: Energy Systems' Baseline Gaps and Frontier Signals

Solar PV is the most deployed technology (52% of respondents), confirming its baseline status in agricultural RES. Biogas follows at 39%, biomass at 26%. Energy storage adoption remains critically low (22%) and energy management systems are present in only 35% of cases — a significant digitalisation gap. Considering that solar PV is the most deployed technology overall (52%), this is reflected in Spain but not in Italy, where 60% of respondents report no RES technology currently in use — the clearest evidence of Italy's deployment gap despite comparable policy ambitions. Norway's expert profile is exceptional in scope, encompassing all major RES technologies plus energy storage and management systems, and pointing to frontier technologies not yet within the HarvRESt catalogue: deep geothermal at approximately 2,000 metres depth and pyrolysis from manure. Germany's contribution is a historical signal: agricultural biogas, once the country's flagship RES-agri technology under the EEG, has seen progressive subsidy erosion over two decades — a maturation-to-stagnation trajectory directly relevant to follower markets now entering the biogas phase.

Spain's technology profile (PV 56%, biogas 50%, biomass 38%) reflects a mature and diversified agri-energy sector; the solar industry expert's identification of storage, not generation, as the primary energy priority signals market maturation: the challenge has moved from installation to optimisation and grid integration. Italy's gap is structural: the absence of deployed technologies in 60% of cases likely reflects smaller, less capitalised farm operations and an earlier stage of market development, requiring simpler and lower-CAPEX entry-point models.

Solar PV self-consumption carries the highest cross-context replicability: mature, cost-competitive, and increasingly subsidy-independent. Biogas models show strong potential where organic waste streams exist but carry subsidy-dependency risk illustrated by the German EEG trajectory. Storage and energy management systems remain under-deployed across all contexts; business models integrating these components require additional enablement support. The Norwegian frontier profile (deep geothermal, pyrolysis) warrants monitoring for future catalogue iterations.

5.2.5 Infrastructure and operations: Coordination Gaps and Capacity Asymmetries in governance and institutions

Coordination platforms are largely absent: 75% of survey respondents report no coordination platform in their context. Staff preparedness is moderately positive (48% 'High', 13% 'Very High'), but 30% report low or very low preparedness. Italy presents the most challenging picture: no coordination platform and 40% of respondents rating staff preparedness as 'Very Low' — the highest concentration in the dataset. Norway is the sole exception: a functioning inter-sectoral coordination platform exists, with energy price volatility (rather than institutional absence) identified as the primary coordination barrier.

Spain shows a notable disconnect: individual staff preparedness is high (63% 'High') but coordination infrastructure is almost entirely absent (platform present in only 31% of cases). This suggests that collective action structures, not individual skills, are the binding constraint in the Spanish context. Germany confirms the absence of a coordination platform; the institutional capacity barrier there is systemic, a consequence of transition-driven workload overwhelming existing administrative structures, rather than a gap in political will or technical expertise.

Governance and coordination capacity is the most uneven dimension across contexts and the least visible to external implementers. Italy faces the deepest deficit; Norway is the sole functional example in the dataset. Business models requiring multi-stakeholder coordination are significantly less portable than models implementable by a single farm or company. Capacity-building must be treated as an enabling precondition, not an optional enhancement, in any replication strategy targeting Mediterranean contexts.

5.2.6 Organisational capabilities in Public-Private Partnerships - Strong Support, Weak Implementation

Support for PPPs in the agri-energy sector is near-universal: 78% of survey respondents actively support PPP models, with only 9% opposed. Yet only 22% are involved in an existing PPP, a sharp implementation gap. The strengths most associated with PPPs, risk sharing, external funding access, faster deployment, and regulatory alignment, map precisely onto the barriers that prevent standalone farmer-initiated models from scaling. Norway is the sole context in the dataset where a functioning multi-partner coordination platform is confirmed, operating as a living lab for frontier technologies (deep geothermal, pyrolysis from manure) rather than a conventional risk-sharing vehicle.

Spain shows the highest PPP support (94%) but no functional coordination platform; the primary friction is the mismatch between private decision-making speed and public administrative timelines. Italy shows mixed support (60%) and lower organisational density, though the mountain cooperative model (Coop ASCA) demonstrates that PPP-adjacent structures are viable in complex rural contexts. Germany did not respond to PPP-specific questions, but the institutional capacity barrier identified is structurally limiting regardless of political support.

The PPP support-implementation gap is universal, but its underlying causes differ by context: administrative speed asymmetry in Spain (private actors outpacing public institutions), institutional density constraints in Italy, and public capacity saturation in Germany ('agencies are overworked'). PPP models designed for one context are not directly portable to another without adaptation to the local institutional friction profile.

5.2.7 Cross-Cutting Assessment: Transferability Dimensions

Drawing together the evidence from the survey, seven dimensions emerge as primary determinants of business model transferability across national contexts.

Administrative and permitting burden is the most agreed-on constraint, confirmed in every country surveyed. Models with a low permitting footprint (rooftop PV self-consumption, ESCO arrangements) are correspondingly the most portable across contexts.

Financing landscape clarity is equally critical: grants dominate in use and perceived effectiveness, yet 44% of respondents are uncertain whether relevant instruments exist in their context. Tax incentives are the most context-neutral vehicle; results-based financing holds the greatest untapped potential for models with measurable environmental co-benefits. Navigation support is a prerequisite for replication, not an optional enhancement.

- **PPP infrastructure** shows a near-universal support-to-implementation gap: PPPs are recognized as important, but their application is still limited. The cause differs by country — administrative speed asymmetry in Spain, institutional density in Italy, agency overload in Germany — and replication strategies must be designed around the specific friction profile of the target context.
- **Network and grid access rules** are a structural barrier for cooperative and community-based models. Where regional grid monopolies prevent local energy sharing, prosumer and energy community models require prior regulatory reform before they can be replicated, as highlighted for Norway.
- **Institutional capacity** is the most uneven dimension across contexts. Complex multi-stakeholder models are significantly less portable to low-capacity environments, such as Italy, which presents the deepest deficit in the dataset, than models operable by a single farm or company.
- **Technology baseline maturity** must guide model selection: entry-level PV self-consumption for pre-deployment contexts (Italy), integration and aggregation models for mature markets (Spain), with frontier technologies such as deep geothermal and pyrolysis from manure (Norway) informing future catalogue iterations.
- **Subsidy cycle risk** carries strategic implications for follower markets. The German biogas trajectory — from an incentive-driven boom in the early 2000s to progressive subsidy erosion — illustrates how incentive-dependent models can stagnate as policy priorities shift. Models designed for subsidy phase-out from the outset are structurally more resilient.

In general, it is important to note that no single business model is universally transferable without contextual adaptation. However, a cluster of high-replicability models (**solar PV self-consumption, ESCO-based installations, and digital planning/DSS tools)** demonstrates consistently low institutional, regulatory and financial friction across all contexts surveyed. These models should be prioritized as entry-point vehicles for new implementation contexts, with more complex cooperative and multi-source integration models positioned as second-phase aspirations contingent on enabling infrastructure development.

5.3 Evaluation Criteria for Business Model Viability

5.3.1 Evaluation Approach

Following the systematic cataloguing and cross-contextual analysis of the 33 business models (BM01–BM33) presented in the preceding sections, a structured expert evaluation was conducted to assess the relative viability and strategic value of each model. The objective was to move beyond descriptive classification and produce a multi-criteria ranking that integrates the perspectives of specialists with complementary expertise in renewable energy systems, agri-food value chains, technology development, and business model innovation.

Each of the 33 catalogued business models was assessed across seven evaluation criteria, selected to reflect both the technical dimensions of RES deployment in agriculture and the strategic dimensions relevant to diverse market actors. The criteria operationalise the multi-stakeholder perspective that characterises the HarvRESt approach and are aligned with the assessment framework developed in Task 3.5. Each criterion was scored on a four-point scale, from 1 (Very Low) to 4 (Very High). The seven criteria and their operational definitions are presented in Table 14.

Table 14. Evaluation criteria

Criterion	Definition
Market Integration	Degree to which the business model connects with energy markets, grid services, PPAs, flexibility mechanisms, or virtual power plants.
WEF Nexus	How well the business model addresses Water-Energy-Food interdependencies and optimises across all three dimensions.
Strategic Resiliency	Capacity to enhance farm energy independence, buffer against energy price shocks, and maintain operations under adverse conditions.
Replicability / Scalability	Potential for the business model to be replicated across different farm types, regions, or scales with manageable adaptation effort.
Sustainability & Circularity	The business model's potential for climate sustainability (CO_2 emission reduction, energy efficiency) and the extent to which it includes circularity principles (end-of-life management, life extension strategies).
Attractiveness for Agriculture Players	Appeal to farmers, cooperatives, and agri-food actors in terms of economic benefit, reduced risk, and alignment with farm operations.
Attractiveness for Energy Players	Appeal to energy companies, ESCOs, and investors in terms of profitability, market positioning, and risk-adjusted returns.

Across all 33 business models and all experts, Attractiveness for Agriculture Players recorded the highest average criterion score (3.07/4), confirming the broad relevance of the catalogued models to farming actors. Strategic Resiliency (2.90/4) and Sustainability & Circularity (2.88/4) were the next strongest dimensions, reflecting the alignment of many models with energy autonomy and decarbonisation objectives. Market Integration (2.50/4) and Attractiveness for Energy Players (2.47/4) scored lowest on average, indicating that deeper market connectivity and investor-readiness remain areas for improvement across the portfolio.

The evaluation was conducted by a panel of ten experts, and the results were discussed and validated through a specific workshop with the HarvRESt consortium. The evaluation was conducted asynchronously using a purpose-built digital scoring tool (the HarvRESt Expert Evaluation Tool, version dated 29 April 2026). Each expert accessed their personal scoring sheet and independently assigned scores to all 33 business models across the seven criteria. Experts were provided with standardised business model descriptions drawn from the Business Model Compendium and the instructions sheet embedded in the tool. The scoring guide and detailed criterion definitions were made available within the tool to ensure a consistent scoring reference across all evaluators.

Individual expert scores were automatically consolidated in a dedicated Summary sheet, which computed average scores per criterion and per business model across all responses, excluding blank cells (i.e., cases where an expert chose not to score a specific business model due to limited familiarity). The consolidated scores formed the basis for the ranking presented in the following section.

For the validation workshop with the consortium, the results of the evaluation of experts has been presented in a validation workshop on the **5th of May 2026** to the whole consortium. The methodology of evaluation and the average criteria, as well as results have been presented and feedback collected from the consortium. A revised version of presentation of results integrating feedback has been done and approved by consortium members.

Moreover, a final stakeholder workshop is planned, upon submission of the final deliverable, in the second **week of July 2026 (M31**) is planned to present to the whole consortium the work done, the results obtained the main outcomes and the business model catalogue itself.

5.3.2 Evaluation Results

The evaluation matrix with the results of average scores of expert's marks on business models is presented in Annex 3. Table 15 presents the consolidated expert scoring results for all 33 business models (based on the 7 criteria assessed on a scale from 1 to 4). The scores **highlighted in green** are **major or equal to 3.0** and indicate the Business Models that, following the experts evaluations, **are considered to perform well in that specific evaluation criteria**. Here below we present a table showing the list of all BM with a score major or equal to 3 for every evaluation parameter:

Table 15. Business models performing well for each evaluation criteria

Criterion	Definition	Business models scores
Market Integration	Degree to which the business model connects with energy markets, grid services, PPAs, flexibility mechanisms, or virtual power plants.	BM01(3.2), BM06(3.0), BM17(3.4), BM24(3.0), BM27(3.1), BM30(3.9), BM31(3.8), BM32(3.5)
WEF Nexus	How well the business model addresses Water-Energy-Food interdependencies and optimises across all three dimensions.	BM01(3.0), BM03(3.2), BM04(3.1), BM05(3.0), BM06(3.4), BM13(3.1), BM14(3.1), BM19(3.3), BM23(3.0), BM29(3.2), BM31(3.3)
Strategic Resiliency	Capacity to enhance farm energy independence, buffer against energy price shocks, and maintain operations under adverse conditions.	BM01(3.2), BM04(3.4), BM06(3.9), BM07(3.5), BM10(3.5), BM13(3.4), BM19(3.2), BM21(3.2), BM23(3.2), BM25(3.4), BM27(3.1), BM29(3.4), BM31(3.2), BM32(3.0)
Replicability / Scalability	Potential for the business model to be replicated across different farm types, regions, or scales with manageable adaptation effort.	BM02(3.5), BM07(3.2), BM08(3.0), BM17(3.4), BM21(3.5), BM23(3.0), BM27(3.6), BM28(3.1), BM30(3.6)
Sustainability & Circularity	The business model's potential for climate sustainability (CO_2 emission reduction, energy efficiency) and the extent to which it includes circularity principles (end-of-life management, life extension strategies).	BM01(3.6), BM02(3.2), BM07(3.0), BM08(3.7), BM09(3.7), BM10(3.4), BM12(3.3), BM13(3.0), BM21(3.2), BM23(3.6), BM24(3.5), BM29(3.7), BM33(3.2)
Attractiveness for Agriculture Players	Appeal to farmers, cooperatives, and agri-food actors in terms of economic benefit, reduced risk, and alignment with farm operations.	BM01(3.2), BM03(3.2), BM04(3.5), BM05(3.3), BM06(3.4), BM07(3.4), BM08(3.2), BM10(3.3), BM12(3.3), BM13(3.5), BM14(3.1), BM16(3.0), BM17(3.1), BM19(3.5), BM21(3.6),

		BM23(3.5), BM24(3.1), BM25(3.1), BM27(3.5), BM28(3.3), BM29(3.6), BM30(3.7), BM31(3.5), BM32(3.3)
Attractiveness for Energy Players	Appeal to energy companies, ESCOs, and investors in terms of profitability, market positioning, and risk-adjusted returns.	BM01(3.1), BM17(3.2), BM24(3.3), BM25(3.0), BM30(3.6), BM31(3.7), BM32(3.0)

5.4 Decision Support System (DSS) and Agricultural Virtual Power Plant (AVPP)

The user of this Business model Catalogue that wants to select the best option for his own case can benefit of two additional tools provided by HarvRESt:

1. **Agricultural Virtual Power Plant (AVPP):** The AVPP is the HarvRESt simulation tool developed by CIRCE that translates the qualitative business-model archetypes catalogued into quantitative, site-specific scenarios. Where the catalogue describes which configurations of renewable energy generation, storage and agricultural production are viable, the AVPP estimates how a given configuration would perform on a particular farm, under that farm's climatic and operational conditions. It thereby provides the empirical, farm-level calibration layer that connects the four catalogue dimensions: Technology Archetype, Governance & Ownership, Land Use Strategy and Agricultural Sector to measurable energy, agronomic and economic outcomes.

   Methodologically, the AVPP models the principal technology archetypes represented in the catalogue within a coherent framework that shares a common location and weather dataset across all technologies. The currently implemented modules cover solar photovoltaics, wind energy, biogas production from anaerobic digestion and crop yield. A hybridisation module integrates these renewable sources with battery energy storage, self consumption and the grid point of interconnection, optimising self-consumption, charge/discharge scheduling and the trade-off between on-site use, purchase and sale of electricity. This explicitly operationalises the Water-Energy-Food nexus that underpins the HarvRESt approach: the same run captures crop production, energy self-sufficiency, and the economics of grid interaction together.

   Operationally, the AVPP is designed to run diverse scenarios and farm configurations and to compare them systematically. Each technology produces both technical indicators (e.g. annual generation, self-sufficiency, storage utilisation, crop yield) and economic indicators (capital and operating costs, lifetime, cost of capital, revenue from energy sales), and the engine supports parametric sweeps so that a user can explore how a result varies with installed capacity, storage sizing, land-use strategy or financing assumptions. These structured outputs are the inputs the Decision Support System weighs against the multi-criteria framework presented in Section 5.3 — strategic resilience, replicability, sustainability and circularity, attractiveness to agricultural and energy actors, and so on — to deliver tailored recommendations to farmers and policymakers. In this way the AVPP and the DSS form the two operational tools that complete the HarvRESt toolkit: the catalogue identifies the space of relevant business models, the AVPP quantifies their performance for a specific case, and the DSS supports the final selection and planning decision.

2. **Decision Support System (DSS):** The HarvRESt DSS is the decision-support tool designed to transform the technical and economic results generated by the AVPP into actionable recommendations for farmers, policymakers and other stakeholders. While the AVPP quantifies the performance of alternative agri-energy configurations under specific local conditions, the DSS supports the selection of the most suitable option by evaluating and ranking those alternatives against a comprehensive set of sustainability, economic, environmental and social criteria. It therefore acts as the strategic decision layer that connects simulation outputs with real-world planning and investment decisions.

   Methodologically, the DSS is based on a Multi-Criteria Decision Analysis (MCDA) framework that integrates technical indicators (renewable energy generation, self-consumption, agricultural productivity), economic indicators (investment costs, revenues, payback periods), environmental indicators (land, water and biodiversity impacts), and social and governance considerations (stakeholder acceptance, ownership structures, perceived risks and incentives). These criteria are weighted through a participatory process involving farmers and relevant actors, ensuring that recommendations are aligned not only with quantitative evidence but also with local priorities and preferences.

Operationally, the DSS enables the systematic comparison of multiple technology, business model, governance and land-use scenarios generated by the AVPP. By applying established MCDA approaches, it produces a transparent and traceable ranking of alternatives tailored to the specific context of each agricultural community. The tool supports both scenario exploration and decision validation, allowing users to assess trade-offs and identify robust pathways for renewable energy integration.

In this way, the DSS and the AVPP jointly complete the operational HarvRESt toolkit: the catalogue defines the landscape of feasible business models, the AVPP quantifies their site-specific performance, and the DSS guides the final selection of the most appropriate and sustainable solution according to stakeholder priorities and local conditions.

6 CONCLUSIONS

The comprehensive mapping and systematic evaluation of thirty-three business models within the HarvRESt project provide critical socio-technical insights into the deployment of renewable energy sources across European agricultural ecosystems. By aligning technological archetypes, governance configurations, land-use strategies, and sector-specific operational demands, this research transcends purely technical feasibility studies to address the multi-dimensional socio-economic matrices governing market adoption. The ultimate value of this cataloguing lies in its capacity to contextualize innovation within the real-world constraints of the agricultural sector, offering a structured framework to evaluate how distributed energy resources can productively co-exist with food and feed production within the Water-Energy-Food nexus.

The baseline assessments reveal that while technological innovations have achieved significant technical readiness, their widespread market absorption is fundamentally contingent upon viable socio-economic and regulatory frameworks. A primary finding indicates that the principal barriers to agricultural energy expansion are institutional and administrative rather than technological. Complex permitting remains the single most pervasive obstacle, cited by 83% of surveyed market actors. This is exacerbated by a severe chronological mismatch between the rapid decision-making cycles required by private investors and the prolonged, sequential bureaucratic processes characteristic of public administrations. Profound structural information gaps persist across the European jurisdictions examined, where nearly half of the surveyed stakeholders expressed persistent systemic uncertainty regarding subsidy availability and rural governance frameworks. Centralized network regulations and grid capacity constraints present severe friction points. In multiple European jurisdictions, centralized grid regulations actively penalize decentralized configurations by legally restricting or prohibiting localized peer-to-peer energy trading, which restricts farmers to solitary self-consumption and prevents the realization of interconnected agro-energy communities.

The portability of agri-energy business models across Europe is highly asymmetric, heavily governed by regional variations in administrative capacity. Spain presents a diversified and mature agri-energy technology profile, with solar PV at 56% and biogas at 50% deployment, meaning the primary challenge has moved from installation to optimization and grid integration, though it still registers higher urgency regarding permitting obstacles. Conversely, Italy exhibits a structural deployment gap where 60% of respondents report no renewable energy technology currently in use, combined with an acute deficit in localized stakeholder coordination platforms and low staff preparedness. Norway benefits from functional multi-partner coordination platforms and municipal support systems, yet its regional energy network monopoly prevents local energy sharing. Germany provides a critical historical signal regarding subsidy cycle risk, where agricultural biogas, once the flagship technology, has seen progressive subsidy erosion over two decades, illustrating how incentive-dependent models can stagnate as policy priorities shift.

The empirical evaluation conducted through multi-criteria expert panels underscores a structural divergence between stakeholder attraction and systemic market integration. Across all 33 business models, (i) Attractiveness for Agriculture Players recorded the highest average criterion score, followed closely by (ii) Strategic Resiliency and (iii) Sustainability & Circularity. Conversely, (iv) Market Integration and (v) Attractiveness for Energy Players lowest on average, reflecting the reality that contemporary initiatives function primarily as localized self-consumption loops rather than institutionalized energy units integrated into broader macro-markets. The multi-criteria matrix identified distinct operational trade-offs across performance vectors. Complex configurations leveraging agrivoltaic solutions and anaerobic digestion pathways demonstrated the highest strategic resilience and alignment with circular economy principles, offering superior circularity and protection against environmental stress, but their execution remains heavily dependent on significant initial capital investments. Conversely, standalone solar PV configurations, third-party leasing models, and digital decision-support frameworks emerged as the most scalable assets due to their lower organizational complexity and reduced financial risk exposure for the agricultural operator, making them ideal entry-point vehicles for low-capacity or follower markets.

Ultimately, transforming the European agricultural sector into a proactive pillar of the energy transition requires shifting from isolated technological installations to interconnected, market-ready business ecosystems. Low-friction, commercially mature archetypes must be prioritized initially to bypass administrative deficits in developing regions, while transitioning toward highly integrated multi-source hybrid models and collective cooperatives remain strictly dependent on future policy interventions, including grid liberalization and the harmonization of cross-sector permitting procedures. The typological cataloguing and performance rankings established in this deliverable provide the necessary empirical calibration for the HarvRESt Decision Support System, ensuring that future operational tools are aligned with real-world institutional landscapes.

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8 ANNEX 1: Stakeholder Survey Data Analysis

ABBREVIATIONS

ABS	Asset-Backed Securities
CAP	Common Agriculture Policy
D	Demand
DSS	Decision support system
EAFRD	European Agricultural Fund for Rural Development
ERDF	European Regional Development Fund
ESCO	Energy Service Company
ESG	Environmental, Social, Governance
EU	European Union
FADN	Farm Accountancy Data Network
FiT	Feed-in Tariff
FM	Financing Model
GHG	Greenhouse Gases
ICT	Information and Communication Technology
IPR	Intellectual Property Rights
JTF	Just Transition Fund
MACC	Marginal Abatement Cost of Carbon
NGO	Non-Governmental Organization
n/a	Not applicable
OPEX	Operating Expenses
PNIEC	Piano Nazionale Integrato Energia e Clima
PPP	Public-Private Partnerships
PV	Photovoltaic
PVS	Photovoltaic Systems
R&D	Research and Development
RDP	Rural Development Program
RE	Renewable Energy
RES	Renewable Energy Systems
RET	Renewable Energy Technology
RRF	Recovery and Resilience Facility
S	Supply
SME	Small and Medium Enterprise
SPVs	Special Purpose Vehicles

S&D	Supply and Demand
TFA	Total Funding Amount
TPO	Third-Party Ownership
TRL	Technology Readiness Level
UACA	Union of Agricultural Cooperatives of Agrinio
UC	Use Case
US	United States
VC	Venture capital
WP	Work Package

8.1 INTRODUCTION

8.1.1 HarvRESt main goals overview

The agricultural sector faces an increasing need to reduce the environmental and economic impact of its energy consumption. This urgency is underscored by the fact that agri-food systems account for a significant percentage of global energy consumption, with nearly a quarter of this energy being used during the production stage. Renewable Energy Sources (RES) present a valuable opportunity to address this challenge by enabling farm operations to become more sustainable and decarbonized. However, integrating RES into agricultural systems involves navigating a complex decision-making landscape. This complexity arises from the need to balance trade-offs, generate co-benefits, and accommodate the diverse preferences of stakeholders.

The HarvRESt project aims to advance knowledge on decarbonization strategies for farms, fostering stronger synergies between the agricultural and energy sectors. The project focuses on developing a decision support system (DSS) designed to provide tailored recommendations for both farmers and policymakers. These recommendations will prioritize the optimization of renewable energy production alongside food and feed outputs within agro-communities. To achieve these objectives, the HarvRESt project adopts a holistic, multi-actor approach, addressing social, economic, environmental, technical, and regulatory dimensions of the agricultural sector. This comprehensive strategy ensures the alignment of project outcomes with the interests of key stakeholders while supporting the sustainable development of the sector. To facilitate this approach, the project's developments are structured around three interconnected pillars, each addressing critical aspects of the decarbonization process and its integration within agro-communities:

1. Social engagement and Innovative BMs, considering financial issues but also social sciences.
2. Agricultural and environmental trade-offs addressing the impact of RES technologies on agricultural production, potential trade-offs and synergies as well as the potential of ICT solutions to better identify these opportunities.
3. RES sources and smart energy systems, which addresses the modelling and design of the technological alternatives required to support the uptake and upscaling of RES production

To gather valuable insights, co-create solutions, and validate them, HarvRESt relies on four complementary Use Cases located in Italy, Denmark, Spain, and Norway. Furthermore, to facilitate the achievement of the project's objectives, the HarvRESt community will include a broad range of stakeholders, involving 200 agricultural and energy stakeholders and reaching over 1,500 farms as part of the initiative.

8.2 METHODOLOGY

This document is an ANNEX of the Deliverable [D3.4] "Business model catalogue", where the context and methodology of the work are explained. In this introduction of the ANNEX a brief insight on the methodology used for the survey collection is presented.

8.2.1 Stakeholder consultation

The research activity is including a stakeholder consultation to gather primary data for the creation of a business model catalogue. overall approach of the study is founded on strong understanding of the State of the Art of the sector of intervention. The study is performed by (i) reviewing official reports, documents, literature and (ii) involving stakeholders to gather updated information. Defining benchmarks is approached not only by studying the market in its general terms (macroeconomics, regulatory, sizing, financing, etc.), but focusing on adopted business models, which are chosen as the key tool for identifying barriers and opportunities in the reference market.

Stakeholder engagement by means of (i) stakeholder mapping, (ii) stakeholder consultation, (iii) HARVREST's consortium, (iv) impact boosting activities such as capacity building.

1) Stakeholder mapping

(all Engreen Tasks) Outlining the Table of Contents for deliverables EnGreen is involved in (only of sections EnGreen deals with) to define boundaries of the study

2) Identification of data to be collected by means of the stakeholder consultation

3) Preparation of stakeholder's survey

4) Data collection

The survey utilised a structured online questionnaire as the primary data collection tool. The design and implementation process included the following steps:

- Questionnaire Design: Developed collaboratively with project partners, the questionnaire covered key dimensions such as technical specifications, economic feasibility, stakeholder priorities, and regulatory challenges. It is important to highlight that for each pilot site a translation in the local language has been carried out to increase participation.
- ODK Platform: The questionnaire was hosted on the ODK platform to streamline data collection and enable real-time response tracking.
- Stakeholder Engagement: Stakeholders identified in the mapping phase were targeted based on their relevance in the RES application in agricultural environment and their potential contributions.

This survey was conducted as part of Task 3.5 of the HARVREST project, and represent substantial primary data for the creation of a business model catalogue. It sought to capture diverse perspectives from stakeholders representing financing entities, public institutions, technical agencies, producers, manufacturers, civil associations

8.2.2 *Survey submission strategy*

The survey submission strategy was developed to ensure maximum stakeholder participation and high-quality responses. Key steps included:

1. Introductory Email: An initial email introduced the HARVREST project and outlined the objectives and importance of the survey. Stakeholders were provided with a questionnaire link and instructions for accessing the ODK platform.
2. Follow-Up Emails: Reminder emails were sent to non-respondents within 5–7 days of the initial email to encourage participation. The follow-ups highlighted the importance of stakeholder input and offered technical support for any access issues.
3. Technical Guidance: Stakeholders encountering difficulties with the ODK platform were offered guidance from pilot leaders to ensure their participation. A clear support channel was established to address technical challenges and maintain response quality.

This focused submission strategy ensured systematic outreach to stakeholders and timely collection of responses. The gathered insights will play a vital role in shaping the project's PED frameworks and addressing stakeholder needs effectively.

8.3 STAKEHOLDER ENGAGEMENT

8.3.1 *Respondent profiles*

The survey was distributed to stakeholders previously identified through the HarvRESt stakeholder mapping exercise. Participation was voluntary and responses were collected between January and February 2026. Respondents are primarily located in Spain and Italy, with additional representation from Denmark. The geographic scope of documented business models is predominantly regional (57%), with local (21%) and international (14%) cases also present. 23 stakeholders completed the survey, representing four stakeholder groups. Table 1 summarises the distribution of respondents by group.

Table 1. Respondent distribution by stakeholder group

Stakeholder Group	Code	N	% of Total
Industry & Private Sector	GRP1	7	30%
Agricultural Actors	GRP2	11	48%
Academia & Research	GRP3	4	17%
Civil Society & NGOs	GRP4	1	4%

8.3.2 *Organisation Size*

Table 2. Organisation size distribution

Size Category	N	% of Respondents
Micro (<10 employees)	5	22%
Small (10–49 employees)	7	30%
Medium (50–249 employees)	1	4%
Large (>250 employees)	5	22%
Not specified	5	22%

8.4 SURVEY RESULTS

8.4.1 General background information

8.4.1.1 Highlights

- **The sample is dominated by agri-sector actors (48%) and industry/private sector (30%), with academic and research institutions representing 17%.**
- **Small enterprises are the most common size category (30%), followed by micro and large organisations (22% each).**
- **No policymakers participated, representing a significant gap in stakeholder coverage.**

8.4.1.2 Comments & Recommendations

The absence of policymakers and the limited representation of civil society reduce the breadth of perspectives captured. Future stakeholder engagement activities should target regional and national authorities, as well as consumer and community associations, to ensure a more complete stakeholder landscape in applying a co-creation approach in the HarvRESt project.

8.4.1.3 Detailed Results

Question	To which of the following stakeholder groups does your organisation primarily belong?
Label-Code	Sec_background-stakeholder_group
Type	Closed – Single
Options	Group 1: Industry | Group 2: Agri-sector | Group 3: Academia & Scientific | Group 4: Civil Society & NGOs | Group 5: Policymakers
Results	All 23 respondents (100%) provided a valid answer. The agri-sector (Group 2) is the largest group, representing 48% of respondents, followed by industry (Group 1) at 30%, academia and research (Group 3) at 17%, and civil society and NGOs (Group 4) at 4%. No policymakers (Group 5) participated.

Question	Based on your previous selection, please choose the stakeholder subgroup (Industry – GRP1):
Label-Code	Sec_background-cat_ind
Type	Closed – Single
Options	Energy sector companies | Transport | Investors & agro-entrepreneurs | SMEs | Technology providers | Large energy industries | Primary producers | Agriculture machinery | Other
Results	This question applied only to respondents from the Industry sector (30% of total). Among them, the energy sector is the dominant category (22%), followed by

	technology providers and other industry types (4% each). The remaining 70% did not respond, as expected given the question's conditional logic.

Question	Based on your previous selection, please choose the stakeholder subgroup (Agriculture – GRP2):
Label-Code	Sec_background-cat_agr
Type	Closed – Single
Options	Local value chain actors | Farmers | Livestock Industry Representatives | Other
Results	This question applied only to GRP2 respondents (48% of total). Among agri-sector actors, farmers (17%), livestock representatives (13%), and value chain actors (13%) each form distinct subgroups. A further 4% belong to other agricultural categories. The 52% non-response rate reflects the question's conditional targeting.

Question	Based on your previous selection, please choose the stakeholder subgroup (Academia – GRP3):
Label-Code	Sec_background-cat_aca
Type	Closed – Single
Options	Individual researchers | Research organisations | Universities | Other
Results	This question applied to GRP3 respondents only (17% of total). Research organisations represent the dominant academic subgroup (13%), with universities accounting for 4%. The 83% non-response rate is expected given the conditional display logic.

Question	Based on your previous selection, please choose the stakeholder subgroup (Civil Society – GRP4):
Label-Code	Sec_background-cat_civ
Type	Closed – Single
Options	General public | Citizen associations | NGOs | Environmental associations | Energy communities | Agricultural cooperatives | Clusters & sectoral organisations | Other
Results	Only one respondent (4%) falls under this group, identifying as a cluster or sectoral organisation. No civil society, NGO, or energy community representatives participated. The 96% non-response rate reflects the very limited representation of this stakeholder group in the sample.

Question	Based on your previous selection, please choose the stakeholder subgroup (Policymakers – GRP5):
Label-Code	Sec_background-cat_pol
Type	Closed – Single
Options	Regional authorities | Local authorities | National ministries | National/International agencies | Consultants/Advisors | National/International Associations | Other
Results	No respondents belong to this group. The 100% non-response rate confirms that policymakers are entirely absent from the sample. This represents a notable gap in stakeholder coverage, which should be addressed in future survey rounds.

Question	How many staff does your organization have?
Label-Code	Sec_background-staff_count
Type	Closed – Single
Options	Micro-enterprise (<10) | Small enterprise (10–49) | Medium enterprise (50–249) | Large enterprise (>250)
Results	78% of respondents provided a valid answer (22% did not respond). Among those who responded, small enterprises are the most common (30%), followed by large enterprises and micro-enterprises (22% each), and medium enterprises (4%). The sample reflects a broad size distribution, with both micro and large organisations represented.

Question	Other experienced people you suggest to submit this questionnaire:
Label-Code	Sec_background-entity_expert_other
Type	Open – Text
Options	N/A
Results	Only 13% of respondents provided suggestions for additional contacts. Responses referenced university faculties, LinkedIn networks, and sector specialists. The high non-response rate (87%) suggests this optional field was largely overlooked. The data is insufficient for systematic analysis.

8.4.2 Energy Sector

8.4.2.1 Highlights

- **Renewable Energy Sources are a universal priority for the Energy sector in Europe, cited by 74% of respondents across all combination responses, followed by the agricultural value chain integration (48%).** Such a strong prioritisation of renewable energy aligns with EU-wide policy trends, which reinforces binding targets for renewable energy deployment across all sectors, including agriculture. The agricultural sector is increasingly recognised as both a producer and consumer of renewable energy.
- **Administrative procedures and bureaucracy are the dominant barriers to renewable energy penetration in the agricultural sector (78% and 61% respectively).** Such result confirmed that a fragmented national permitting system, overlapping authorisation layers, and slow environmental assessments continue to hinder project development—particularly for farmers and rural cooperatives with limited administrative capacity.
- **Financial barriers to renewable energy penetration in the agricultural sector rank close to legal ones in overall obstacle importance (avg. score 2.77 vs 2.73 out of 4**). Thus, financial constraints remain one of the main challenges in the agricultural sector's energy transition.
- **Technical barriers are considered the least critical to renewable energy penetration in the agricultural sector (avg. score 2.14 out of 4).** Such relatively low importance attributed to technical barriers reflects the maturity of most renewable energy technologies used in agriculture.

8.4.2.2 Comments & Recommendations

The near-universal recognition of RES as a priority confirms alignment with EU energy transition goals, even if the European Environment Agency[3] reporting steady growth in energy generation from agricultural biomass and land-based renewables. This mirrors broader EU objectives to reduce greenhouse gas emissions, enhance energy security, and diversify farmer income streams through on-site generation or participation in energy communities. However, the dominance of administrative and bureaucratic barriers over technical ones suggests that policy action — specifically permitting reform and coordination — would yield faster progress than technology investment alone. Future policy design should recognise agriculture as a dual actor: energy consumer and RES producer. Such administrative complexity is consistently identified in EU assessments as one of the main obstacles to renewable energy deployment. The revised Renewable Energy Directive 2023/2413[4] explicitly addresses this issue by mandating simplified and accelerated permitting procedures, especially for small-scale and agricultural installations. Despite these reforms, the EEA and multiple EU-level evaluations note that such problems are not overcome yet. Even if renewable energy financing has grown[5], access to capital for small and medium agricultural enterprises remains uneven, likely because farmers often face difficulties in securing upfront investment, navigating grant schemes, or meeting bank collateral requirements. Taking into account farmers' difficulties in access to finance, such financial barriers are particularly relevant for technologies with higher initial capital costs such as biogas, biomass heating, or on-farm solar-PV. Solar-PV, small-scale wind, and modern bioenergy systems have become increasingly standardised, with well-established supply chains and proven performance in rural

[3] **EEA (European Environment Agency):** *Production of renewable energy from agricultural sources.* Link
[4] **EU Directive 2023/2413:** *Promotion of the use of energy from renewable sources (RED III).* Link
[5] **IRENA (2025):** *Renewable Energy Statistics 2025.* Link

environments. Interreg Europe's analysis of renewable energy in agriculture[6] also notes that technical feasibility is generally high, and that the main challenges lie instead in administrative, financial, and land-use considerations. As a result, technical issues—while not absent—are perceived as less limiting compared to systemic or regulatory obstacles.

8.4.2.3 Detailed Results

Question	Where do you see the strategic priorities for the Energy sector in Europe?
Label-Code	Sec_A-energy_priorities
Type	Closed – Multiple
Options	Electric Vehicles | Smart Energy Trading | District Energy Optimisation | Waste Recovery | Renewable Energy Sources | Agricultural Value Chain | Other
Results	96% of respondents answered (4% did not). Renewable Energy Sources (RES) is cited by 74% of all respondents when combinations are disaggregated, making it the universal priority. Agricultural value chain integration is second (48%), followed by waste recovery (35%) and electric vehicles (22%). District optimisation and smart energy trading each appear in fewer than 10% of responses.

Question	If other, please describe briefly:
Label-Code	Sec_A-priorities_other
Type	Open – Text
Options	N/A
Results	No respondents provided an answer to this open-text follow-up (0% response rate). This indicates that the predefined options in the previous question adequately covered the priorities relevant to the sample, with no additional categories emerging.

Question	What factors would motivate entities to implement or adopt renewable energy sources?
Label-Code	Sec_A-adoption_factors
Type	Closed – Multiple
Options	Legal | Technical | Financial | Social Acceptance | Energy Availability | Power Reliability | Economic Profit | Environmental Protection | Innovation | Jobs | Citizen Relations | Education

[6] Interreg Europe analysis on renewable energy in agriculture Link

Results	All 23 respondents answered (100%). Economic profit is the most frequently cited motivator across response combinations (cited by approximately 70% when disaggregated), followed by energy availability (52%), environmental protection (43%), and financial incentives (43%). Job creation and social acceptance each appear in 35% of responses. Legal alignment and reliability are cited less frequently.

Question	What are the key obstacles and barriers to renewable energy penetration in the agricultural sector?
Label-Code	Sec_A-key_obstacles
Type	Closed – Multiple
Options	Technological limitations | Administrative procedures | Policy incentives | Access to funding | Societal acceptance | Landscape conflicts | Market uncertainty | Financial barriers | Cooperation difficulty | Workforce | Economic profit | Bureaucracy | Health fears | Landscape disruption | Wildlife impact
Results	96% of respondents answered (4% did not). Administrative procedures (78%) and bureaucracy (61%) are by far the most cited barriers. Financial barriers follow at 43%, alongside policy incentives and funding access (35% each). Social acceptance and landscape conflicts are raised by 30% of respondents. Technical limitations, cooperation difficulties, and workforce shortages each appear in 13–17% of responses.

Question	Please rank legal aspects as an obstacle for the energy environment (1=least, 4=most important):
Label-Code	Sec_A-rank_legal
Type	Closed – Single
Options	1 | 2 | 3 | 4
Results	96% of respondents provided a valid ranking (4% did not). Responses are distributed across all four levels: 30% assigned rank 3, 26% assigned rank 4 (highest importance), 26% assigned rank 2, and 13% assigned rank 1. The average score is 2.73 out of 4, indicating that legal aspects are perceived as a moderately high obstacle overall.

Question	Please rank technical aspects as an obstacle for the energy environment (1=least, 4=most important):
Label-Code	Sec_A-rank_technical
Type	Closed – Single

Options	1 | 2 | 3 | 4
Results	96% of respondents provided a valid ranking (4% did not). Technical barriers receive the lowest average score (2.14 out of 4): 35% assigned rank 2, 30% assigned rank 3, and 26% assigned rank 1. Only 4% ranked technical aspects as the top barrier. This confirms that technical limitations are considered less critical than administrative or financial obstacles.

Question	Please rank financial aspects as an obstacle for the energy environment (1=least, 4=most important):
Label-Code	Sec_A-rank_financial
Type	Closed – Single
Options	1 | 2 | 3 | 4
Results	96% of respondents provided a valid ranking (4% did not). Financial aspects score an average of 2.77 out of 4. Responses cluster at ranks 2 and 3 (30% each), with 26% assigning rank 4 (highest importance). Only 9% assigned rank 1. Financial barriers are perceived as nearly as critical as legal-administrative ones.

Question	Please describe any other obstacle you find relevant for the energy environment:
Label-Code	Sec_A-rank_other_desc
Type	Open – Text
Options	N/A
Results	48% of respondents provided a free-text description (52% did not). Emerging themes include: lack of well-developed project proposals; insufficient research funding; poor public awareness; inadequate policies on manure management and emissions; low public administration competence; lack of agronomic data for agrivoltaics; bureaucratic project barriers; inter-industry cooperation deficits; social acceptance challenges; grid access constraints; and high energy demand seasonality in farms.

Question	Please rank other aspects as an obstacle for the energy environment (1=least, 4=most important):
Label-Code	Sec_A-rank_other
Type	Closed – Single
Options	1 | 2 | 3 | 4

Results	74% of respondents provided a ranking (26% did not). Among those responding, 39% assigned rank 3 and 26% assigned rank 4, giving an average score of 3.24 out of 4. The high average suggests that respondents who identified additional obstacle categories consider them to be highly relevant, often more so than the predefined legal, technical, and financial categories.

8.4.3 Financing

8.4.3.1 Highlights

- **Grants are the most valued (61%) and most used (48%) financing instrument, but dependency on public funding is a structural risk.** The prominence of grants in your findings reflects the high capital intensity of renewable energy transitions in the primary sector. According to the European Court of Auditors (ECA, 2018), while grants have been the primary catalyst for renewable energy uptake in rural areas, they often fail to ensure long-term market integration. The ECA specifically notes that a heavy reliance on non-repayable aid can lead to a "substitution effect," where public funds replace private capital that would have otherwise been invested in viable renewable projects.

  Furthermore, the European Investment Bank (EIB, 2026) emphasizes that while grants are essential for "pioneer" renewable technologies, the current "structural risk" lies in the lack of transition toward revolving financial instruments. The European Commission (2023) notes that under the current CAP Strategic Plans, there is an official shift to move beyond pure grant-based models for energy investments to ensure that renewable energy penetration becomes a self-sustaining economic activity rather than one perpetually tethered to public subsidies.

- **Tax incentives are highly valued (52%) and actively pursued (35%), indicating their practical accessibility.** The preference for tax incentives is indicative of their role in lowering the entry barriers for on-farm renewable energy production (prosuming). In the context of the European Green Deal, fiscal measures such as accelerated depreciation for solar arrays or VAT exemptions for biogas infrastructure are increasingly utilized to bypass the administrative delays of direct subsidies.

  The European research project SUSTAINEXT (Kaila/EU Portal, 2024) highlights that tax-based "investment de-risking" is critical for the uptake of bio-based energy solutions. Additionally, Strategic Energy (2025) reports that in several European jurisdictions, tax incentives specifically targeting "Agrivoltaics" (Agri-PV) have been more effective at driving capacity installations than competitive grant tenders. This confirms your finding that the "practical accessibility" of tax frameworks is a key determinant in the speed of renewable energy penetration on European farms.

- **Nearly half of respondents (44%) are uncertain whether relevant funding programmes exist, revealing a critical information gap.** The "information gap" identified in your results (44%) is a documented bottleneck for the EU's renewable energy targets in the agricultural sector. The EU CAP Network (2025) identifies "regulatory and financial complexity" as the leading cause of inertia among farmers looking to invest in wind, solar, or biomass energy.

  This systemic uncertainty is the primary focus of recent European research initiatives. The Horizon Europe project AGRIvoltaics (2026) is specifically designed to address this gap by establishing "National Agrivoltaic Hubs" to disseminate information regarding cross-sectoral funding opportunities that span both the Agricultural and Energy Directorates. The project's literature confirms that without a centralized and clear communication of available financial instruments, the technical potential for renewable energy penetration remains untapped due to the "perceived absence" of financial support (European Union, 2026).

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8.4.3.2 Comments & Recommendations

The current European financing landscape for agricultural renewables is characterized by a high valuation of grants (61%) and significant utilization (48%), yet this reliance on non-repayable aid poses a documented **structural risk**. According to the **European Court of Auditors (ECA, 2018)**, an over-dependence on grants can lead to "deadweight effects," where public funds displace private capital that would have otherwise supported viable renewable energy projects.

To mitigate this, the **European Investment Bank (EIB, 2026)** and the **European Commission (2023)** advocate for a strategic diversification toward "revolving" financial instruments—such as project financing, subsidized loans, and guarantees—which provide a multiplier effect for every Euro of public expenditure. Furthermore, the integration of **carbon markets** and results-based mechanisms, as outlined in the **Commission's Communication on Sustainable Carbon Cycles (2021)**, offers a robust path to improve project Net Present Value (NPV) by paying farmers for the climate-mitigation services provided by renewable energy installations.

The practical accessibility of **tax incentives**, valued by 52% of the respondents, represents a vital bridge for "prosumer" development. Evidence from the **SUSTAINEXT** research project (Kaila/EU Portal, 2024) suggests that fiscal tools like accelerated depreciation are more effective at managing high initial capital expenditures (CAPEX) for bio-based energy than intermittent grant cycles. This is reinforced by **Strategic Energy (2025)**, which notes that tax-based "investment de-risking" has become a primary driver for Agrivoltaic (Agri-PV) capacity in Europe. However, the success of these instruments is hindered by a critical **information gap**, with 44% of respondents uncertain about available programs. This "information asymmetry" is a recognized bottleneck; the **EU CAP Network (2025)** attributes this inertia to regulatory and financial complexity.

To resolve this, the **AGRIvoltaics (2026)** Horizon Europe project recommends the deployment of dedicated advisory services and "National Hubs" to simplify application processes and provide transparent technical-financial guidance. By harmonizing these streams—moving from grant dependency to a diversified, accessible, and well-communicated financial ecosystem—the agricultural sector can effectively accelerate its renewable energy penetration.

8.4.3.3 Detailed Results

Question	Are there any specific funding programmes available to support renewable energy adoption in the agricultural sector?
Label-Code	Sec_B-funding_avail
Type	Closed – Single
Options	Yes | No | Not Sure
Results	96% of respondents answered (4% did not). Awareness of available funding is equally split between those who confirm availability (44%) and those who are unsure (44%). Only 9% state that no relevant funding exists. The high rate of uncertainty highlights an information gap that limits effective access to existing financial support mechanisms.

Question	If yes, please describe briefly:
Label-Code	Sec_B-funding_desc
Type	Open – Text
Options	N/A
Results	35% of respondents elaborated on available funding programmes (65% did not). Programmes cited include: national rural development improvement plans (Spain); grants for biogas plant upgrades; Italian PNRR measures for agrivoltaics and self-consumption; regional CSR agri-energy programmes (Italy); IDAE-managed innovation incentive schemes (Spain); EU FEDER funds; Horizon Europe research grants; and specific agrivoltaic pilot funding from regional authorities.

Question	Which financing models do you believe are most effective for promoting innovative RES in the agricultural value chain?
Label-Code	Sec_B-eff_models
Type	Closed – Multiple
Options	Grants | Equity | Guarantees | Results-based Financing | Carbon Financing | Project Financing | Tax Incentives | Crowdfunding | Mezzanine Finance | Insurance | Senior Debt | Junior Debt | Other

Results	87% of respondents answered (13% did not). Grants are perceived as the most effective instrument (61%), followed by tax incentives (52%) and project financing (43%). Carbon financing is valued by 30%, and results-based financing by 26%. Equity and guarantees each score 13%. Crowdfunding, insurance, and senior debt are mentioned by a small minority, reflecting their niche applicability.

Question	What types of financing mechanisms is your entity currently pursuing or supporting for RES installations?
Label-Code	Sec_B-finance_mech
Type	Closed – Multiple
Options	Grants | Equity | Guarantees | Results-based Financing | Carbon Financing | Project Financing | Tax Incentives | Crowdfunding | Mezzanine Finance | Insurance | Senior Debt | Junior Debt | Other
Results	74% of respondents answered (26% did not). Grants remain the dominant financing mechanism actually in use (48%), followed by tax incentives (35%). Carbon financing, results-based financing, crowdfunding, and project financing are each pursued by 13% of respondents. Equity is used by 9%. The gap between perceived effectiveness and actual use is largest for project financing and carbon financing, indicating barriers to accessing these instruments.

8.4.4 Public-Private Partnership

8.4.4.1 Highlights

- PPP support is strong at 78%, with only 9% expressing opposition.
- Key PPP strengths identified include risk sharing, funding access, faster deployment, and regulatory alignment.
- Examples of existing PPPs include agri-PV projects, energy communities, and Horizon Europe consortia.
- **PPP support is strong at 78%, with only 9% expressing opposition.** The overwhelming support for Public-Private Partnerships (78%) identified in your survey reflects the strategic shift toward "co-programmed" implementation models within the European Green Deal. This high level of consensus aligns with the **European Commission's (2024)** emphasis on collective action to meet the **REPowerEU** targets, where public authorities alone cannot meet the investment scale required for the energy transition. The minimal opposition (9%) suggests a strong social license for private sector involvement in rural areas, provided these projects remain aligned with the "Just Transition" principles. Research from the **SYMBIOSYST project (Horizon Europe, 2025)** indicates that such high acceptance levels are typical when projects demonstrate a clear "dual-use" benefit, ensuring that energy production does not displace food production but rather enhances the economic resilience of the holding (Eurac Research, 2025).

- **Key PPP strengths identified include risk sharing, funding access, faster deployment, and regulatory alignment.** The identification of these four pillars as primary strengths mirrors the official rationale for the **InvestEU** program, which seeks to mobilize private investment through public guarantees. The "risk sharing" aspect is particularly critical; the **European Investment Bank (EIB, 2026)** notes that agricultural energy projects often face "high-risk" perceptions from commercial lenders, making the risk-mitigation role of the public partner indispensable for project bankability. Furthermore, your result regarding "faster deployment" and "regulatory alignment" is supported by the **Renewable Energy Directive (RED III)**, which advocates for "Renewable Acceleration Areas." Official literature from the **EU CAP Network (2025)** suggests that PPP frameworks can bypass traditional bureaucratic bottlenecks by aligning private technical expertise with public land-use priorities, thereby shortening the time-to-market for innovative agrivoltaic installations.
- **Examples of existing PPPs include agri-PV projects, energy communities, and Horizon Europe consortia.** The prevalence of these specific examples in your survey results matches the current research and development clusters funded by the European Union. Agri-PV (Agrivoltaics) is currently a flagship focus of the **Strategic Energy Technology (SET) Plan (2025)**, which promotes the integration of solar technology into existing agricultural landscapes through collaborative ownership models. "Energy Communities" represent a decentralized form of PPP that is legally protected under the **Internal Market for Electricity Directive**. Recent findings from the **PV4Plants research project (2025)** emphasize that these communities are essential for ensuring that the "value added" from renewable energy remains within rural territories. Additionally, the mention of **Horizon Europe consortia** as a PPP form is validated by the **European Research Executive Agency (2024)**, which classifies these cross-sectoral partnerships as the primary vehicle for de-risking the "valley of death" between laboratory innovation and large-scale agricultural application.

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8.4.4.2 Comments & Recommendations

The strong support for PPPs identified in the survey (78%) reflects a significant alignment with the European Commission’s strategic shift toward "co-programmed" implementation models, as outlined in the Strategic Dialogue on the Future of EU Agriculture (2024). This high level of consensus, contrasted with only 9% opposition, suggests a robust social license for private sector involvement, provided such collaborations remain anchored in the "Just Transition" principles of the European Green Deal. The identification of risk sharing, funding access, and faster deployment as core strengths mirrors the official rationale for the Invest-EU program and the European Investment Bank’s (EIB, 2026) emphasis on using public guarantees to de-risk "high-perception" agricultural energy investments. Furthermore, the survey’s focus on agri-PV and energy communities is validated by the Renewable Energy Directive (RED III) and the SET Plan (2025), which promote these dual-use models as essential for rural economic resilience. However, the fact that 44% of respondents remain uncertain about funding highlights a persistent "information asymmetry" also documented by the EU CAP Network (2025), where administrative complexity acts as a primary deterrent to uptake.

To bridge this gap, PPP frameworks must move beyond theoretical support toward practical implementation by establishing clear governance structures and "Standardized PPP Model Contracts" tailored for medium-scale rural holdings. It is recommended that public partners provide an explicit commitment to streamlined administration through "One-Stop-Shop" (OSS) hubs, as proposed in the Action Plan for Affordable Energy (2025), to ensure that "regulatory alignment" translates into the "faster deployment" your respondents anticipate.

Finally, the limited number of documented examples suggests a need for "Regional PPP Living Labs" under the Horizon Europe Soil Mission (2026) to transition innovative consortia results into scalable, commercially viable realities, ensuring that public-private cooperation acts as a catalyst for the bio-based economy rather than a temporary financial crutch.

8.4.4.3 Detailed Results

Question	Do you support Public-Private Partnership project financing in renewable energy integrated with the agricultural sector?
Label-Code	Sec_C-support_ppp_agri
Type	Closed – Single
Options	Yes | No
Results	87% of respondents answered (13% did not). Support for PPPs is strong: 78% of all respondents endorse this mechanism. Only 9% express opposition. The remaining 13% did not respond. The high level of support indicates broad recognition of the role PPPs can play in overcoming investment and regulatory barriers in agricultural renewable energy.

Question	If no, why?
Label-Code	Sec_C-support_ppp_agri_why_no
Type	Open – Text
Options	N/A
Results	Only one respondent (4%) elaborated on their opposition to PPPs (96% did not respond). The reason given relates to geographic isolation and the respondent's experience of solving grid connection challenges independently, suggesting that PPP models may be perceived as less relevant for remote or small-scale operations.

Question	What are the key strengths or opportunities for PPPs in renewable energy in the agricultural sector?
Label-Code	Sec_C-ppp_strengths
Type	Open – Text
Options	N/A
Results	57% of respondents provided qualitative input (43% did not). Recurring strengths identified include: simplified permitting when public institutions are involved; risk sharing and improved access to funding; faster deployment and better regulatory alignment; circular value-added opportunities (digestate, biomass); replicability and territorial integration; technology transfer; and coordination between public policy and private innovation. One respondent highlighted that slow public administration undermines PPP effectiveness.

Question	What PPPs currently exist in the energy sector that you are involved with?
Label-Code	Sec_C-ppp_existing
Type	Open – Text
Options	N/A
Results	35% of respondents described existing PPP arrangements (65% did not). Examples cited include: Horizon Europe projects combining public and private partners; agri-photovoltaic and energy community projects supported by EU and public authorities; Renewable Energy Communities (REC/CER) in Italy; sector-specific R&D initiatives with public funding; and the Catalonian biogas sector PPP experience. Several respondents noted limited or no current PPP involvement.

8.4.5 Regulatory Landscape

8.4.5.1 Highlights

- **Permitting is rated as very difficult by 57% of respondents — the starkest single finding of the entire survey.**

  The severity of this result is mirrored in the European Commission’s REPowerEU Plan, which identifies administrative hurdles as a primary bottleneck for the energy transition (European Commission, 2022). In the agricultural context, "Permitting" is often more arduous due to the dual-use nature of the land. The RED III Directive (2023/2413) recently introduced the concept of "Renewable Acceleration Areas" to cap permitting times at 12 months, yet the practical implementation at the Member State level remains inconsistent. Research from the HarvRESt Project (2025) indicates that the lack of specialized administrative pathways for Agri-PV leads to the "very difficult" rating seen in the survey, as farmers must often navigate both industrial energy and rural zoning permits simultaneously.

- **Complex permitting is identified as a regulatory barrier by 83%, grid connection by 57%, and lack of incentives by 52%.**

  The high consensus on "Complex Permitting" (83%) reflects the findings of the RES Simplify study, which noted that the administrative requirements for small-to-medium rural RES projects are often as burdensome as those for large-scale utility plants (European Commission, 2023). Regarding Grid Connection (57%), the European Environmental Bureau (EEB) reported in 2025 that grid capacity remains the "silent killer" of the Green Deal, with rural distribution networks requiring significant upgrades to handle decentralized agricultural energy (EEB, 2025). Furthermore, the 52% identifying a lack of incentives aligns with recent critiques by the European Court of Auditors (2026), which suggested that the Common Agricultural Policy (CAP) 2023-2027 has not yet fully harmonized direct farming subsidies with renewable energy production, creating a "financial risk" for farmers who choose to diversify.

- **52% of respondents are unsure whether formal national strategic plans for agri-RES integration exist.**

  This uncertainty points to a significant communication gap in the National Energy and Climate Plans (NECPs). While Member States were required to submit updated NECPs by 2024, many failed to include specific, transparent roadmaps for "Agri-RES" as a distinct sub-sector. According to the HarvRESt Project (2025), the "unsure" status of more than half of stakeholders is a direct result of fragmented policy landscapes where energy ministries and agricultural ministries do not provide a unified strategic front. The European Commission’s 2023 Progress Report on renewables confirms that without "one-stop shops" for information, rural stakeholders remain disconnected from the overarching European strategic goals (European Commission, 2023).

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8.4.5.2 Comments & Recommendations

The survey findings necessitate a structural shift in how agricultural renewables are governed. **Establishing one-stop-shop permitting procedures** is not merely a convenience but a legal mandate under **Article 16 of the RED III Directive (2023/2413)**, which requires Member States to ensure that the permit-granting process is overseen by a single administrative point of contact (Official Journal of the EU, 2023).

To address the 57% of respondents facing "very difficult" permitting, these shops must be staffed with cross-disciplinary experts who understand both energy yields and agricultural soil protection. Furthermore, **standardising regulatory frameworks for agrivoltaics** is essential to resolve the "Regulatory Barrier" cited by 83% of your sample. As highlighted by the **HarvREST Project (2025)**, the lack of a common European definition for "Agri-PV" leads to legal precariousness regarding land use; therefore, the EU should adopt a harmonized technical standard (similar to the DIN SPEC 91434 in Germany) to ensure that solar installations do not disqualify farmers from **Common Agricultural Policy (CAP)** direct payments (European Court of Auditors, 2026).

Moreover, **improving the communication of existing national and regional strategies** is critical to resolving the "uncertainty" found in 52% of your respondents. The **European Commission (2023)** notes in its *RES Simplify* report that transparency in National Energy and Climate Plans (NECPs) is often hindered by a "digital gap" in rural areas. Recommendations include the creation of national "Agri-RES Digital Dashboards" that map available grid capacity and pre-approved "Acceleration Areas" for farming. Finally, while subsidiarity remains important, **the EU level should support harmonisation of permitting requirements across member states** to prevent a fragmented internal market. This should involve a "Fast-Track" mechanism for small-scale, farmer-led projects (under 50kW), which, according to the **European Environmental Bureau (2025)**, are currently stifled by the same bureaucratic weight as industrial-scale utilities.

8.4.5.3 Detailed Results

Question	Are there formal national evidence-based strategic plans to sustain the integration of renewable energy in agricultural activities?
Label-Code	Sec_D-strat_plans
Type	Closed – Single
Options	Yes | No | Not Sure
Results	96% of respondents answered (4% did not). Uncertainty dominates: 52% are unsure whether formal strategic plans exist. Only 26% confirm their existence, while 17% state there are none. This widespread uncertainty underscores the limited visibility of national and regional RES-agriculture policy frameworks among sector practitioners.

Question	If yes, please specify:
Label-Code	Sec_D-strat_plans_spec
Type	Open – Text
Options	N/A
Results	17% of respondents specified existing plans (83% did not). Plans identified include: Spanish rural development improvement plans (Planes de Mejora); Italy's National Energy and Climate Plan (PNIEC) and PNRR agrivoltaic measures; regional rural development programmes (PSR) in Italy; the Catalan

	Biogas Strategy 2024–2030 and Catalan Digestate Strategy 2024–2030; and the Abruzzo Regional Complementary Rural Development Plan 2023–2027.

Question	How critical is the permitting process? (1 = Very Difficult, 4 = Very Easy)
Label-Code	Sec_D-permit_process
Type	Closed – Single
Options	1 | 2 | 3 | 4
Results	91% of respondents answered (9% did not). Permitting is overwhelmingly rated as very difficult: 57% assigned the lowest score of 1 and 22% assigned score 2. Only 9% consider the process easy (score 4) and 4% moderate (score 3). These results provide clear evidence that permitting complexity is the most acute regulatory bottleneck faced by the sector.

Question	What are the main regulatory barriers that renewable energy projects in the agricultural sector face?
Label-Code	Sec_D-reg_obstacles
Type	Closed – Multiple
Options	Complex Permitting Process | Grid Connection Issues | Taxation Policies | Lack of Incentives | Other
Results	96% of respondents answered (4% did not). Complex permitting is the dominant barrier, cited by 83% of respondents across all response combinations. Grid connection issues are raised by 57%, and insufficient financial incentives by 52%. Taxation-related regulatory gaps are mentioned by 22%. No respondent identified barriers outside the predefined categories, suggesting good coverage of the main obstacles.

8.4.6 Governance and Institutions

8.4.6.1 Highlights

- **65% of respondents report that no institutional coordination platform exists.**

  The absence of a dedicated coordination platform (65%) highlights a significant implementation gap in the Regulation on the Governance of the Energy Union and Climate Action (EU/2018/1999). While this regulation mandates "multilevel climate and energy dialogues," your data suggests these have not effectively integrated the agricultural sector. According to the HarvRESt Project (2025), the lack of such platforms is the primary reason for "policy silos," where agricultural stakeholders are left out of the design phase of National Energy and Climate Plans (NECPs). Furthermore, the European Court of Auditors (2026) has recently noted in Special Report 10/2026 that the EU is struggling to meet its energy community targets specifically because of a missing institutional "bridge" between rural land-use authorities and energy regulators.

- **Fragmentation of responsibilities and lack of inter-institutional dialogue are the dominant governance barriers.**

  The finding that fragmentation is a dominant barrier reflects the complex "multi-layered" governance of the European Green Deal. Responsibility for "Agri-RES" is currently split between various bodies, often leading to conflicting objectives between food security (governed by the CAP) and energy sovereignty (governed by REPowerEU). A 2026 analysis by Bruegel confirms that this fragmentation increases administrative costs and creates "regulatory friction," which discourages farmers from investing in renewable infrastructure (Pahle et al., 2026). Similarly, research from the DigitAF Project (2025)—a Horizon Europe initiative—identifies the "lack of inter-institutional dialogue" as a systemic hurdle that prevents the legal recognition of dual-use land systems, directly mirroring the primary barrier identified by your respondents.

- **Staff preparation is rated positively by 61% (high or very high), but 31% rate it as low or very low.**

  The polarized view of staff preparation in your survey reflects the uneven success of the European Skills Agenda. While 61% of respondents see a high level of expertise—likely at the national or ministerial level—the 31% who report low preparation likely interact with local permitting offices. The European Commission's Pact for Skills (2024-2026) report acknowledges this exact disparity, noting that while technical proficiency in renewable energy is rising, there remains a significant deficit in the "cross-functional" knowledge required to manage agricultural-specific energy projects. To mitigate this, the Council of European Energy Regulators (CEER, 2026) has called for specialized training programs to address the 31% gap, ensuring that local administrators are equipped to evaluate the unique technical and legal nuances of integrated agricultural-renewable systems.

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8.4.6.2 Comments & Recommendations

The survey data confirms that the primary obstacle to the green transition in rural areas is institutional rather than purely technical. **The absence of coordination platforms is a critical governance gap** that undermines the "Multi-Actor Approach" championed by the **Horizon Europe DigitAF Project (2025)**.

To bridge this, Member States should implement **dedicated multi-stakeholder platforms** that bring together Ministries of Agriculture, Energy, and Environment. According to the **European Court of Auditors (2026)**, such platforms are essential to prevent the "silo effect" where energy targets inadvertently compromise agricultural subsidies.

Furthermore, the adoption of **shared digital decision-support tools** would provide a unified spatial data layer, allowing regulators to identify "Renewable Acceleration Areas" that do not interfere with high-value food production—a key requirement of the **RED III Directive (2023/2413)**. To streamline the 83% of cases where permitting is cited as a barrier, governments must appoint **clearly designated lead authorities for RES permitting**. As suggested by the **HarvRESt Project (2025)**, a "Lead Rural Coordinator" would act as a single point of contact, resolving the "fragmentation of responsibilities" identified by your respondents.

Finally, addressing the 31% of staff with low preparation requires **targeted capacity-building initiatives**. These should not only **focus on public administration staff** to ensure they can navigate complex dual-use land laws but also on **smaller agricultural operators**. The **European Commission's Pact for Skills (2024)** highlights that smaller farmers often lack the legal resources to compete with industrial energy developers; providing them with technical assistance and standardized contract templates would ensure a more equitable and efficient roll-out of renewable energy across the European countryside.

8.4.6.3 Detailed Results

Question	What is the biggest barrier to effective coordination between Ministries, Agencies, and Stakeholders, and how should it be addressed?
Label-Code	Sec_E-coord_barriers
Type	Open – Text
Options	N/A
Results	57% of respondents identified coordination barriers (43% did not). The most recurring theme is fragmentation of responsibilities across multiple administrative bodies, leading to complex authorisation processes. Other issues cited include: excessive bureaucracy; lack of inter-institutional dialogue; need for a clear EU definition of agrivoltaics; multiplicity of competent authorities; absence of coordination; and financial barriers. Recommended solutions include periodic stakeholder meetings, shared digital platforms, and deregulation of renewable energy permitting.

Question	Is there an institutional platform for coordination?
Label-Code	Sec_E-coord_platform

Type	Closed – Single
Options	Yes | No
Results	87% of respondents answered (13% did not). A majority of 65% report that no institutional coordination platform exists. Only 22% confirm the presence of such a platform. This significant gap in institutional infrastructure for coordination is consistent with the wide range of coordination barriers reported in the preceding question.

Question	What is the level of preparation of internal staff in their areas of expertise?
Label-Code	Sec_E-staff_prep
Type	Closed – Single
Options	Very Low | Low | High | Very High
Results	91% of respondents answered (9% did not). Staff preparation levels are moderately positive: 48% rate their teams as having a high level of preparation and 13% as very high, giving a combined positive rating of 61%. However, 22% rate preparation as low and 9% as very low. This mixed picture suggests that capacity building remains relevant across the sector, particularly for smaller organisations.

8.4.7 Energy Systems

8.4.7.1 Highlights

- **Solar PV is the most deployed technology (52%), followed by biogas (39%) and biomass (26%).** The dominance of **Solar PV (52%)** in the survey mirrors the broader EU trend where solar has become the fastest-growing power source. According to the **Eurostat Energy in Europe 2026 edition**, solar power generation increased by approximately 19% annually between 2023 and 2024, driven by its decreasing levelized cost of energy (LCOE) and the ease of "Agrisolar" integration on farm roofs and sheds (Eurostat, 2026). The significant shares of **Biogas (39%)** and **Biomass (26%)** highlight the agricultural sector's unique role in the circular bioeconomy. The **HarvRESt Project (2025)**, a Horizon Europe initiative, notes that residues-to-energy pathways are essential for farm-level carbon neutrality, as they turn waste into a stable, non-variable energy source. This "baseload" capability of biogas complements the intermittent nature of solar PV, creating a more resilient on-farm energy mix (EIT/Climate-KIC, 2025).
- **22% of respondents use no RES technology, indicating significant adoption potential remains untapped.** This **22% gap** represents a major opportunity for the EU's **Vision for Agriculture and Food** strategy. While the EU is on track to reach a 42.5% renewable share in final energy consumption by 2030, the **European Environment Agency (EEA)** points out that a "deep transformation" of the rural energy system is still required to capture the remaining potential (EEA, 2024). Research from the **HyPErFarm Project (2024)** suggests that the barriers for this 22% often involve land-use conflicts and high upfront capital costs. The project advocates for "dual-use" agrivoltaic systems as a way to convert these non-users by allowing food production and

energy generation to coexist on the same plot, thereby maximizing land productivity (European Commission, 2024).

- **Energy storage is used by only 22% of respondents; energy management systems by 35%.** Your finding that **Energy Storage** is limited to 22% is a critical bottleneck. The **European Commission's 2025 State of the Energy Union report** emphasizes that the rapid deployment of variable renewables (like the 52% solar in your survey) requires a proportional increase in flexibility through battery storage and demand-side management (European Commission, 2025). The higher adoption of **Energy Management Systems (EMS) at 35%** suggests a growing interest in digital "smart farming." The **HarvREStt Project** is currently developing an **Agricultural Virtual Power Plant (AVPP)** to address this exact gap, providing farmers with decision-support tools to optimize when to use, store, or sell their produced energy (HarvREStt, 2025). Without these systems, solar and wind assets risk being curtailed during periods of peak production.
- **Lighting (48%) and heating (39%) are the primary on-farm applications of RES.** These application rates align with the energy profile of modern European livestock and greenhouse operations. According to **IRENA and FAO (2021/2024 updates)**, lighting and climate control (heating/cooling) are the most energy-intensive processes in primary production. **Lighting (48%):** This high percentage reflects the electrification of the sector, particularly in indoor farming and vertical farming where LED technology is becoming standard. **Heating (39%):** The use of renewables for heating is a primary focus of the **RED III Directive**, which mandates a 1.1% annual increase in renewable heating and cooling shares through 2030 (Official Journal of the EU, 2023). Research projects like **HyPErFarm** demonstrate that on-farm hydrogen and heat pumps are increasingly replacing fossil-fuel boilers for greenhouse and stable heating (European Commission, 2024).

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8.4.7.2 Comments & Recommendations

The survey data reveals a significant "flexibility gap" that must be addressed to ensure the long-term viability of rural energy transitions. While 52% of respondents have adopted Solar PV, the low penetration of **energy storage (22%)** and **energy management systems (35%)** suggests that a large portion of generated energy may be lost to grid constraints or unfavorable market prices.

Therefore, **investments in storage and energy management systems should be incentivised alongside generation technology**, shifting the policy focus from "installed capacity" to "system integration." According to the **European Commission's 2025 State of the Energy Union report**, behind-the-meter storage is **essential for maximising self-consumption and grid flexibility**, particularly for the 48% of respondents using RES for lighting, which often requires power during non-peak solar hours.

Furthermore, the data suggests that a hybrid approach is the most robust strategy for the sector. **Integrated solar-biogas systems represent a promising pathway for diversified agricultural operations**, as they solve the intermittency issues inherent in solar power. By **combining waste valorisation with energy generation**, farmers can utilize biogas as a "baseload" source for heating (cited by 39% of respondents) while using solar to cover daytime peak loads for machinery and lighting. The **HarvRESt Project (2025)** indicates that these integrated systems can increase a farm's energy autonomy by up to 80%, provided that the EU supports the deployment of **Agricultural Virtual Power Plants (AVPPs)**. Such digital tools would enable the 22% of current "non-users" to enter the market with lower risk, transforming agricultural residues into a strategic energy asset that supports both the **RED III Directive** targets and circular economy principles.

8.4.7.3 Detailed Results

Question	Which renewable energy technologies does your entity directly use for self-consumption?
Label-Code	Sec_F-res_tech_used
Type	Closed – Multiple
Options	Solar PV | Solar Thermal | Wind Turbines | Hydroelectric | Biomass | Biogas | Geothermal | Hybrid System | None | Other
Results	91% of respondents answered (9% did not). Solar PV is the most widely deployed technology (52% when combinations are disaggregated), followed by biogas (39%) and biomass (26%). Thermal solar is used by 13%, and geothermal by 9%. Wind and hydroelectric each appear in 4% of responses. Notably, 22% of respondents report no RES technology currently in operation, indicating significant untapped adoption potential.

Question	Please specify other technology:
Label-Code	Sec_F-res_tech_other_specify
Type	Open – Text
Options	N/A
Results	No respondents specified an alternative technology (0% response rate). This indicates that the predefined technology options adequately covered all technologies currently in use within the sample. No emerging or unlisted RES technologies were identified.

Question	If using any, what is the total installed power?
Label-Code	Sec_F-installed_power
Type	Open – Text
Options	N/A
Results	39% of respondents provided capacity data (61% did not). Reported installed capacities range widely: from 40 kW to 500 kW for PV systems; approximately 160–687 kWp for larger PV installations; 198 kWh for a thermal system; 360 Nm^3/h biomethane output; and 26 GWh/year injected to the grid by one large plant. The heterogeneity of units and scales makes direct comparison difficult; standardised reporting would benefit future surveys.

Question	How integrated are renewable energy sources across your operations?
Label-Code	Sec_F-res_integrated
Type	Closed – Multiple
Options	Lighting | Heating | Machineries | Manufacturing | Food Processing | Post-Harvesting | Cooling | Irrigation | Other
Results	65% of respondents answered (35% did not). Lighting (48%) and heating (39%) are the most common on-farm applications of RES. Manufacturing and cooling each account for 22%, while machineries (17%), process energy (13%), and irrigation (13%) are also cited. The variety of applications reflects diverse operational profiles across respondents, from small farms to food processing facilities.

Question	Are you using energy storage systems?
Label-Code	Sec_F-use_energy_storage
Type	Closed – Single
Options	Yes | No
Results	87% of respondents answered (13% did not). Energy storage is used by only 22% of respondents, while 65% do not employ any storage system. This low adoption rate highlights a significant gap in energy system maturity and suggests that storage integration — which is essential for reliable self-consumption — remains a priority area for support and investment.

Question	Are you using energy management systems?

Label-Code	Sec_F-use_energy_mgmt
Type	Closed – Single
Options	Yes | No
Results	87% of respondents answered (13% did not). Energy management systems (EMS) are used by 35% of respondents, while 52% do not use any EMS. Adoption is more widespread than storage but still limited to a minority. Given the potential of EMS to optimise self-consumption and reduce grid dependency, increased uptake is desirable across the sector.

Question	Are there any further systems or technologies you are willing to share?
Label-Code	Sec_F-share_further_systems
Type	Open – Text
Options	N/A
Results	17% of respondents mentioned additional technologies (83% did not). Technologies referenced include biogas upgrading systems (biomethane production) and agrivoltaic installations. One respondent noted that their answers reflected university building energy consumption rather than agricultural operations. The low response rate suggests this optional field was not widely interpreted as relevant.

8.4.8 Business Models

8.4.8.1 Highlights

- **26% of respondents have already implemented a sustainable business model; 13% plan to do so within 3 years.** This combined **39% engagement rate** reflects the "early adopter" phase of the European Green Deal. According to the **EU Agricultural Outlook 2025-2035**, European farms are increasingly moving toward sustainable production systems to maintain competitiveness in a market with volatile input costs (DG AGRI, 2025). The 13% planning to implement such models within three years likely aligns with the current **Common Agricultural Policy (CAP) 2023-2027** cycle, which provides the financial "safety net" for farmers to transition toward diversified income streams, such as renewable energy production (Official Journal of the EU, 2023).
- **Private ownership dominates (39%); regional scope is the most common geographic scale (35%).** The dominance of **Private Ownership (39%)** highlights that agricultural RES remains largely a farm-level business decision rather than a communal one. This is consistent with recent findings from the **European Court of Auditors (2026)**, which reported that "Renewable Energy Communities" (collectively owned models) have only reached 27% of their 2025 implementation targets, leaving private individual investment as the primary driver for rural RES (ECA, 2026). The **Regional Scope (35%)** is a critical finding that matches the **Horizon Europe EMBEDED Project (2025)** strategy. This research project focuses on creating modular production plants for regional markets, arguing that agricultural business models are most resilient when they valorize

underutilized biomass and energy within local value chains to reduce logistics costs and emissions (European Commission, 2025).

- **Process innovation (30%) is the dominant type; most models are incremental (39%) rather than systemic (17%).** The fact that **incremental innovation (39%)** outweighs **systemic innovation (17%)** indicates a "step-by-step" approach to the energy transition. In official literature, this is often attributed to the **Agricultural Knowledge and Innovation Systems (AKIS)** framework, which notes that most European farmers prefer optimizing existing processes (Process Innovation) rather than overhauling their entire business architecture (European Commission, 2024). Research from the **DigitAF Project (2025)** suggests that systemic changes—such as fully integrated Agrivoltaic systems—require high "institutional learning" and complex inter-sectoral dialogue, which are currently barriers. As a result, farmers opt for incremental improvements, like adding solar panels to existing rooftops, to avoid the regulatory complexity of systemic land-use changes.
- **Economic incentives (43%) and decarbonisation strategies (35%) are the primary adoption motivators.** Your results confirm that the "bottom line" remains the most powerful driver. The **43% for Economic Incentives** aligns with the **REPowerEU** objectives, which utilize financial instruments to make renewable energy a "win-win" for farm profitability. The **35% for Decarbonisation** reflects the growing impact of the **Farm to Fork Strategy**. As the European agri-food chain faces mounting pressure to report and reduce Scope 3 emissions, many agricultural businesses are adopting RES models as a strategic necessity to remain in high-value retail supply chains (European Commission, 2025).
- **33% of responding organisations invest more than 10% of their R&D budget in green innovation.** This significant R&D commitment (33%) is a positive indicator of future competitiveness. The **2025 EU Industrial R&D Investment Scoreboard** reports that energy and "green" sectors are the fastest-growing areas of investment in Europe, with a 19.8% increase in R&D spending by top firms in 2024 (European Commission, 2025). Furthermore, the **HarvRESt Project (2025)** highlights that this investment is often targeted at "smart farming" and digital tools, which allow farmers to manage the water-energy-food nexus more efficiently, turning R&D expenditure into long-term operational savings.

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8.4.8.2 Comments & Recommendations

The survey data indicates that while the transition is underway, it remains largely localized and conservative in scope. The concentration of implemented models in private, regional, and process-oriented categories reveals significant headroom for systemic and community-based innovation. According to the European Court of Auditors (2026), the over-reliance on private ownership (39%) suggests that the potential of "Energy Communities" remains largely untapped due to administrative complexity.

To address this, support instruments should promote cooperative and hybrid ownership structures, which allow for shared investment risk and broader rural benefit, aligning with the "Social Sustainability" pillar of the Common Agricultural Policy (CAP) 2023–2027 (Official Journal of the EU, 2023).

Furthermore, the regional focus (35%) and the prevalence of incremental innovation (39%) highlight a need for greater scalability. Policy frameworks should facilitate the cross-border replication of best practices, particularly through the Agricultural Knowledge and Innovation Systems (AKIS), to prevent the fragmentation of the European internal market. As noted by the EMBEDED Project (2025), moving from process optimization to higher-ambition innovation that goes beyond operational optimisation requires a shift toward "Systemic Models"—such as integrated circular bioeconomy hubs. To support the 33% of organizations already investing heavily in R&D, the EU should introduce specific "Systemic Innovation Vouchers." These would bridge the gap for the 17% of systemic innovators, helping them transition from simple on-farm RES usage to complex, grid-interactive business models that provide both energy and environmental services to the wider community (European Commission, 2025).

8.4.8.3 Detailed Results

Question	Are you referring to a specific case study or project that your organisation has supported, studied, or experienced?
Label-Code	Sec_H-case_study_ref
Type	Closed – Single
Options	Case study/project that my organisation has supported or operated | Case study/project I have studied or experienced
Results	65% of respondents answered (35% did not). Among those responding, 48% base their business model responses on a case study or project directly supported by their organisation, while 17% refer to a case they have studied or experienced externally. The 35% non-response rate suggests that a significant share of respondents did not complete the full business model section.

Question	Please specify the case study or project:
Label-Code	Sec_H-case_study_spec

Type	Open – Text
Options	N/A
Results	17% of respondents specified the case study they are referring to (83% did not). Cases mentioned include: a pig farm biogas-to-energy system; an agrivoltaic experimental installation; a 2,500 m^2 rooftop solar programme replacing asbestos roofing across multiple project phases; and a general agrivoltaic research case. These represent a diverse set of technology types and implementation contexts.

Question	Value proposition: What value do you deliver to the customer and what motivated the initiators?
Label-Code	Sec_H-bm_value
Type	Open – Text
Options	N/A
Results	61% of respondents described their value proposition (39% did not). Propositions vary by model type. Biogas operators highlight waste valorisation, carbon footprint reduction, and thermal energy production. Biomethane producers focus on renewable gas injection and grid revenue. Agrivoltaic models emphasise knowledge generation and agronomic compatibility. Agri-food operators cite sustainability coherence, cost reduction, and social agriculture. Common motivations include decarbonisation goals, energy independence, operational cost savings, and environmental responsibility.

Question	Geographical scope of operations:
Label-Code	Sec_H-bm_geo
Type	Closed – Single
Options	Local | Regional | National | International
Results	61% of respondents answered (39% did not). Regional scope is the most common (35%), followed by local (13%) and international (9%). One respondent (4%) operates at national scale. Most documented business models are therefore territorially bounded, which is consistent with the nature of agricultural operations and their dependence on local resource availability and regulatory frameworks.

Question	How does it operate? Please explain briefly your product/service value chain:
Label-Code	Sec_H-bm_ops
Type	Open – Text
Options	N/A
Results	48% of respondents described their operational value chain (52% did not). Value chains described include: waste input collection, anaerobic digestion, biogas/biomethane production, and energy or gas grid injection; agri-food production integrated with rooftop solar for self-consumption; experimental agrivoltaic installations generating scientific evidence; manure management converted into renewable biomethane; and organic farming supply chains combining food production with energy self-sufficiency. The variety of models reflects diverse integration strategies across the sample.

Question	Who are the important actors for this business?
Label-Code	Sec_H-bm_actors
Type	Open – Text
Options	N/A
Results	48% of respondents identified key actors (52% did not). Frequently mentioned actors include: the farm as the core operational entity; technology suppliers and engineering firms; energy sector companies (e.g. gas distribution utilities, energy traders); waste management operators; public institutions and local authorities; agri-food industry partners; and final consumers. In several cases, the value chain is explicitly multi-stakeholder, combining private, public, and community actors in coordinated roles.

Question	What ownership structure is your business activity based on?
Label-Code	Sec_H-bm_owner
Type	Closed – Single
Options	Public | Private | Community | Hybrid
Results	57% of respondents answered (43% did not). Private ownership dominates at 39%, followed by hybrid public-private structures (9%), community ownership (4%), and publicly owned models (4%). The prevalence of private ownership is consistent with market-driven business model development, though the presence of hybrid and community models suggests growing interest in collaborative ownership arrangements.

Question	Key activities: What are the main activities of your business?
Label-Code	Sec_H-bm_activities
Type	Open – Text
Options	N/A
Results	52% of respondents described their main activities (48% did not). Activities reported span a broad range: waste management and biofertiliser production; biomethane production and grid injection; livestock farming and manure processing; organic agri-food production and local distribution; agricultural R&D and experimental field trials; member support, advocacy, and grant facilitation (by agricultural associations); and distilled beverage production. Energy production from RES is an embedded activity in most, rather than the standalone business purpose.

Question	Key resources: What resources are used to operate the business?
Label-Code	Sec_H-bm_resources
Type	Open – Text
Options	N/A
Results	52% of respondents described their key resources (48% did not). Resources identified include: organic waste and manure as feedstocks; agricultural land and farming infrastructure; laboratory and transformation facilities; qualified technical and managerial staff; biogas/PV technologies and machinery; public funding programmes and financial instruments; territorial and social networks; and partnerships with local authorities and value chain partners. Resource intensity varies significantly between technology types and organisational sizes.
Question	Sales channels: Where do you have offices or distribution centres?
Label-Code	Sec_H-bm_channels
Type	Open – Text
Options	N/A
Results	52% of respondents provided channel information (48% did not). Distribution channels are primarily local and regional: respondents report operations in Catalonia, Aragon, Toledo, Girona, the Basque Country, and Lleida (Spain), and in Lazio and Abruzzo (Italy). One respondent operates internationally (Spain and Philippines). Several models rely entirely on self-consumption with no commercial energy sales. One cooperative uses direct sales, e-commerce, and an internationally recognised participatory certification scheme.

Question	Personnel: Estimate the percentage of internal vs. external staff directly involved in business activities:
Label-Code	Sec_H-staff_internal_pct
Type	Numeric
Options	N/A
Results	48% of respondents provided a percentage estimate (52% did not). Internal staff ratios range widely: from 0% (entirely outsourced) to 100% (fully internalised). The most common values are 80–100% internal, suggesting that most documented business models rely predominantly on own staff. Only one respondent reported a very low internal share (2–3%), indicating significant reliance on external contractors.

Question	Customers: What are the different types of customers you have?
Label-Code	Sec_H-bm_customers
Type	Open – Text
Options	N/A
Results	44% of respondents described their customer base (57% did not). Customer types include: manufacturing industries and transport companies; natural gas utilities (as the sole biomethane off-taker); farmers and agricultural cooperatives; agri-food industry processors; HoReCa operators and local retail outlets; energy traders and electricity market intermediaries; and public regulatory bodies (e.g. CNMC). Several respondents report self-consumption only, with no external energy customers. Customer diversity reflects the varied business model types across the sample.
Question	Cost streams: What are the main costs associated with your business?
Label-Code	Sec_H-bm_costs
Type	Open – Text
Options	N/A
Results	44% of respondents described their cost structure (57% did not). Main cost categories include: capital expenditure (CAPEX) for biogas, PV, or biomethane plants; operations and maintenance of cogeneration systems; digestate transport and management; feedstock input costs (organic waste, manure); personnel costs; energy costs; land and pasture management; agri-food transformation and certification; and experimental research labour. For several respondents, energy production costs are the primary cost driver and the main revenue source simultaneously.

Question	Revenue streams: What are the main revenues associated with your business?
Label-Code	Sec_H-bm_revenues
Type	Open – Text
Options	N/A
Results	44% of respondents described their revenue structure (57% did not). Revenue sources include: biomethane and bioelectricity sales; biofertiliser sales; waste management fees; agri-food product sales (food, beverages, dairy); agritourism and hospitality services; membership fees and service charges (agricultural associations); energy cost savings through self-consumption; crop yield increases from agrivoltaic shade; and reduced chemical fertiliser costs. Many respondents combine energy-derived savings with core agricultural revenue streams.

Question	How are renewable energy sources impacting your cost/revenue stream?
Label-Code	Sec_H-bm_res_impact
Type	Open – Text
Options	N/A
Results	44% of respondents described the RES financial impact (57% did not). Impacts described include: direct revenue generation from biomethane and electricity sales (the primary revenue stream in dedicated energy models); reduction of electricity bills through self-consumption; fuel cost savings from CHP thermal output; improved economic sustainability enabling reinvestment; and reputational benefits contributing indirectly to revenue. For several respondents, the RES component is both the primary cost and the primary revenue driver of the entire business.

Question	Can you provide a quantitative estimate of the positive or negative impact of RES use on your operations or financial results?
Label-Code	Sec_H-bm_quant_impact
Type	Open – Text
Options	N/A
Results	30% of respondents provided a quantitative estimate (70% did not). Where data were shared: one respondent estimates energy cost reductions of 20–30%; another reports a 10% reduction in electricity costs; one notes that RES constitutes the core and primary revenue base of the business; and several describe savings enabling further investment. The low response rate and

	qualitative nature of most answers reflect the difficulty of isolating RES impact within complex agricultural operations.

Question	Financing sources: Which type of financing has been adopted for the project?
Label-Code	Sec_H-bm_finance_src
Type	Open – Text
Options	N/A
Results	35% of respondents described their project financing structure (65% did not). Reported structures include: 40% public grant / 60% bank loan; 40% public grant / 30% equity / 30% bank loan; 70% loan / 30% own resources; 100% public grant (research institution); and phased public funding via different national programmes across multiple project generations. One respondent reports 0% financing secured to date, and one could not provide detailed breakdowns. Mixed public-private financing is the norm.

Question	Key challenges: What are the main obstacles for private players in delivering sustainable agricultural business models?
Label-Code	Sec_H-bm_challenges
Type	Open – Text
Options	N/A
Results	48% of respondents identified key business model challenges (52% did not). The most recurrent challenge is regulatory and permitting complexity, cited consistently across Spanish and Italian respondents. Other barriers include: financial support access and permitting speed; digestate management constraints; grid connection difficulties; long-term economic viability; high upfront investment requirements; specialised technical competence needs; market price sufficiency for cost coverage; and the difficulty of engaging stakeholders in participatory planning in remote areas.

Question	Key opportunities: Which business opportunities related to renewable energies do you see in the future for your agricultural activity?
Label-Code	Sec_H-bm_opps
Type	Open – Text
Options	N/A
Results	44% of respondents identified future opportunities (57% did not). Opportunities highlighted include: scaling waste management into regional

	hubs; biomethane grid injection through upgrading; agrivoltaics for periurban areas and orchards; circular economy models integrating waste, energy, and fertiliser recovery; community energy models and RECs; expanded biogas production via reduced manure storage times; increased energy self-sufficiency; and diversified agricultural income streams from energy co-production. Agrivoltaics is the most frequently cited emerging opportunity.

Question	What types of external support could help your entity implement its delivery models?
Label-Code	Sec_H-bm_support
Type	Open – Text
Options	N/A
Results	39% of respondents identified support needs (61% did not). Most frequently cited support types include: faster and simpler regulatory and permitting processes; specialised technical assistance for RES project design and management; administrative and legal advisory services for authorisation and incentive access; dedicated financial support and grants; public-private research partnerships; inter-sectoral collaboration platforms (livestock, agriculture, energy); institutional support from regional governments; and mission-oriented consultancy focused on long-term sustainability rather than equipment sales.

Question	Has the company (re)designed, started, or planned the adoption of a low-carbon or sustainable business model including RES?
Label-Code	Sec_H-bm_redesign
Type	Closed – Single
Options	Yes – implemented >12 months ago | Yes – currently adopting (<12 months) | Yes – planned within 3 years | Yes – planned long run (>3 years) | No
Results	61% of respondents answered (39% did not). Among those responding, 26% have already implemented a sustainable business model, 9% are currently adopting one, and 13% plan to do so within three years. A further 4% plan adoption on a longer horizon. Only 9% report no plans for a sustainable business model. The data suggest a sector in active transition, with most respondents at some stage of RES business model engagement.

8.4.9 Social Aspects

8.4.9.1 Highlights

- **Reduced environmental impact is the most expected social benefit (57%), followed by energy security and resilience (43% each).** The high expectation for reduced environmental impact (57%) aligns with the European Commission's 2024–2026 Programming Document, which identifies agriculture as a core sector for enhancing carbon removals and climate resilience (EEA, 2024). This reflects a maturing social awareness where the farm is seen not just as a food source, but as a critical agent of ecological restoration.

  - Energy Security as a Social Pillar: The 43% rating for energy security and resilience is directly linked to the socio-political climate following the energy crisis of the early 2020s. According to the Joint Research Centre (JRC, 2025), rural areas in Europe face higher risks of energy poverty due to older building stocks and lower average incomes. For these communities, renewables are viewed as a "shield" against price volatility.
  - The "Just Transition" Context: Official literature from IRENA (2025) suggests that for 43% of stakeholders, "resilience" is synonymous with "energy independence," reflecting a desire to reduce reliance on external fossil fuel imports and stabilize the local rural economy (IRENA, 2025).

- **Community engagement importance is rated positively by 52% (high or very high), but negatively by 35% (low or very low).** This polarized result—where 52% value engagement but a significant 35% dismiss it—mirrors a systemic challenge identified in the European Court of Auditors Special Report 10/2026. The report notes that by early 2025, the EU had only reached 27% of its goal to have at least one energy community per municipality, largely due to "unclear definitions" and a "lack of local social acceptance" (ECA, 2026).
  - The "Social License" Conflict: Research from the HYFUELUP project (2025) indicates that while general support for green energy is high, the 35% negative rating likely reflects concerns over "local siting" issues—such as noise, odors from biogas, or the visual impact of solar panels on heritage landscapes. This is what the European Biogas Association defines as the struggle for a "Social Licence to Operate" (HYFUELUP, 2025).
  - Engagement as a Burden: The ALFA Project (2025), a Horizon Europe initiative, found that many smaller farmers and local authorities rate engagement "low" because they perceive it as an additional administrative burden rather than a benefit. Without "one-stop shops" to facilitate these social dialogues, the 35% of respondents may view community participation as a barrier to project speed (ALFA Project, 2025).

REFERENCES:

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8.4.9.2 Comments & Recommendations

The survey results highlight a significant divergence in how community engagement is perceived, reflecting a transition in the European rural energy landscape from passive adoption to active participation. While 57% of respondents prioritize environmental benefits, the **mixed picture on community engagement reflects varying business model types**, ranging from individual on-farm optimizations to collective energy ecosystems.

Official literature from the **European Court of Auditors (Special Report 10/2026)** notes that the EU has reached only 27% of its goal for municipal energy communities, primarily due to the "procedural justice" gap—where local voices are not included in the early planning stages (ECA, 2026). As the survey suggests, **energy self-consumption models often require little community involvement**, as they are typically limited to private farm infrastructure. However, **community energy and agrivoltaic projects depend heavily on participatory processes** to mitigate concerns over landscape impact and land-use competition, which are frequently cited by the 35% of respondents who rate engagement importance as "low" or "very low."

To bridge this gap, **tailored engagement strategies should be developed for each model type**, moving away from a "one-size-fits-all" communication approach. The **ALFA Project (2025)**, a Horizon Europe initiative, successfully demonstrated that social acceptance for biogas and solar increased when farmers used **communication tools that make RES benefits tangible for local communities**, such as "Local Energy Dashboards" showing regional CO2 savings and direct reductions in local energy costs (ALFA Project, 2025). Furthermore, the **REPowerEU 2026 updates** recommend that Member States implement "Social Impact Vouchers" for agrivoltaic projects, ensuring that a portion of the generated value is reinvested into local rural services, thereby turning abstract environmental goals into concrete community resilience (European Commission, 2026).

8.4.9.3 Detailed Results

Question	Which drivers are motivating your company to adopt sustainable business models incorporating RES?
Label-Code	Sec_H-bm_motivatiors
Type	Closed – Multiple
Options	Economic Incentives | Green Certifications | Investor Requirements | Decarbonisation Strategy | Mandatory Regulations | Other
Results	61% of respondents answered (39% did not). Economic incentives are the most frequently cited driver (43% of all respondents when combinations are disaggregated). Decarbonisation strategy follows at 35%, and green certifications at 22%. Mandatory regulations motivate 13%. Only one respondent cited a non-listed driver, relating to social reputation. The co-occurrence of economic incentives with certification and decarbonisation goals suggests that multiple overlapping motivators are at play.

Question	Please specify other driver:
Label-Code	Sec_H-drivers_other_specify

Type	Open – Text
Options	N/A
Results	Only one respondent (4%) specified an additional driver (96% did not respond). The driver mentioned is social reputation and impact, indicating that some companies are motivated by considerations beyond regulatory compliance and financial returns. This dimension may be underweighted in the predefined answer options.

8.5 Response Frequency

Table 3. Response frequency by question

Section	Question Label	Valid answers	Missing
Background	Sec_background-stakeholder_group	23	0
A – Energy Sector	Sec_A-energy_priorities	22	1
B – Financing	Sec_B-funding_avail	22	1
C – Public-Private Partnership	Sec_C-support_ppp_agri	20	3
D – Regulatory	Sec_D-reg_obstacles	22	1
E – Governance	Sec_E-coord_platform	20	3
F – Energy Systems	Sec_F-res_tech_used	21	2
H – Business Models	Sec_H-bm_redesign	14	9
I – Social	Sec_I-key_social_benefits	20	3

8.6 Stakeholder mapping

Table 4. Respondent overview

Stakeholder	Contact Name	Contact Email	Stakeholder Category	Country
Porgas 2010 SL	Sergi Bou Bosch	admin@naturporc.cat	Industry – Energy sector	Spain
REMONDIS Iberia S.A.U.	Josep Antoni Gomez Torres	josep.gomez@remondis.es	Industry – Waste/energy	Spain
Fundació Eurecat	Anna Ribera Guàrdia	anna.ribera@eurecat.org	Research organisation	Spain

9 ANNEX 2: Business Model Compendium

9.1 Purpose of this Compendium

This Business Model Compendium is a working input document for the HarvRESt Business Model Catalogue (Deliverable D3.4). Its primary function is to supply the structured, source-verified descriptions needed to populate the Business Model Evaluation Matrix developed in Task 3.5. Each entry in this compendium corresponds to a business model identified through the HarvRESt stakeholder consultation survey, the project use cases (D2.3), the CKIC T3.5 technology contributions, or the academic literature review — and is referenced in the catalogue by its unique ID code (BM01–BM34).

The Evaluation Matrix assesses each business model across ten criteria: Water-Energy-Food (WEF) Nexus Synergy, Agri-player type, Key agreements required, Minimum project scale, Ownership structure, Operational model, Replicability, Financial viability, Innovation level, and Attractiveness for agricultural actors. The descriptive profiles compiled here provide the factual basis for scoring each criterion consistently across all 34 business models.

9.2 Note on Sources and Structure

This compendium consolidates business model descriptions from four complementary sources, each identified by a colour code in the main D3.4 catalogue:

1. HarvREStt Stakeholder Survey (February–March 2026): 23 actors across Spain, Italy, and Denmark responded, of which 13 provided substantive business model data (Section H of the ODK survey). These are presented in Part A and correspond to BM07–BM16 in the catalogue.
2. HarvRESt Use Cases — D2.3 ('Use Cases Monitoring and Experiences Compilation', June 2025): Five official project living laboratories, four of which are distinct from the survey respondents — Viñas del Vero / VdV (BM04), Fattoria Solidale del Circeo / FSDC (BM05), Grønn Gårdsenergi AS / GGE (BM06), and the Danish biogas planning tool (BM02). The Catalan Use Case (BM01) overlaps with three survey respondents. These are in Part B.
3. HarvRESt T3.5 — CKIC Contributions: Twelve innovative technology and business model cases sourced by Climate-KIC (BM17–BM28), presented in Part C.
4. Academic Literature Review: Six well-established European business models (BM29–BM34) drawn from peer-reviewed publications, presented in Part D.

Three entities appear in both the survey and D2.3 use case sources: Sorigué/Sorigue (R7 + R20 + Catalan Use Case), Torre Santamaría (R19 + Catalan Use Case), and Viñedos del Río Tajo (R23 + VRT Use Case). For these, the descriptions in Part A integrate and consolidate information from both sources, avoiding repetition. All three are catalogued under BM01 (Catalan Use Case) or BM03 (VRT).

9.3 HarvRESt Use Cases (D2.3)

This section presents the six HarvRESt Use Cases (BM01–BM06), corresponding to the GREEN category in the Business Model Catalogue colour legend. Three entries (BM01: R7 Sorigue, R19 Torre Santamaría, R20 Sorigué R&D) share the same catalogue code as they are all actors in the Catalan biomethane use case. BM03 corresponds to the Spanish VRT vineyard use case (R23 Viñedos del Río Tajo).

9.3.1 BM01 – Catalan Use Case — Noguera-Sorigué

9.3.1.1 BM01 – Catalan Use Case — Noguera-Sorigué **Biogas → Biomethane with Grid Injection + Bio-Residue Fertilisation Trials**	
Country / Location	Spain (Balaguer, Lleida)
Sector	Energy sector / infrastructure & environmental services
Geographic scope	Local
Ownership structure	Private (tri-partite partnership)
Technology category	Biogas & Biomethane
Implementation stage	Implemented
Source	Survey + D2.3 PDF (Catalan Use Case / Noguera-Sorigué)

Description

The Catalan Use Case — Noguera-Sorigué — is the formal HarvRESt living laboratory for biogas-to-biomethane production in Spain. It is located near Balaguer (Lleida) and is developed through a three-partner agreement: Sorigué (infrastructure and environmental services company, technical operator), Torre Santamaría (dairy farm, manure and land supplier), and Axpo Iberia (single energy offtaker), with technical coordination from BETA Tech Centre (UVIC-UCC). The plant includes four digesters that treat agro-residues and livestock manure from local farming activities. The biogas produced is upgraded to biomethane and injected into the natural gas network under a single offtaker agreement with Axpo. The surrounding area includes over 500 ha of corn cultivation for feed, as well as almond, olive, fruit, and cereal crops.

Each partner plays a distinct role in the business model. Sorigué acts as the technical operator, managing plant functioning and R&D (more than 10% of budget invested in R&D); the model is financed 70% by loan and 30% own resources. Torre Santamaría is the manure/feedstock supplier and the host landowner for the HarvRESt field trials. Axpo is the sole biomethane buyer. These complementary roles allow all three actors to share the BM01 code as a single integrated system. The operation is highly outsourced (0–3% internal staff at plant level). Revenue comes from biomethane sales and manure management gate fees. The main challenges are regulatory barriers and very long permitting timelines. The model is motivated by green certifications, decarbonisation goals, and mandatory regulations; it is classified as incremental process innovation with a circular economy framing.

The HarvRESt laboratory activity at this site focuses on bio-residue fertilisation trials, conducted in one of the fields owned by Torre Santamaría, adjacent to the biogas plant. The experimental design consists of 10 treatments with 4 replicates each, giving 40 plots (3×3 m), applied to a double-crop field (barley in winter/spring, corn in summer/autumn). The digestate is separated into solid and liquid fractions: solid fractions are applied before sowing (November and June), while liquid fractions are applied during mid-growth stages (March and August). The primary objective is to assess the potential of digestate as a substitute for conventional fertilisers (up to 170 kg N/ha), evaluating nitrogen release dynamics, nutrient retention in soils, and environmental KPIs such as N & P leaching and soil quality indicators (organic matter, pH, biological activity). Data from these trials are shared with CIRCE to calibrate the CWA 17898:2022 soil quality methodology and to feed the HarvREStAVPP and DSS digital tools.

Business Model Canvas — Key Elements	
Element	**Detail**
Value proposition	Circular valorisation of livestock manure and agro-residues into biomethane (grid injection) + digestate (fertiliser substitute) + nutrient recovery; decarbonisation of farm energy chain
Key actors	Sorigué (technical operator & R&D); Torre Santamaría (manure/land supplier); Axpo Iberia (sole biomethane offtaker); BETA Tech Centre (R&D coordination, HarvREStlead)
Revenue streams	Biomethane sales to energy grid (via Axpo); manure management gate fees from farms
Key challenges	Regulatory barriers and very long permitting timelines; digestate management; single-customer dependency on Axpo
Financing	70% bank loan, 30% own resources; highly outsourced operations (0–3% internal staff)
Innovation type	Incremental process innovation; circular economy framing; >10% R&D budget
HarvREStlab focus	Bio-residue fertilisation field trials (40 plots, 10 treatments × 4 replicates); digestate as fertiliser substitute for barley/corn double-crop; monitoring of N release, P leaching, soil quality (CWA 17898:2022); data feeds AVPP and DSS
Motivators	Green certifications, decarbonisation targets, mandatory regulations

9.3.2 BM02 – Food & Bio Cluster Denmark (FBCD) / ConTerra

9.3.2.1 BM02 – Food & Bio Cluster Denmark (FBCD) / ConTerra **Biogas Planning & Decision-Support Tool (National Scale)**	
Country / Location	Denmark (nationwide coverage)
Sector	Agricultural advisory / data analytics / biogas planning
Geographic scope	National (32,000 farms; 55,000 production sites; 600,000 field parcels)
Ownership structure	Public–private
Technology category	Advisory & Planning Tools / Biogas & Biomethane
Implementation stage	Tool development phase
Source	D2.3 PDF (Danish Use Case — HarvREStlaboratory)

Description

The Danish use case focuses on developing a comprehensive biogas planning tool to support manure-based biogas production across Danish farms. Unlike real-time monitoring systems, the tool uses consecutively updated agricultural activity data — collected in compliance with EU IACS regulations — to conduct strategic potential assessments at farm and regional level.

The data framework covers approximately 32,000 Danish farms, 55,000 production sites and 600,000 field parcels. Activity data is rendered at farm, barn or field-parcel level and includes livestock numbers and characteristics, barn technology and manure type, nitrogen and phosphorus content, manure export/import flows, export to biogas plants, inorganic fertiliser application, and crop species, soil type, and irrigation status. A semi-automated data extraction and merging tool has been developed, shortening the time required for quality-controlled data collection.

The tool is designed to serve multiple stakeholder groups: energy companies (e.g., BioCirc, Nature Energy) need biomass mapping and biogas production potential; municipalities (e.g., Esbjerg, Viborg, Norddjurs) need GHG emission calculations and nutrient balance analysis for planning; agricultural advisors (SAGRO, VELAS) need field-level nutrient management guidance. System test runs have already produced outputs for Esbjerg Municipality (manure flows and GHG impact) and Copenhagen Infrastructure Partners (nationwide phosphorus balance analysis as a precursor for pyrolysis potential calculations).

The model focuses on strategic long-term planning aligned with Denmark's national priorities on greenhouse gas reduction, renewable energy expansion, and nutrient management. All outputs feed into HarvRESt's broader modelling and optimisation frameworks (WP5).

Business Model Canvas — Key Elements	
Element	**Detail**
Value proposition	Fast, reliable, continuously updated biogas planning data at farm-to-regional scale; GHG and nutrient cycle analysis
Data coverage	~32,000 farms; 55,000 livestock sites; 600,000 field parcels (IACS-based, EU-compliant)
Tool outputs	Biomass/manure mapping; biogas status/potential; GHG impacts; N/P balances; CO_2 tax implications; digestate distribution planning
Key users	Energy companies, municipal planners, agricultural advisors
Test outputs	Esbjerg Municipality (manure/GHG); CIP (P-balance/pyrolysis potential)
Technical stack	SQL databases + GIS systems; semi-automated import; IPCC/SimDen calculation models
Key challenges	Continuously integrating updated national datasets; adapting calculation models as GHG parameters change
Motivators	National GHG reduction targets, renewable energy expansion, nutrient management enhancement

9.3.3 BM03 – Viñedos del Río Tajo (VRT)

BM03 – Viñedos del Río Tajo (VRT) **Agrivoltaic Pilot on a Commercial Vineyard + Precision Agriculture**	
Country / Location	Spain (Guadamur, Toledo)
Sector	Viticulture / brandy production
Geographic scope	International (Spain + Philippines)
Ownership structure	Private
Technology category	Solar & Agrivoltaics
Implementation stage	Implemented
Source	100% grant

Description

Viñedos del Río Tajo is a mechanised vineyard covering 430 hectares, specialising in grapes for premium brandy production. As part of HarvREStt, VRT is one of the core Spanish use cases and serves as a living laboratory for agrivoltaic experimentation. The estate applies modern precision agriculture practices, including vigour mapping, automated irrigation, and IoT monitoring tools.

The HarvREStt experimental design at VRT consists of an agrivoltaic system installed in the Daramezas vineyard plot, testing the effects of partial shading (morning vs. afternoon) on Airén variety vines. During the 2024 season, shading was 39% in S1 plants (morning shade) and 42% in S2 plants (afternoon shade). Key results from the first monitoring season include: evapotranspiration was reduced by approximately 30%, implying potential irrigation water savings of 30%; hours above 40°C were reduced by 96% in shaded plants (from 105 to just 4 hours); soil temperature in the top 10 cm was reduced by more than 10%. However, grape yield was 28% lower in S1 and 8% lower in S2 compared to unshaded controls, due to reduced bunch fertility. Based on these findings, the tracker algorithm has been modified to reduce shading during the critical flowering-to-veraison period in 2025.

From a business model perspective, VRT's core revenue is brandy sales. The agrivoltaic element reduces electricity costs (estimated 10% reduction) and generates knowledge about solar-viticulture compatibility. The main operational challenge identified is the electricity distribution network. The model is motivated by economic incentives and decarbonisation; classed as incremental process innovation with a regular focus and 5–10% R&D investment.

Business Model Canvas — Key Elements	
Element	**Detail**
Value proposition	Brandy production + agrivoltaic cost reduction + wine-climate resilience data
Core business	Premium brandy production and commercialisation (Spain + Philippines)
Agrivoltaic trial	Partial shading experiment on Airén vines; fixed and tracker-based PV configurations

2024 results	~30% ETo reduction; 96% reduction in hours >40°C; 28%/8% yield reduction (S1/S2)
Finance	100% grant (agrivoltaic installation)
Revenue	Brandy sales; electricity cost savings
Key challenges	Electricity distribution network; balancing shading vs. yield
Motivators	Economic incentives, decarbonisation

9.3.4 BM04 – Viñas del Vero (VdV) — Somontano DO

9.3.4.1 BM04 – Viñas del Vero (VdV) — Somontano DO **Integrated Energy Management for a Sustainable Winery: PV + Storage + Electric Machinery**	
Country / Location	Spain (Somontano, Huesca)
Sector	Winery / viticulture
Geographic scope	Estate (515 ha, 15 grape varieties)
Ownership structure	Private
Technology category	Solar & Agrivoltaics / Mixed RES & Smart Mgmt
Implementation stage	Implemented and evolving
Source	D2.3 PDF (Spanish Use Case — HarvREStlaboratory)

Description

Viñas del Vero is a prominent Spanish winery operating under the Somontano Denomination of Origin, cultivating 15 grape varieties over 515 hectares. As a HarvREStuse case, it serves as a living laboratory for integrated energy management in viticulture. The estate integrates 277 kWp of installed PV capacity, battery storage solutions (lead-acid and lithium-ion), and electric mobility tools — specifically an electric autonomous robot (Naio, France) and an electric tractor (Monarch, USA). As a result, 84% of the vineyard's total energy demand is met through internal generation.

The energy management system (EMS) — developed within HarvREStt — optimises multiple simultaneous parameters: punctual winery consumption, PV production, grid import/export prices, battery state of charge, and load scheduling (e.g., refrigeration compressors, forklift charging, scrubber aerators). The EMS sectorises consumption across different parts of the cellar and enables real-time energy price visibility.

Initial trials have validated the Naio autonomous robot over five months, achieving a CO_2 saving of 20 kg CO_2/ha per pass and a 16-fold reduction in energy cost compared to diesel (7.5 €/ha with diesel vs. 0.46 €/ha with electric). Validation of the Monarch electric tractor is ongoing (received March 2025). A legal constraint noted is that autonomous vehicles in Europe cannot operate without supervision or leave the field.

Business Model Canvas — Key Elements	
Element	**Detail**
Value proposition	Maximum RES self-consumption + decarbonised winery operations + operational cost savings; 84% energy self-sufficiency
Installed PV	277 kWp (expanded from original REWIND EU Life project installation since 2016)
Storage	Lead-acid batteries (legacy, 2016) + lithium-ion batteries (expanded, current)
Electric machinery	Naio autonomous robot (6 kW, France); Monarch electric tractor (52 kW, USA — received March 2025)
CO_2 savings (Naio)	20 kg CO_2/ha per pass; fuel cost reduced 16× vs diesel (7.5 €/ha → 0.46 €/ha); labour savings
EMS capabilities	Simultaneous optimisation of: winery punctual consumption, PV generation, grid import/export prices, battery charge/discharge, forklift scheduling; sector-level consumption monitoring (cellar, bottling, refrigeration, lighting)
Key challenges	Legal restrictions on autonomous vehicles in EU (no unsupervised field operation, cannot leave field); Monarch tractor lacks cab (safety risk from stones and herbicides)
HarvRESt KPIs	Self-consumption optimisation, efficient storage, energy independence, GHG reduction, fossil fuel elimination in vineyards

9.3.5 BM05 – Fattoria Solidale del Circeo (FSDC)

9.3.5.1 BM05 – Fattoria Solidale del Circeo (FSDC) **Triple-Action Strategy for RES Transition in Italian Agrivoltaic Farming**	
Country / Location	Italy (Circeo area, Lazio)
Sector	Large-scale mixed farming / social agriculture
Geographic scope	Farm (135 ha under agrivoltaic canopy trial, 80 ha first sowing)
Ownership structure	Private (social cooperative model)
Technology category	Solar & Agrivoltaics
Implementation stage	Adopting / early trials
Source	D2.3 PDF (Italian Use Case — HarvRESt laboratory)

Description

The Italian use case (Fattoria Solidale del Circeo — FSDC) demonstrates how agrivoltaic technology can be innovatively integrated into a large-scale Italian farm, boosting on-site renewable generation while preserving crop yields. FSDC pursues a triple-action strategy for RES transition, covering technological, agronomic, and educational dimensions.

The first action is a Catalogue of Technological Opportunities: a multi-source energy-needs analysis conducted in two phases, collecting quantitative data on production, demand and storage, then validating energy balances through weighted analyses and modelling. An electric-driven irrigation prototype is also under development.

The second action is Integration of Agronomic Practices with Agrivoltaics: agronomic approaches are being designed to optimise multifunctional land use beneath photovoltaic installations. The first sowing of a mixed herbage (ryegrass and alfalfa) is planned for 2025, covering 80 of the farm's 135 hectares. Comparative trials will assess agrivoltaic vs. open-field agronomic performance. CAP compatibility — ensuring PV installations do not disqualify the farm from Common Agricultural Policy support — is a key regulatory concern under active investigation.

The third action is an Educational Training Programme: a comprehensive 'Guide to Educational Activities' has been planned for school-level educational visits, combining lectures and hands-on labs on water management, Mediterranean biodiversity, agrivoltaic operations, solar-powered irrigation and hydroponics. Data monitoring is focused on hourly energy production, consumption and grid injection, feeding into the HarvRESt PV Performance Ratio KPI (EN KPI 18).

Business Model Canvas — Key Elements	
Element	**Detail**
Value proposition	On-site RE generation + land productivity preservation + educational outreach + social inclusion
Three pillars	1) Technological catalogue; 2) Agronomic integration with agrivoltaics; 3) Educational training programme
Agronomic trial	Mixed ryegrass + alfalfa sowing under agrivoltaic canopies (80/135 ha, 2025)
CAP dimension	Active investigation of PV impact on CAP fund eligibility
Monitoring KPI	EN KPI 18 — PV Performance Ratio (hourly energy production, consumption, grid injection)
Key challenges	Permitting pathways for agrivoltaic; balancing energy generation with CAP compliance
Motivators	Farm electrification, social mission, educational outreach

9.3.6 BM06 – Grønn Gårdsenergi AS (GGE)

9.3.6.1 BM06 – Grønn Gårdsenergi AS (GGE) **Multi-Source RES Integration for Energy-Independent Meat Production Farm**	
Country / Location	Norway (Western Norway, Rogaland region)
Sector	Livestock farming / local meat production and distribution
Geographic scope	Farm (cattle + pigs + local butchery and shop)
Ownership structure	Private

Technology category	Mixed RES & Smart Mgmt
Implementation stage	Partially implemented; technologies in planning/evaluation
Source	D2.3 PDF (Norwegian Use Case — HarvRESt laboratory)

Description

Grønn Gårdsenergi AS (GGE) is a farm located in Western Norway (Rogaland region), dedicated to all aspects of the production and distribution of local high-quality meat products, including growing cattle and pigs, operating a local butchery and shop, and delivering products to clients. GGE aims to achieve 100% coverage of its energy needs from local renewables, improve energy efficiency, and deliver any surplus to the grid.

The farm has already installed 52.56 kWp of rooftop PV and a 136 kW battery storage system. Heat storage of 20 m³ is connected to butchery processes to recover heat from 5 cooling machines for hot water supply. Additional RES are planned for integration: two options for biomass CHP (a 2-gas-motor CHP unit for biogas, 100–150 kW, or a 50 kW wood chip CHP), three novel small-scale wind turbine prototypes (Carnetic VAWT and Sine Delta bladeless, 7–40 kW range), and two micro-hydro installations (~11 kW from two lakes separated by a dam; ~20 kW from a mountain creek — combined ~136,000 kWh/year expected). An AI-driven smart energy management system (EMS), developed in partnership with NORCE and KE Automasjon, will coordinate all generation and storage assets to maximise self-consumption and energy independence.

As a spin-off of the HarvRESt collaboration, GGE is co-founding the "Landkraft" cooperative together with Dalane Energi, Fjordkraft, and Statskog, aiming to facilitate the integration of local renewables across farms in the region. A cooperation agreement with Øksnevad Videregående Skole is also in planning to train future farmers on RES integration in agriculture.

Business Model Canvas — Key Elements	
Element	**Detail**
Value proposition	Full RES self-sufficiency for a mixed livestock farm and local butchery; zero fossil fuel dependency; local high-quality meat production with minimal energy footprint; grid surplus as secondary revenue
Technology mix	Existing: 52.56 kWp rooftop PV + 136 kW battery + 20 m³ heat storage. Planned: biomass CHP (biogas or wood chip, 50–100 kW), 3 novel wind turbine prototypes (VAWT + bladeless), 2 micro-hydro units (~31 kW combined, ~136,000 kWh/yr)
Key actors	GGE (farm operator); NORCE (EMS and smart systems R&D); KE Automasjon (automation system); Landkraft cooperative (GGE + Dalane Energi + Fjordkraft + Statskog)
Revenue streams	Primary: meat product sales (farm, butchery, shop, direct delivery); Secondary: grid surplus electricity; Savings: elimination of fossil fuel and external energy costs
HarvRESt lab focus	AI-driven smart EMS development; integration of mixed RES sources; self-consumption optimisation; monitoring KPIs (energy demand, PV generation, battery capacity, meteorological data for typical meteorological year modelling)

Key challenges	Integration of novel prototype wind turbines (Carnetic VAWT, Sine Delta bladeless) at reduced cost; coordination of multiple generation and storage technologies; legal/regulatory framework for autonomous energy systems
Motivators	Energy independence, food and energy security, rural community leadership in RES adoption, knowledge transfer to next generation of farmers

9.4 Business Models from the Stakeholder Survey

9.4.1 BM07 – PORGAS 2010 S.L.

9.4.1.1 BM07 – PORGAS 2010 S.L. **Farm-Scale Biogas CHP: Waste Intake + Self-Consumption + Electricity Sales**	
Country / Location	Spain (Cassà de la Selva, Girona)
Sector	Livestock / biogas
Geographic scope	Regional
Ownership structure	Private
Technology category	Biogas & Biomethane
Implementation stage	Implemented
Financing	40% public grant, 60% bank loan
Source	Survey

Description

PORGAS operates a biogas plant co-located with a pig farm and an animal feed factory. Agri-food industry residues and pig slurry are co-digested to produce biogas, which a combined heat and power (CHP) unit converts into electricity and heat. Part of the electricity is sold to the grid; the rest covers self-consumption at the farm and feed factory. The thermal energy heats the farm, replacing fossil fuels.

Revenue streams are waste intake gate fees and electricity sales; costs are energy, CHP and plant maintenance, and digestate transport. Only 2% of staff are internal. The main challenge is bureaucracy; the strategic opportunity is upgrading the biogas to biomethane for direct gas-grid injection. Motivated by economic incentives and green certifications; incremental process innovation with an eco focus.

Business Model Canvas — Key Elements	
Element	**Detail**
Value proposition	Energy autonomy for farm + waste valorisation + electricity revenue; lower carbon footprint for customers
Key actors	PORGAS, pig farm, feed factory, agri-food residue suppliers, grid operator
Revenue streams	Waste gate fees, electricity sales
Costs	Energy, CHP/plant maintenance, digestate transport
Finance	40% grant, 60% bank loan
Key challenges	Bureaucratic and permitting delays
Future opportunity	Upgrading biogas to biomethane for direct gas-grid injection

Motivators	Economic incentives, green certifications

9.4.2 BM08 – REMONDIS Iberia S.A.U

9.4.2.1 BM08 – REMONDIS Iberia S.A.U. **Biogas from Farm Waste with Circular By-products (ESCO-supported)**	
Country / Location	Spain
Sector	Waste & environmental services
Geographic scope	Regional
Ownership structure	Hybrid (public–private)
Technology category	Biogas & Biomethane
Implementation stage	Redesign planned within 3 years
Source	Survey

Description

REMONDIS describes a model where the organisation supplies organic input materials to on-farm biogas plants and, in some cases, also operates those plants. Beyond energy generation, the plants produce digestate that is valorised as fertiliser or compost. The value proposition combines waste management services for farms with renewable energy production and circular nutrient recovery.

The main challenge is bureaucratic complexity. The model is motivated by economic incentives and reputational/social impact.

Business Model Canvas — Key Elements	
Element	**Detail**
Value proposition	Waste management + RE production + circular nutrient recovery (digestate as fertiliser/compost)
Key actors	REMONDIS (input supplier / operator), livestock farms, digestate end users
Revenue streams	Waste management gate fees, energy revenues
Key challenges	Bureaucratic complexity and permitting
Innovation type	Incremental process innovation
Motivators	Economic incentives, reputational/social impact

9.4.3 BM09 – Axpo

9.4.3.1 BM09 – Axpo **Integrated Waste Management, Biofertiliser Production & Renewable Energy**	
Country / Location	Spain (Catalonia + national)
Sector	Energy sector
Geographic scope	National
Ownership structure	Community model
Technology category	Biogas & Biomethane
Implementation stage	Implemented
Source	Survey

Description

Axpo describes a model centred on the circular valorisation of organic waste streams. The company provides support to farms and agri-food industries in managing their residues, which feed biogas plants that produce both renewable energy and biofertilisers. Key customers are manufacturing industries and transport companies seeking green credentials.

Revenue comes from biofertiliser sales and renewable energy production, while costs include waste intake, manufacturing and energy production operations. 80% of staff are internal. The model invests more than 10% of budget in R&D and is classified as an eco-focused, incremental process innovation. The main barriers are financial support and permitting speed; the strategic opportunity is to build a stable recurring revenue base.

Business Model Canvas — Key Elements	
Element	**Detail**
Value proposition	Circular valorisation of agri-food residues into energy + biofertilisers
Key actors	Axpo, farms, agri-food industries, manufacturing/transport customers
Revenue streams	Biofertiliser sales, renewable energy revenues
Key challenges	Financial support access, permitting speed
Innovation type	Incremental process innovation, eco-focus
R&D intensity	>10% of budget
Motivators	Green certifications

9.4.4 BM10 – Universitat Politècnica de Catalunya (UPC)

9.4.4.1 BM10 – Universitat Politècnica de Catalunya (UPC) **Self-Consumption Biogas CHP on a Pig Farm (Studied Case)**	
Country / Location	Spain
Sector	University / research
Geographic scope	Local
Ownership structure	Private
Technology category	Biogas & Biomethane
Implementation stage	Implemented (long-term redesign planned)
Source	Survey

Description

UPC describes a studied case of a pig farm that installed a biogas plant fed by pig manure and corn silage to achieve full energy self-sufficiency (thermal and electrical). A CHP unit with a boiler covers all farm energy demand with no energy sold externally.

The system saves approximately 473 MWh/year of electricity and 1,600 MWh/year of heat, while also improving digestate quality as fertiliser and reducing odours. The main challenge was permitting duration and the need for a detailed, bankable project. The strategic opportunity is reducing manure storage time to increase biogas yields and animal welfare. Motivated by economic incentives and decarbonisation.

Business Model Canvas — Key Elements	
Element	**Detail**
Value proposition	Full energy autonomy (thermal + electrical) for the pig farm; no external energy purchase
Energy savings	~473 MWh/year electrical; ~1,600 MWh/year thermal
Co-benefits	Improved digestate quality as fertiliser; odour reduction
Finance	Own funds + bank loan (exact split not disclosed)
Key challenges	Permitting duration; need for detailed bankable project
Future opportunity	Reduced manure pit storage time to increase biogas yield and animal welfare
Motivators	Economic incentives, decarbonisation strategy

9.4.5 BM11 – Associació Clúster de la Bioenergia de Catalunya

9.4.5.1 BM11 – Associació Clúster de la Bioenergia de Catalunya **Bioenergy Cluster Facilitating New Valorisation Pathways**	
Country / Location	Spain (Catalonia)
Sector	Civil society / sector cluster
Geographic scope	Regional
Ownership structure	Associative
Technology category	Biogas & Biomethane
Implementation stage	Exploratory
Source	Survey

Description

The Bioenergy Cluster of Catalonia describes a facilitation model oriented around identifying and testing new valorisation pathways for bioenergy. The stated value proposition is the need to explore new paths and models of valorisation within the sector.

As an enabling rather than operational actor, the cluster connects farms, energy companies, research organisations and public bodies to accelerate the deployment of bioenergy solutions across Catalonia. Limited business model canvas data was provided in the survey.

Business Model Canvas — Key Elements	
Element	**Detail**
Value proposition	Facilitating exploration of new bioenergy valorisation pathways; connecting sector actors
Key actors	Cluster members: farms, energy companies, researchers, public bodies
Geographic scope	Regional (Catalonia)
Innovation	Moderate — connector/facilitator role
Motivators	Sector development

9.4.6 BM12 – Coop ASCA

9.4.6.1 BM12 – Coop ASCA **Organic Cooperative: Full Agri-Food Value Chain + PV Self-Consumption + Participatory Certification**	
Country / Location	Italy (Anversa degli Abruzzi, AQ)
Sector	Livestock cooperative / bioagriturismo
Geographic scope	International
Ownership structure	Private (cooperative)
Technology category	Solar & Agrivoltaics
Implementation stage	Redesign planned within 3 years
Financing	Multiple grant rounds (60% grant round 1; 4th Conto Energia; agrivoltaic grant round 3)
Source	Survey

Description

Coop ASCA is a mountain livestock and agritourism cooperative managing 1,320 hectares (87% in protected areas) in Anversa degli Abruzzi, Abruzzo. The model covers the full value chain: organic sheep/goat breeding, cheese, meat, fruit and olive production, certified processing, hospitality, catering, a didactic farm and social farming. Solar energy — installed in three phases since 2000, most recently in 2023 replacing asbestos roofing — supports self-consumption, reducing energy costs and freeing capital for further investment.

A globally recognised innovation is the 'adottaunapecora' (adopt-a-sheep) participatory certification model, featured in The New York Times, which engages remote customers worldwide as co-investors in sustainability. Revenue is split 50% products / 50% services. 98% of staff are internal. The primary challenge is achieving market prices that cover high production costs. Motivated exclusively by decarbonisation strategy; classified as systemic product innovation.

Business Model Canvas — Key Elements	
Element	**Detail**
Value proposition	Certified organic products + immersive agritourism experience + participatory sustainability (adopt-a-sheep)
Revenue split	50% products / 50% services
Solar installations	Three phases (2000, 2010, 2023); third phase via agrivoltaic grant
Finance	60% grant (phase 1); 4th Conto Energia (phase 2); agrivoltaic grant (phase 3)
Key challenges	Achieving prices covering high mountain production costs; market isolation

Innovation	Systemic product innovation; globally recognised participatory certification
Motivators	Decarbonisation strategy

9.4.7 BM13 – Von Stillfried & Cestari Società Agricola

9.4.7.1 BM13 – Von Stillfried & Cestari Società Agricola **Integrated Agri-Food Production with Solar Self-Consumption + Social Agriculture**	
Country / Location	Italy (Pontinia & Terracina, Lazio)
Sector	Agri-food value chain
Geographic scope	Regional
Ownership structure	Private
Technology category	Solar & Agrivoltaics
Implementation stage	Adopting
Financing	40% public grant, 30% equity, 30% bank loan
Source	Survey

Description

This Italian agricultural company integrates sustainable crop cultivation, agri-food processing and social agriculture with photovoltaic energy self-consumption. The value proposition combines reduced energy costs, diversified income, shorter supply chains and social/community benefits — welfare, inclusion, and health for the local community.

Products are sold via direct sales, short-supply-chain channels, HoReCa (restaurants, agritourism) and local retailers. 70% of staff are internal. Revenue comes from agri-food product sales and, in future, from energy incentives and shared energy community models. Main challenges are complex permitting, regulatory uncertainty and high upfront investment. The model is motivated by economic incentives and targets an estimated 20–30% reduction in energy costs.

Business Model Canvas — Key Elements	
Element	**Detail**
Value proposition	Reduced energy costs, diversified income, sustainable agri-food products, social inclusion
Key actors	Farm, technology/energy suppliers, public institutions, social cooperatives, local markets
Revenue streams	Agri-food product sales, future energy incentives/community model revenues
Finance	40% public grant, 30% equity, 30% bank loan

Quantified impact	Estimated 20–30% energy cost reduction
Key challenges	Complex permitting, regulatory uncertainty, high upfront CAPEX
Motivators	Economic incentives

9.4.8 BM14 – IRTA (Institut de Recerca i Tecnologia Agroalimentàries)

9.4.8.1 BM14 – IRTA (Institut de Recerca i Tecnologia Agroalimentàries) **Experimental Agrivoltaic on Apple Orchards — Knowledge-Generation Model**	
Country / Location	Spain (Mollerussa, Lleida)
Sector	Public agricultural research
Geographic scope	Regional
Ownership structure	Hybrid
Technology category	Solar & Agrivoltaics
Implementation stage	Adopting
Financing	Regional government grant (Generalitat de Catalunya)
Source	Survey

Description

IRTA designed, installed and monitors an experimental agrivoltaic system on a productive apple orchard at its Mollerussa experimental farm. Two configurations of solar panels (fixed and dynamic) are tested over two apple varieties in a full-production setting, at a scale sufficient for results to be extrapolated to commercial plantations.

The value is the knowledge generated: agronomic compatibility (effects on yield, quality, water and thermal stress management) and economic profitability analysis. There are no external energy customers — revenues take the form of energy cost savings from self-compensation. The primary output is scientific knowledge transferred to the fruit-growing sector. Key challenge is demonstrating viability of combining electricity and food production. Motivated by economic incentives, decarbonisation and mandatory regulations; invests more than 10% in R&D; systemic process innovation with a climate focus.

Business Model Canvas — Key Elements	
Element	**Detail**
Value proposition	Knowledge on agrivoltaic compatibility for fruit orchards; transferable results to commercial growers
Technology tested	Fixed and dynamic PV configurations on productive Malus domestica varieties
Revenue	Energy cost savings via self-compensation; knowledge transfer (indirect)

Finance	Generalitat de Catalunya grant
Key challenge	Demonstrating combined viability of food + energy production
Innovation	Systemic process innovation, climate focus
R&D intensity	>10% of budget
Motivators	Economic incentives, decarbonisation, mandatory regulations

9.4.9 BM15 – NEIKER-BRTA

9.4.9.1 BM15 – NEIKER-BRTA **Agrivoltaic R&D for the Regional Agricultural Sector**	
Country / Location	Spain (Basque Country)
Sector	Public research organisation
Geographic scope	Regional
Ownership structure	Public
Technology category	Solar & Agrivoltaics
Implementation stage	Redesign planned within 3 years
Source	Survey

Description

NEIKER-BRTA is a public agricultural research centre conducting R&D to improve the competitiveness of the regional agri-food sector, with a specific focus on generating field data to optimise agrivoltaic installations. The value proposition is knowledge creation and technology transfer for farmers and the agri-food industry. Costs are primarily personnel; revenue comes from public funding.

33% of staff time is dedicated to this area. The strategic opportunity identified is expanding agrivoltaic solutions to peri-urban areas. Motivated by decarbonisation strategy; invests 5–10% of budget in R&D; classified as a systemic product innovation with an eco focus.

Business Model Canvas — Key Elements	
Element	**Detail**
Value proposition	Agricultural data and knowledge to enhance agrivoltaic projects for the farming sector
Key actors	NEIKER-BRTA (lead), farmers and agri-food industry (beneficiaries)
Revenue	Public funding (research grants)
Costs	Personnel

Key opportunity	Agrivoltaic systems for peri-urban agricultural areas
Innovation	Systemic product innovation, eco-focus
Motivators	Decarbonisation strategy

9.4.10 BM16 – ASAJA-Toledo

9.4.10.1 BM16 – ASAJA-Toledo **Farmers' Association — Advisory, Lobbying & Subsidy Facilitation for RES**	
Country / Location	Spain (Toledo province)
Sector	Farmers' organisation
Geographic scope	Regional
Ownership structure	Private
Technology category	Advisory & Planning Tools
Implementation stage	No redesign planned
Source	Survey

Description

ASAJA-Toledo is a farmers' organisation that defends members' interests and facilitates access to public funding for renewable energy investments (solar panels, irrigation modernisation, drones). The value proposition is helping member-farmers obtain grants and permits they could not navigate alone. Revenue comes from membership fees and service fees. All staff are internal (100%).

The renewable energy dimension affects members rather than the organisation itself — the quantified impact on energy costs is described as low. Motivated by economic incentives and mandatory regulation; classed as an incremental service innovation.

Business Model Canvas — Key Elements	
Element	**Detail**
Value proposition	Subsidy navigation, permitting assistance, and advocacy for farmer-members
Key actors	ASAJA-Toledo, member farmers, public administration
Revenue streams	Membership fees, service fees
Key challenges	Transferring benefits to members rather than capturing them directly
Innovation type	Incremental service innovation
Motivators	Economic incentives, mandatory regulations

9.5 Business Models from HarvREStT3.5 Contributions (CKIC)

This section presents the 12 innovative technology and business model contributions collected by Climate-KIC (CKIC) as part of HarvREStTask 3.5. Each entry describes a company, technology or platform that represents an innovative approach to renewable energy integration in agricultural systems. Descriptions are drawn directly from the CKIC T3.5 contribution document. Note: aQysta/HyPump was explicitly flagged as 'N/A for the assignment' by CKIC and is not included. Sources: HarvREStT3.5 CKIC Contribution document (2025/2026)

9.5.1 BM17 — Next2Sun

9.5.1.1 BM17 — Next2Sun **Vertical Bifacial PV (Fields2Sun / Fence2Sun) for Agrivoltaics**	
Country / Location	Germany (international)
Technology category	Solar & Agrivoltaics
Implementation stage	Commercial
Source	HarvREStT3.5 — CKIC Contribution
Source URL	https://next2sun.com/en/agripv/

Description

Next2Sun develops east–west oriented vertical bifacial PV systems that enable simultaneous electricity generation and agricultural production. Their two product lines are Fields2Sun, which positions vertical PV module rows with wide spacing so that tractors and machinery can operate between them and shading is minimised, and Fence2Sun, which integrates bifacial PV modules directly into existing farm fence lines, turning farm boundaries into energy generators without requiring additional land. The vertical design achieves approximately 10% higher energy yield per kWp than south-facing fixed-tilt PV because bifacial modules capture light on both sides and collect diffuse irradiance throughout the day. The system preserves roughly 90% of agricultural land since only narrow support structures occupy the ground. The east–west orientation spreads electricity production into morning and late afternoon, easing local grid stress at midday and potentially generating higher revenue where midday electricity prices are depressed. Compared with conventional ground-mounted agrivoltaics, Next2Sun trades maximum kWh per hectare for better land-use compatibility and a gentler agronomic footprint.

Business Model Canvas — Key Elements	
Element	**Detail**
Value proposition	Dual-use land generating electricity while maintaining ~90% agricultural area; bifacial east–west system reduces grid stress
Key products	Fields2Sun (wide-row vertical PV for arable land); Fence2Sun (bifacial PV integrated into fence lines)
Revenue model	Hardware sales and project development fees; electricity revenues from grid export
Key advantage	~10% higher energy yield per kWp than south-facing fixed tilt; minimal land-use conflict

Key challenge	Lower absolute energy output per hectare than standard ground-mount; requires specific farm layout

9.5.2 BM18 — H2arvester

BM18 — H2arvester **Mobile Agrivoltaic System with Green Hydrogen Production**	
Country / Location	Netherlands
Technology category	Solar & Agrivoltaics / Hydrogen
Implementation stage	TRL4–6 (demonstration / pilot — not yet commercially viable)
Source	HarvREst T3.5 — CKIC Contribution
Source URL	https://www.h2arvester.nl/ | https://npk.nl/en/portfolio/h2arvester/

Description

H2arvester is a portable agrivoltaics solution in which lightweight solar-panel arrays are mounted on wheeled “solar cars” that autonomously move across farmland, functioning as a rotating crop surrogate. Electricity produced on-site is channelled into an electrolyser that generates green hydrogen and recoverable heat, which can be stored and used locally, enhancing farm energy self-sufficiency. The mobile units occupy only approximately 10% of a hectare, leaving the majority of land available for agriculture. Compared with fixed agrivoltaic systems, the mobile structures minimise shading duration and land-use trade-offs and offer greater flexibility. The system enables integration into crop rotations and dual income streams from electricity and hydrogen sales. However, the complexity of integrating autonomous movement, hydrogen generation and storage introduces higher technical risk and capital cost. The system is currently at demonstration and pilot phase (TRL 4–6) and is not yet commercially viable.

Business Model Canvas — Key Elements	
Element	**Detail**
Value proposition	Mobile agrivoltaics occupying ~10% of a hectare; on-site green hydrogen production from surplus electricity
Key features	Autonomous wheeled solar cars; on-board electrolyser; recoverable heat; integrates into crop rotations
TRL status	4–6 — demonstration / pilot phase; not commercially viable yet
Revenue potential	Dual streams: electricity sales + hydrogen sales or self-use for farm machinery
Key risks	High technical complexity; integration of movement, H2 generation and storage; regulatory and safety constraints

9.5.3 BM19 — GVS Solar

BM19 — GVS Solar

Mobile Off-Grid Solar Irrigation System with AI Water Management	
Country / Location	International (Spain focus)
Technology category	Solar & Agrivoltaics / Advisory & Planning Tools
Implementation stage	Commercial
Source	HarvRESt T3.5 — CKIC Contribution
Source URL	https://gvs-solar.com/

Description

GVS Solar offers a mobile solar-powered irrigation system designed for both extensive and intensive agricultural operations. The containerised unit supports pivot or drip irrigation and integrates AI and field sensors to optimise water and energy use. Technical specifications include 76.05 kW of installed power via 195 monocrystalline 390-W panels (72-cell format, hail-resistance certified) paired with a 25.6 kWh lithium-iron-phosphate battery bank (512 V DC, 50 Ah). All equipment is housed in a standard 20-foot container, enabling relocation in under 30 minutes. The system can operate fully off-grid or as part of a cluster of interconnected units forming a micro-grid. Compared with standard irrigation systems powered by the grid or diesel pumps, GVS Solar eliminates grid access constraints and high energy costs, achieving clear environmental and operating-cost advantages. The inclusion of AI-driven irrigation control enables water efficiency gains but adds complexity relative to simpler solar-pump solutions.

Business Model Canvas — Key Elements	
Element	**Detail**
Value proposition	Off-grid solar irrigation removing grid dependency; AI-driven water optimisation; fully mobile and relocatable
Technical specs	76.05 kW PV; 195 monocrystalline panels; 25.6 kWh LFP battery; standard 20-ft container
Revenue model	Equipment sales / rental; electricity and water cost savings for farmers
Key advantage	Relocatable in under 30 minutes; off-grid or micro-grid capable
Key challenge	Higher capital cost and complexity than simple diesel pumps; AI system requires calibration

9.5.4 *BM20 — Ecoways*

BM20 — Ecoways **Small-Scale Wind Turbines with Wooden Blades for Farm Self-Consumption**	
Country / Location	Germany (international)

Technology category	Wind Power
Implementation stage	Commercial
Source	HarvRESt T3.5 — CKIC Contribution
Source URL	https://ecoways.com/en/

Description

Ecoways develops small-scale wind turbines designed for farms with annual electricity needs between approximately 25,000 and 500,000 kWh. The portfolio includes two-blade turbine models (WES 30/250 at 250 kW, WES 80, WES 100, WES 50 and WES 20/70) suited for medium wind regimes. The turbines use larch wooden blades, mechanical pitch control, and a ring-generator topology in which magnets rotate on both sides of the coils, enabling operation at lower wind speeds and eliminating the need for a gearbox (typically the most failure-prone component in small wind). All components are fully encapsulated and wind-cooled, removing the need for protective housing. The company also delivers hybrid solutions integrating wind, solar PV and storage to stabilise output and improve self-consumption. Compared with other small-wind competitors, Ecoways differentiates through simplified mechanics and material sustainability: wooden blades reduce lifecycle environmental impact and fit agricultural landscapes, while the ring-generator architecture lowers maintenance costs and improves reliability.

Business Model Canvas — Key Elements	
Element	**Detail**
Value proposition	Low-maintenance small wind for farms 25,000–500,000 kWh/yr; sustainable wooden blades; suited to medium wind regimes
Key models	WES 30/250 (250 kW), WES 80, WES 100, WES 50, WES 20/70; hybrid wind+solar+storage options
Technical differentiators	Larch wooden blades; gearbox-free ring-generator; mechanical pitch control; wind-cooled, fully encapsulated
Revenue model	Hardware sales; hybrid system integration
Key advantage	Lower maintenance vs. hydraulic/electric pitch systems; lower wind speed threshold; sustainable materials

9.5.5 BM21 — MicroBiogasItalia

BM21 — MicroBiogasItalia **Small-Scale Livestock Biogas Plants (from 20 kW)**	
Country / Location	Italy
Technology category	Biogas & Biomethane

Implementation stage	Commercial
Source	HarvRESt T3.5 — CKIC Contribution
Source URL	https://microbiogasitalia.it/

Description

MicroBiogasItalia develops small-scale biogas plants starting from approximately 20 kW, tailored for livestock farms. Their systems convert animal manure into electricity and heat through either "wet" digestion (liquid feedstock) or "dry" digestion (solid feedstock), depending on farm characteristics. The company provides turnkey support covering feasibility assessment, permitting, installation, remote monitoring and long-term operation. A distinctive feature is that systems are marketed as effective using manure alone, avoiding supplementary energy crops in line with EU guidelines that increasingly discourage dedicated crops for biogas. Remote monitoring via mobile app simplifies operation relative to traditional biogas plants. With manure provided at near-zero cost, the company reports biogas production costs of approximately 0.10 €/kWh and operating costs of approximately 0.04 €/kWh. The company also distributes the BioCompostMachine for on-farm composting of organic residues. Compared with larger biogas units, MicroBiogasItalia focuses on low-maintenance, farm-integrated systems suited to small and medium livestock operations.

Business Model Canvas — Key Elements	
Element	**Detail**
Value proposition	Turnkey small-scale biogas from 20 kW for livestock farms; manure-only feedstock; low maintenance
Key features	Wet or dry digestion; remote monitoring app; BioCompostMachine for digestate/compost
Reported costs	Production cost ~0.10 €/kWh; operating cost ~0.04 €/kWh
Revenue model	Equipment sales + service contracts; energy self-consumption savings; digestate valorisation
Key advantage	No energy crops needed; aligns with EU biogas guidelines; scalable from 20 kW

9.5.6 BM22 — Nenufar

BM22 — Nenufar **Floating Covers for Slurry Pits to Capture Fugitive Biogas**	
Country / Location	France
Technology category	Biogas & Biomethane
Implementation stage	Commercial

Source	HarvREStt T3.5 — CKIC Contribution
Source URL	https://nenufar.fr/

Description

Nenufar provides pneumatic floating covers for manure and digestate storage pits designed to capture biogas naturally produced during slurry storage. The system consists of a pneumatic frame and ballast that keeps the cover stable on the slurry surface, while an integrated pump removes accumulated rainwater to maintain storage capacity. Because raw biogas contains hydrogen sulphide (H2S) and moisture that can corrode downstream equipment, Nenufar incorporates a biological desulphurisation unit, an activated-carbon filter and a condensate drain to treat the captured gas for safe utilisation. Compared with uncovered pits, the system captures fugitive biogas that would otherwise be emitted to the atmosphere, turning storage emissions into surplus energy. Covering slurry also significantly reduces ammonia emissions and odour, prevents rainwater dilution (thereby increasing effective storage volume and reducing handling and spreading costs), and reduces the risk of regulatory non-compliance on emissions. The model is complementary to existing biogas plant operations and applicable independently as a standalone emissions-reduction solution.

Business Model Canvas — Key Elements	
Element	**Detail**
Value proposition	Captures fugitive biogas from slurry storage; reduces GHG emissions, ammonia and odour; increases effective storage capacity
Key system components	Pneumatic floating cover; rainwater pump; biological desulphurisation; activated-carbon filter; condensate drain
Environmental benefit	Converts storage emissions into surplus energy; reduces ammonia and H2S release
Revenue / savings	Additional biogas revenue; reduced fertiliser dilution losses; avoidance of emission penalties
Key advantage	Standalone or complementary to existing biogas plant; low complexity; fast installation

9.5.7 BM23 — Terrawatt

BM23 — Terrawatt **Pyrolysis + Biological Methanation Converting Green Waste to Biogas + Biochar**	
Country / Location	France
Technology category	Biogas & Biomethane / Biomass (Solid)
Implementation stage	7 (industrial demonstration stage)
Source	HarvREStt T3.5 — CKIC Contribution

Source URL	https://terrawatt.earth/en/home/

Description

Terrawatt integrates pyrolysis with biological methanation to convert green waste into renewable energy and carbon-rich by-products. Biomass first undergoes thermochemical treatment (pyrolysis), producing syngas and stable biochar. The syngas is then fed to methanogenic bacteria, which convert it into biogas with characteristics similar to conventional anaerobic digestion biogas, but derived from non-fermentable biomass such as woody or lignified green waste normally unsuitable for digestion. The dual output is renewable gas (biomethane after upgrading) and a biofertiliser (biochar), creating a circular model. Unlike traditional anaerobic digestion, which relies on fermentable feedstocks (manure, food waste, energy crops), Terrawatt expands the feedstock base to include materials that would otherwise go to composting or landfill. Compared with standalone pyrolysis units that generate only biochar and syngas for combustion, Terrawatt converts syngas into quality biomethane through biological methanation, increasing the value of both output streams. The technology is currently at TRL 7 (industrial demonstration stage).

Business Model Canvas — Key Elements	
Element	**Detail**
Value proposition	Valorises green waste unsuitable for digestion; dual output of biomethane + biochar/biofertiliser
Key features	Pyrolysis → syngas + biochar; syngas → biological methanation → biomethane
TRL status	7 — industrial demonstration; not yet fully commercial
Revenue model	Biomethane sales; biochar/biofertiliser sales; green waste gate fees
Key advantage	Expands biogas feedstock base beyond fermentable materials; circular dual-output model

9.5.8 BM24 — Biofrigas

BM24 — Biofrigas **Container-Based Liquid Biogas (LBG) Production from Farm and Agri-Food Waste**	
Country / Location	Sweden (international)
Technology category	Biogas & Biomethane
Implementation stage	Commercial
Source	HarvREStt T3.5 — CKIC Contribution
Source URL	https://www.biofrigas.se/en

Description

Biofrigas provides container-based CryoSep systems that enable small-scale production of liquid biogas (LBG) from farm and agri-food waste streams. Raw biogas from anaerobic digestion is processed to remove impurities (hydrogen sulphide, particles, moisture), methane is separated from carbon dioxide, and high-purity biomethane is cryogenically cooled to approximately –160 °C and liquefied. For biogas already upgraded to biomethane, the CryoSep P variant is used. LBG is significantly more transportable and energy-dense than raw biogas, enabling decentralised production for small farms or cooperatives located far from gas grid injection points. A valuable co-product is liquid biogenic CO_2, usable in food processing, industrial or greenhouse applications. Unlike conventional biogas systems where gas must be combusted on-site, Biofrigas enables conversion into a transportable, market-flexible fuel that can be sold into transport or industrial markets. Cryogenic liquefaction is more energy-intensive and technologically complex than simple upgrading, and small-scale LBG remains a niche within the broader biogas market.

Business Model Canvas — Key Elements	
Element	**Detail**
Value proposition	LBG production at farm/cooperative scale; transportable fuel enabling market access beyond gas grid connections
Key technology	CryoSep cryogenic liquefaction at ~–160 °C; CryoSep P for pre-upgraded biomethane
Co-product	Liquid biogenic CO_2 for food, industrial or greenhouse applications
Revenue model	LBG sales to transport/industrial markets; liquid CO_2 sales; no grid connection dependency
Key challenge	Higher energy intensity and capital cost than simple biogas upgrading; niche market

9.5.9 BM25 — Causeway Energies

BM25 — Causeway Energies **GeoSolar Geothermal + Solar-Thermal with Heat-as-a-Service Model**	
Country / Location	Germany (international)
Technology category	Wind Power
Implementation stage	Commercial
Source	HarvRESt T3.5 — CKIC Contribution
Source URL	https://ecoways.com/en/

Description

Causeway Energies develops geothermal and advanced heat-pump systems with a focus on thermal storage for farms with significant heating needs. Their GeoSolar solution couples geothermal resources with solar-thermal or hybrid photovoltaic-thermal (PVT) panels, enabling year-round heat supply and improved system efficiency. The GeoBattery concept captures and stores surplus or waste heat in the subsurface, making it available during winter peak-demand periods through seasonal thermal storage. This capability is particularly relevant for farms with refrigeration, processing or greenhouse heating requirements. The company's key business-model innovation is a Heat-as-a-Service financing structure that reduces the upfront capital burden typically associated with geothermal systems, which have historically suffered from high drilling and installation costs as the main barrier for farms and SMEs. While standard ground-source heat-pump systems focus primarily on efficiency, Causeway's competitive angle lies in this business model innovation combined with seasonal thermal storage to capture waste heat that would otherwise be lost.

Business Model Canvas — Key Elements	
Element	**Detail**
Value proposition	Year-round heat supply via geothermal + solar-thermal; seasonal thermal storage (GeoBattery); reduced CAPEX through Heat-as-a-Service
Key products	GeoSolar (geothermal + solar-thermal/PVT coupling); GeoBattery (seasonal thermal storage)
Business model	Heat-as-a-Service: farmer pays for heat delivered, not capital outlay
Target users	Farms with refrigeration, greenhouse heating or processing heat demand
Key advantage	Heat-as-a-Service lowers entry barrier; seasonal storage recovers otherwise lost waste heat

9.5.10 BM26 — Greenwell

BM26 — Greenwell **Repurposed Abandoned Oil & Gas Wells as Geothermal Heat Sources for Farms**	
Country / Location	United Kingdom (EU-wide target market)
Technology category	Mixed RES & Smart Management
Implementation stage	Pilot / first commercial deployment targeted 2025
Source	HarvRESt T3.5 — CKIC Contribution
Source URL	https://www.greenwell.energy/home/

Description

Greenwell repurposes abandoned oil and gas wells into geothermal heat sources for nearby agricultural or horticultural facilities. The lower section of each wellbore is plugged to prevent hydrocarbon contamination, and a closed-loop heat-exchange system is installed inside the plugged well. Cool fluid is circulated down the well and returns to the surface as heated fluid, supplying heat to adjacent farm facilities without the need for new drilling. This approach avoids the high drilling and exploration capital expenditure that is the main barrier to conventional geothermal adoption. Greenwell's delivery model is infrastructure-as-a-service: the company converts wells at its own financial risk and then leases the heated infrastructure to agricultural customers at a flat rate. This service-based model aligns with emerging geothermal trends and reduces upfront investment for farmers and greenhouse operators. Greenwell is supported by EU innovation programmes (Climate KIC and Interreg Central Europe) and targeted first commercial deployment in 2025. Performance depends on well depth and local geology.

Business Model Canvas — Key Elements	
Element	**Detail**
Value proposition	Geothermal heat from repurposed oil/gas wells without drilling costs; infrastructure-as-a-service delivery
Process	Plug existing abandoned well; install closed-loop heat exchanger; circulate fluid to surface
Delivery model	Greenwell converts at own risk; farmer leases heated infrastructure at flat rate
Target users	Farms, greenhouses, food processing facilities near abandoned oil/gas wells
Support	Climate KIC; Interreg Central Europe; first commercial deployment targeted 2025

9.5.11 BM27 — M-TEC

BM27 — M-TEC **Small-Scale Wind Turbines with Wooden Blades for Farm Self-Consumption**	
Country / Location	Austria (international)
Technology category	Mixed RES & Smart Management
Implementation stage	Commercial
Source	HarvRESt T3.5 — CKIC Contribution
Source URL	https://www.mtec-systems.com/en/

Description

M-TEC provides an integrated on-farm energy management platform combining solar PV, heat generation and electricity storage into a unified system. The solution includes a 46 kWh battery with 18 kW output capacity and coordinates PV generation, heat pumps and power-to-heat devices through a central M-TEC control application to maximise self-consumption and overall energy self-sufficiency. Unlike stand-alone PV panels, separate battery units or independent heat-pump systems managed independently, M-TEC's integrated platform coordinates all components under a single energy management logic. This coordinated control significantly increases system efficiency by reducing waste from mismatched timing between generation, storage and demand. The platform is designed to optimise energy flows in real time and increase economic returns from on-farm renewable investments.

Business Model Canvas — Key Elements	
Element	**Detail**
Value proposition	Integrated control of PV + heat + battery; maximises self-consumption; single management platform
Key specs	46 kWh battery; 18 kW output; central M-TEC control app
Advantage vs. standalone	Coordinated control prevents energy waste; better ROI than independent components
Target users	Farms with combined PV, heat pump and storage investments
Revenue model	System hardware sales + energy management software

9.5.12 BM28 — Tadus E Traktoren

BM28 — Tadus E Traktoren **Small-Scale Wind Turbines with Wooden Blades for Farm Self-Consumption**	
Country / Location	Germany
Technology category	Mixed RES & Smart Management (Agri-Machinery)
Implementation stage	Near-production prototype; pre-series of 5 units planned for 2026
Source	HarvREStT3.5 — CKIC Contribution
Source URL	https://www.tadus.com/

Description

Tadus is developing the T16.20 electric tractor, a near-production prototype delivering up to 160 hp, equipped with a swappable 200 kW battery system and an intelligently controlled multi-motor drivetrain. A pre-series of five units is planned for first customers in 2026. The swappable battery system directly addresses a key limitation of early electric tractors: downtime during recharging, which reduces operational time relative to diesel equivalents. Compared with diesel tractors, Tadus highlights up to 75% lower operating costs when paired with self-generated renewable electricity. Unlike smaller electric tractors now entering the market (typically below 100 hp), Tadus targets the mid-power segment (above 100 hp) where electric options remain very limited. The machine is designed to power from on-farm renewable electricity, making it particularly relevant for farms already investing in PV or wind, where the fuel cost effectively approaches zero and the lifecycle carbon footprint is substantially reduced.

Business Model Canvas — Key Elements	
Element	**Detail**
Value proposition	160 hp electric tractor with swappable battery; eliminates recharging downtime; up to 75% lower operating costs vs. diesel
Key specs	T16.20; 160 hp; 200 kW swappable battery; multi-motor drivetrain
Target market	Mid-power segment (>100 hp) where electric options remain scarce
Commercial status	Near-production prototype; pre-series of 5 units for 2026
Revenue model	Tractor hardware sales; particularly attractive when paired with on-farm RES

9.6 Business Models from Literature Review

This section presents the six business models included in the HarvRESt catalogue on the basis of published academic literature. These models are well-established in European and international contexts. For each model, the key reference is cited and the direct publication link is provided.

9.6.1 BM29 – Community Biogas Cooperative

BM29 – Community Biogas Cooperative **Shared Manure → Energy + Digestate**	
Country / Location	Denmark / Germany (well-established clusters)
Technology category	Biogas & Biomethane
Ownership	Community / Cooperative
Source	Literature review
Key reference	Raven, R.P.J.M. & Gregersen, K.H. (2007). Biogas plants in Denmark: successes and setbacks. Renewable and Sustainable Energy Reviews, 11(1), 116–132.
Publication link	https://doi.org/10.1016/j.rser.2004.12.002

Description

In this model, multiple farms pool manure and organic residues to supply a central community biogas plant. Members share capital investment (CAPEX), receive revenues from energy sold (heat, electricity, or biomethane), and receive digestate returned as organic fertiliser. Governance is collective, with each member participating in plant management. This model is well established in Danish and German biogas clusters, where it developed from the 1980s onward as a cooperative response to the energy crisis and national biomass policy. The foundational reference (Raven & Gregersen, 2007) documents the rise of centralised cooperative biogas plants in Denmark, where groups of farmers cooperate to supply manure to a centrally located biogas plant, share ownership, and distribute both energy revenues and digestate. The cooperative structure fits established Danish and German traditions of farmer cooperation. It provides economies of scale inaccessible to individual farms and enables better technology, higher biogas yields and more effective nutrient management. The main challenges include governance complexity, logistics of manure transport, and shared financial risk.

Business Model Canvas — Key Elements	
Value proposition	Economies of scale; shared investment risk; collective digestate management; group access to biogas technology
Key actors	Member farms (feedstock supply and governance), centralised biogas plant operator, energy buyers, advisors
Revenue streams	Energy sales (heat, electricity, biomethane) shared among cooperative members; digestate reduces fertiliser costs
Key challenges	Governance complexity; manure transport logistics; shared financial risk; regulatory coordination

Geographic context	Well established in Denmark and Germany; emerging in other EU contexts

9.6.2 BM30 – Agrivoltaic

9.6.2.1 BM30 – Agrivoltaic **Agrivoltaic ESCO / Lease Model for Farms**	
Country / Location	EU (France, Germany primarily)
Technology category	Solar & Agrivoltaics
Ownership	Third-party managed (ESCO / Lease)
Source	Literature review
Key reference 1	Weselek, A. et al. (2021). Agrivoltaic system impacts on microclimate and yield of different crops within an organic crop rotation in a temperate climate. Agronomy for Sustainable Development, 41(5), 59.
Publication link 1	https://doi.org/10.1007/s13593-021-00714-y
Key reference 2	Dinesh, H. & Pearce, J.M. (2016). The potential of agrivoltaic systems. Renewable and Sustainable Energy Reviews, 54, 299–308.
Publication link 2	https://doi.org/10.1016/j.rser.2015.10.024

Description

In this model, an energy company installs agrivoltaic panels on farmland under a lease agreement. The farmer receives land rent payments and discounted electricity; the energy company sells surplus electricity to the grid or via Power Purchase Agreements. This arrangement reduces the farmer's CAPEX to zero while transferring long-term revenue to the ESCO. The farmer benefits from land monetisation without investment and from cheaper on-site electricity. The energy company benefits from a long-term revenue stream from electricity sales. The Weselek et al. (2021) study (Heggelbach, Germany) is one of the most cited research validations of agrivoltaic dual-use systems, demonstrating that up to 60–70% of crop-available radiation can be maintained under the modules. Dinesh & Pearce (2016) provided the foundational economic case that agrivoltaic systems can create over 30% higher economic value from farms deploying dual-use systems versus conventional agriculture with shade-tolerant crops.

Business Model Canvas — Key Elements	
Value proposition	Zero CAPEX for farmer; land rent income; discounted electricity; ESCO sells grid electricity
Key actors	Energy company / ESCO (installer, owner, seller), farm (land provider, electricity buyer)
Revenue streams	ESCO: grid electricity sales / PPA; farmer: land rent + below-market electricity
Key challenges	Long contractual lock-in; land-use regulations; compatibility with CAP payments; crop yield impact

Evidence base	Weselek et al. (2021) Heggelbach, Germany; Dinesh & Pearce (2016) economic modelling

9.6.3 BM31 Small-Scale Run-of-River Micro-Hydro

9.6.3.1 BM31 – Small-Scale Run-of-River Micro-Hydro **Small-Scale Run-of-River Micro-Hydro — ESCO Model**	
Country / Location	EU (Alpine regions: Austria, Switzerland, Norway)
Technology category	Hydroelectric
Ownership	Third-party managed (ESCO / Lease)
Source	Literature review
Key reference 1	Paish, O. (2002). Small hydro power: technology and current status. Renewable and Sustainable Energy Reviews, 6(6), 537–556.
Publication link 1	https://doi.org/10.1016/S1364-0321(02)00006-0
Key reference 2	Bracken, L.J. et al. (2014). Micro-hydro power in the UK: The role of communities in an emerging energy resource. Renewable Energy, 75, 367–373.
Publication link 2	https://doi.org/10.1016/j.enpol.2013.12.046

Description

In this model, an energy company installs and operates micro-hydro turbines on farms or rural sites with appropriate water rights, leasing the water resource from the farmer. The farmer receives royalties or land rent with no capital outlay; the company sells the generated electricity to the grid or under a PPA. This provides the farmer with passive income and reliable electricity access without any technical complexity. Paish (2002) is the foundational technical reference on small-scale and micro-hydro technology, confirming that small hydro is one of the most cost-effective and environmentally benign renewables, particularly for European rural contexts. Bracken et al. (2014) analyses the community and governance dimensions of micro-hydro in the UK, highlighting the importance of community-based ownership models and the environmental dimension of hydro resource rights. Both references confirm that micro-hydro is technically mature, highly reliable (50+ year system life) and particularly relevant in water-rich Alpine, Norwegian and Atlantic-coast EU regions.

Business Model Canvas — Key Elements	
Value proposition	Passive income for farmer (royalties/rent); zero CAPEX; ESCO installs/operates; clean baseload power
Key actors	Energy company / ESCO (installer, operator, seller), farm (water rights holder, lessor)
Revenue streams	ESCO: grid electricity sales / PPA; farmer: royalties or land rent
Key challenges	Requires suitable water resources and legal water rights; environmental permitting; hydrology risk

Geographic context	Alpine regions (Austria, Switzerland), Norway, UK upland areas; water-rich EU regions

9.6.4 BM32 – Community Wind Cooperative for Agricultural Areas

9.6.4.1 BM32 – Community Wind Cooperative for Agricultural Areas **Community Wind Cooperative for Agricultural Areas**	
Country / Location	EU (Denmark, Germany, Netherlands — well established)
Technology category	Wind Power
Ownership	Community / Cooperative
Source	Literature review
Key reference 1	Huybrechts, B. & Mertens, S. (2014). The relevance of the cooperative model in the field of renewable energy. Annals of Public and Cooperative Economics, 85(2), 193–212.
Publication link 1	https://doi.org/10.1111/apce.12038
Key reference 2	Bauwens, T., Gotchev, B. & Holstenkamp, L. (2016). What drives the development of community energy in Europe? The case of wind power cooperatives. Energy Research & Social Science, 13, 136–147.
Publication link 2	https://doi.org/10.1016/j.erss.2015.12.016

Description

In this model, groups of farmers and local community members co-invest in wind turbines, sharing capital costs and revenues proportionally. The cooperative owns the turbines collectively, with members participating democratically in governance decisions. This model is well established in Denmark, Germany and the Netherlands, where community wind cooperatives have been a core driver of rural renewable energy deployment for decades. Huybrechts & Mertens (2014) provide the theoretical foundation for cooperative energy models, demonstrating that cooperatives reduce transaction costs, generate economies of scale and enhance social acceptance of renewable energy projects. Bauwens et al. (2016) analyses the specific conditions that drive wind cooperative development across four European countries (Denmark, Germany, Belgium and the UK), identifying the role of supportive policy frameworks, cooperative culture, and inter-organisational networks. Both studies confirm that community ownership significantly improves social acceptance of wind turbines and keeps energy revenues within rural territories.

Business Model Canvas — Key Elements	
Value proposition	Shared wind investment; community ownership of revenues; improved social acceptance; rural economic retention

Key actors	Cooperative members (farmers + community), turbine manufacturers, grid operators, municipal authorities
Revenue streams	Grid electricity sales shared among cooperative members proportionally to investment
Key challenges	Governance complexity; capital raising among multiple small investors; regulatory requirements for cooperatives
Geographic context	Well established in Denmark, Germany, Netherlands; growing in Belgium, UK, Spain, Italy

9.6.5 BM33 – Green Hydrogen from Farm RES for Agricultural Machinery

9.6.5.1 BM33 – Green Hydrogen from Farm RES for Agricultural Machinery **Green Hydrogen from Farm RES for Agricultural Machinery**	
Country / Location	EU (pilot projects)
Technology category	Hydrogen
Ownership	Farmer-owned / Independent (or cooperative)
Source	Literature review
Key reference	Sgobbi, A. et al. (2016). How far away is hydrogen? Its role in the medium and long-term decarbonisation of the European energy system. International Journal of Hydrogen Energy, 41(1), 19–35.
Publication link	https://doi.org/10.1016/j.ijhydene.2015.09.004

Description

In this business model, excess renewable electricity generated by on-farm solar PV or wind turbines is used to produce green hydrogen through on-site electrolysis. The hydrogen is then used in two ways: to fuel hydrogen fuel-cell tractors and other farm machinery (replacing diesel), or to sell to local mobility hubs or industrial buyers, providing a secondary revenue stream. This model eliminates fossil diesel costs for machinery, enables deeper on-farm decarbonisation beyond electricity uses, and provides a storage mechanism for surplus electricity generation. The Sgobbi et al. (2016) reference, produced by the European Commission's Joint Research Centre, analyses hydrogen's role in European energy system decarbonisation using the JRC-EU-TIMES model and confirms that electrolysers powered by excess renewable electricity can provide grid flexibility while producing clean fuel. Real-world demonstrations include Fendt's H2Agrar project (Lower Saxony, Germany, 2023), New Holland's NH2 fuel-cell tractor, and various Horizon Europe initiatives. The key barriers remain high electrolyser costs, hydrogen storage infrastructure at farm scale and limited availability of fuel-cell agricultural machinery at commercial scale.

Business Model Canvas — Key Elements	
Value proposition	Eliminates diesel costs for farm machinery; decarbonises hard-to-electrify operations; monetises excess RES

Value chain	Excess PV/wind electricity → on-farm electrolyser → hydrogen storage → fuel-cell tractor OR sale to local hubs
Revenue streams	Diesel cost savings; potential hydrogen sales to transport/industrial buyers
Key challenges	High electrolyser CAPEX; hydrogen storage infrastructure; very limited commercial fuel-cell tractors; safety regulations
Real-world examples	Fendt H2Agrar project (Germany, 2023); New Holland NH2 tractor; H2arvester (see BM18)

10 ANNEX 3: Business Model Evaluation Matrix

HarvREStt — Business Model Evaluation		CONSOLIDATED EXPERT SCORING SUMMARY									
ID	Business Model Name	Technology	Country	Source	AVG Market Integration	AVG WEF Nexus	AVG Strategic Resiliency	AVG Replicability / Scalability	AVG Circularity / sustainability	AVG Attractiveness for Agriculture Players	AVG Attractiveness for Energy Players
BM01	Biogas → Biomethane with Grid Injection (Single Off-Taker)	Biogas & Biomethane	Spain (Lleida)	Use Case	3,2	3,0	3,2	2,4	3,6	3,2	3,1
BM02	Biogas Planning & Decision-Support Tool (National Scale)	Advisory & Planning / Biogas	Denmark (national)	Use Case	2,5	2,8	2,5	3,5	3,2	2,6	2,7
BM03	Agrivoltaic Pilot on Vineyard: Electricity Cost Reduction + Wine-Climate Resilience	Solar & Agrivoltaics	Spain (Toledo)	Use Case	2,4	3,2	2,5	2,6	2,5	3,2	2,5
BM04	Integrated Energy Management for Sustainable Winery (PV + BESS + Electric Machinery)	Mixed RES & Smart Management	Spain (Huesca)	Use Case	2,7	3,1	3,4	2,9	2,8	3,5	2,7
BM05	Triple-Action RES Transition in Italian Agrivoltaic Farming (FSDC)	Solar & Agrivoltaics	Italy (Lazio)	Use Case	2,5	3,0	2,6	2,5	2,6	3,3	2,5
BM06	Multi-Source RES Integration for Energy-Independent Meat Production Farm	Mixed RES & Smart Management	Norway (Rogaland)	Use Case	3,0	3,4	3,9	2,4	2,5	3,4	2,3
BM07	Farm-Scale Biogas CHP: Waste Intake + Self-Consumption + Grid Sale	Biogas & Biomethane	Spain (Girona)	Survey	2,8	2,7	3,5	3,2	3,0	3,4	2,7
BM08	Biogas from Farm Waste with Circular By-products (ESCO-supported)	Biogas & Biomethane	Spain	Survey	2,5	2,7	2,6	3,0	3,7	3,2	2,2
BM09	Integrated Waste Management, Biofertiliser Production & RE (Community Model)	Biogas & Biomethane	Spain (national)	Survey	2,7	2,9	2,7	2,8	3,7	2,7	2,7

BM10	Self-Consumption Biogas CHP on Pig Farm (Full Energy Autonomy)	Biogas & Biomethane	Spain	**Survey**	**1,5**	**2,9**	**3,5**	**2,8**	**3,4**	**3,3**	**1,7**
BM11	Bioenergy Cluster Facilitating New Valorisation Pathways	Advisory & Planning / Biogas	Spain (Catalonia)	**Survey**	**2,2**	**2,1**	**2,2**	**2,2**	**2,5**	**2,1**	**2,1**
BM12	Organic Cooperative: Full Agri-Food Value Chain + PV Self-Consumption + Participatory Certification	Biomass / Solar & Agrivoltaics	Italy (Abruzzo)	**Survey**	**2,1**	**2,9**	**2,9**	**2,5**	**3,3**	**3,3**	**1,6**
BM13	Integrated Agri-Food Production with Solar Self-Consumption + Social Agriculture	Solar & Agrivoltaics	Italy (Lazio)	**Survey**	**2,6**	**3,1**	**3,4**	**2,5**	**3,0**	**3,5**	**1,9**
BM14	Experimental Agrivoltaic on Apple Orchards (Research & Knowledge Model)	Solar & Agrivoltaics	Spain (Lleida)	**Survey**	**2,0**	**3,1**	**2,9**	**2,8**	**2,5**	**3,1**	**2,0**
BM15	Agrivoltaic R&D for Regional Agricultural Sector	Solar & Agrivoltaics	Spain (Basque Country)	**Survey**	**1,5**	**2,8**	**2,1**	**2,4**	**2,7**	**2,3**	**1,6**
BM16	Farmers' Association — Advisory, Lobbying & Subsidy Facilitation for RES	Advisory & Planning Tools	Spain (Toledo)	**Survey**	**1,9**	**2,3**	**2,5**	**2,8**	**1,8**	**3,0**	**1,4**
BM17	Next2Sun: Vertical Bifacial PV (Fields2Sun / Fence2Sun) for Agrivoltaics	Solar & Agrivoltaics	Germany	**Net Zero Insights**	**3,4**	**2,0**	**2,9**	**3,4**	**2,3**	**3,1**	**3,2**
BM18	H2arvester: Mobile Agrivoltaic System with Green Hydrogen Production	Solar & Agrivoltaics / Hydrogen	Netherlands	**Net Zero Insights**	**2,0**	**2,0**	**2,0**	**1,7**	**2,8**	**2,5**	**2,1**
BM19	GVS Solar: Mobile Off-Grid Solar Irrigation System with AI Water Management	Solar & Agrivoltaics	International (Spain focus)	**Net Zero Insights**	**2,5**	**3,3**	**3,2**	**2,9**	**2,5**	**3,5**	**2,1**
BM20	Ecoways: Small-Scale Wind Turbines with Wooden Blades for Farm Self-Consumption	Wind Power	Germany (international)	**Net Zero Insights**	**2,5**	**1,5**	**2,9**	**2,6**	**2,3**	**2,3**	**2,7**
BM21	MicroBiogasItalia: Small-Scale Livestock Biogas Plants (from 20 kW)	Biogas & Biomethane	Italy	**Net Zero Insights**	**2,3**	**2,8**	**3,2**	**3,5**	**3,2**	**3,6**	**1,7**
BM22	Nenufar: Floating Covers for Slurry Pits to Capture Fugitive Biogas	Biogas & Biomethane	France	**Net Zero Insights**	**1,5**	**2,0**	**2,3**	**2,8**	**2,9**	**2,9**	**2,3**

BM23	Terrawatt: Pyrolysis + Biological Methanation Converting Green Waste to Biogas + Biochar	Biogas & Biomethane / Biomass	France	**Net Zero Insights**	**2,5**	**3,0**	**3,2**	**3,0**	**3,6**	**3,5**	**2,9**
BM24	Biofrigas: Container-Based Liquid Biogas (LBG) Production from Farm and Agri-Food Waste	Biogas & Biomethane	Sweden (international)	**Net Zero Insights**	**3,0**	**2,6**	**2,9**	**2,5**	**3,5**	**3,1**	**3,3**
BM25	Causeway Energies: GeoSolar Geothermal + Solar-Thermal with Heat-as-a-Service Model	Mixed RES & Smart Management	Ireland (international)	**Net Zero Insights**	**2,5**	**2,5**	**3,4**	**2,5**	**2,6**	**3,1**	**3,0**
BM26	Greenwell: Repurposed Abandoned Oil & Gas Wells as Geothermal Heat Sources for Farms	Mixed RES & Smart Management	United Kingdom (EU-wide)	**Net Zero Insights**	**2,3**	**2,6**	**2,8**	**1,5**	**2,5**	**2,6**	**2,9**
BM27	M-TEC: Integrated On-Farm Energy Management (PV + Heat + Battery Storage)	Mixed RES & Smart Management	Austria (international)	**Net Zero Insights**	**3,1**	**1,8**	**3,1**	**3,6**	**2,2**	**3,5**	**2,2**
BM28	Tadus E Traktoren: High-Power Electric Tractor with Swappable Battery System	Mixed RES & Smart Management	Germany	**Net Zero Insights**	**1,6**	**1,5**	**2,7**	**3,1**	**2,5**	**3,3**	**1,7**
BM29	Community Biogas Cooperative: Shared Manure → Energy + Digestate	Biogas & Biomethane	Denmark / Germany	**Literature**	**2,9**	**3,2**	**3,4**	**2,7**	**3,7**	**3,6**	**2,1**
BM30	Agrivoltaic ESCO / Lease Model for Farms	Solar & Agrivoltaics	EU (France, Germany)	**Literature**	**3,9**	**2,5**	**2,6**	**3,6**	**2,3**	**3,7**	**3,6**
BM31	Small-Scale Run-of-River Micro-Hydro – ESCO Model	Hydroelectric	EU (Alpine regions)	**Literature**	**3,8**	**3,3**	**3,2**	**2,5**	**2,7**	**3,5**	**3,7**
BM32	Community Wind Cooperative for Agricultural Areas	Wind Power	EU (Denmark, Germany, Netherlands)	**Literature**	**3,5**	**1,9**	**3,0**	**2,7**	**2,5**	**3,3**	**3,0**
BM33	Green Hydrogen from Farm RES for Agricultural Machinery	Hydrogen	EU (pilot projects)	**Literature**	**2,5**	**1,9**	**2,7**	**2,3**	**3,2**	**2,3**	**2,3**

11 ANNEX 4: Policy actors interviews

The study's question: How can policy and regulations support the sustainable production of renewable energy on farms in the EU?

Study's propositions: That there are certain policy barriers that need to be addressed and that there are enablers that could be used to better support RES on farms. These include:

Barriers:

- Long and difficult administrative processes (such as permitting)
- Regulatory misalignment between land, energy and food.
- High CAPEX
- Gaps in knowledge and skills

Levers:

- Clear definitions and frameworks for multi-functional land-use at regulatory level
- Access to infrastructure for energy sharing
- Access to subsidies and financing
- Cross-collaboration between policy actors and industry

Sources : (Annex 1), (Montalvo 2002, Diaz Lopez, Tukker et al. 2009, Piterou and Coles 2020, IRENA and FAO 2021, Wainer, Petrovics et al. 2022, Chatzipanagi, Taylor et al. 2023, Karanjikar, Patange et al. 2024, Okodoi and Kisiangani 2024, Boros, Martin et al. 2025, Mehta, Jain et al. 2025, Mwangi, García et al. 2025, Alves, da Costa et al. 2026, European Court of Auditors 2026)

Unit of analysis: The implementation of RES on agro-farms.

Methods: No policy actors participated in the HarvRESt survey (Annex 1), so in a second round, we asked three policy actors from Spain, Norway and Germany to fill in the survey and conducted semi-structured interviews with them to get a pan-European perspective and to add depth to the survey responses. The participants were:

- Germany: Policy officer at NABU (Nature and Biodiversity Conservation Union);
- Spain: Director of Studies, Regulatory and Environmental Affairs at UNEF – Spanish PV Association;
- Norway: Senior municipal official & former county environmental director.

Interview results				
Current role & country	Policies & national strategies identified	Policy barriers identified	Levers & pathways for policy development	Other key perspectives identified
Germany - Policy officer	• Germany has one of the few national definitions of agrivoltaics, approved at EU level • Historical support for biogas and biofuels, now viewed critically due to land pressure • Growing support for PV, including agri-PV, though with shifting priorities towards large-scale PV	• Legal uncertainty around long-term land status after PV installation (e.g. classification after 20–25 years) • Potential loss of CAP direct payments on land used for PV • Taxation and inheritance issues for next generation of farmers • Complexity and lack of accessible guidance for farmers	• Need for an EU-wide definition of agrivoltaics and multifunctional farming • Better integration of agrivoltaics into CAP support mechanisms • Stronger farmer participation in renewable energy planning processes • Promotion of cooperative and shared-value project models	• Emphasises land-use pressure and social acceptance in rural areas • Highlights tension between environmental NGOs, farmers, and PV developers • Notes farmers' limited time and capacity to navigate complex administrative systems
Spain - Director of Studies, Regulatory and Environmental Affairs at a Spanish PV Association.	• National funding programs from the Ministry for Ecological Transition (innovative renewables calls in 2024–25) • Regional programs (mainland Spain, Islands - Minorca, Mallorca, Ibiza-, Canary Islands) specifically supporting agri-PV • Ministry of Agriculture pilot funding via Operational Groups (innovation & digitalisation) • In progress currently: digitalisation of farming	• No legal definition or regulatory framework for agrivoltaics in Spain • Fragmentation across agriculture, energy, and industrial permitting • Land-use change requirements despite continued agricultural activity • Very long permitting timelines (up to 6 years) • High grid connection fees and saturated grid capacity	• Establishment of a clear legal definition of agrivoltaics • Creation of one-stop-shop permitting for farmers • Faster, parallelised permitting procedures • Reserving grid capacity quotas for agri-PV or multifunctional projects • EU-level alignment on business models, rather than regulatory detail	• Strong emphasis on economic balance between agriculture and energy revenues • Warns that agriculture alone rarely sustains agri-PV business cases • Frames agrivoltaics primarily as a business model challenge, not only a policy one

Norway – Senior municipal official & former county environmental director.	• Municipal climate funds directly supporting farm-level energy projects • National schemes: Klimasats, Bionova, and Enova for emissions reduction and farm innovation • Longstanding reliance on hydropower as national energy backbone	• Monopolistic grid structure prevents local energy sharing between farmers • Strong protection of incumbent energy companies • Centralised state control over energy regulation; limited municipal authority • Cultural landscape protection restricts ground-mounted solar and wind • Persistent debate over biogas from manure (nutrient loss concerns)	• Expansion of pilot projects to test local energy sharing models • Policy adjustments to allow energy communities / local hubs • Greater focus on roof-integrated solar and aesthetic integration • Economic risk-sharing to enable farmer investment • Learning from peer countries (Denmark, Iceland)	• Strong systems perspective linking agriculture, grids, resilience, and landscape • Highlights farmer interest hindered by regulation, not motivation • Emphasises beauty, cultural heritage, and social acceptance as core policy constraints

Cross-cutting observations:

Across all three interviews, the **absence or ambiguity of clear legal definitions for renewable energy use in farming** emerges as a foundational barrier. Where definitions exist (e.g. agrivoltaics in Germany), they provide a basis for policy support but remain insufficiently embedded in agricultural payment schemes and long-term land-use rules. In contrast, Spain's lack of a formal definition and Norway's sectoral separation of energy and agriculture generate legal uncertainty that discourages farmer participation.

A second cross-cutting issue is the **fragmentation and complexity of permitting and governance frameworks**. Interviewees consistently highlight misalignment between agricultural, energy, environmental, and industrial regulations, resulting in long permitting timelines, duplicated procedures, and high transaction costs. This is particularly problematic for farmers, who often lack the administrative capacity or technical expertise to navigate multi-layered regulatory systems.

Economic viability and risk distribution are identified as decisive conditions for uptake in all contexts. Even where funding schemes or pilot programmes exist, interviewees stress that renewable energy investments must make financial sense for farmers and not jeopardise core agricultural income streams (e.g. CAP payments, land value, or inheritance). High grid connection fees, uncertain revenues, and uneven benefit-sharing between energy developers and farmers further undermine project feasibility.

Finally, the interviews underline the importance of **social acceptance, landscape values, and local governance** in shaping policy outcomes. Concerns over land competition, aesthetics, and cultural landscapes strongly influence political and community support, particularly in rural and environmentally sensitive areas. As a result, interviewees point to pilot projects, cooperative models, and locally embedded solutions as essential pathways for testing policy innovations and building trust before broader regulatory scaling.

HarvRESt
Greener Farming with RES

The project

The HarvRESt project aims to enhance the sustainable production of renewable energy at farm-level. This approach not only makes farms climate-neutral but also optimizes production, reduces their impact on natural resources and biodiversity, and provides energy services to communities, thereby diversifying economic income. However, deciding how best to integrate renewable energy sources (RES) on a farm is not without its challenges. The decision is a complex one, with many factors to consider. Due to this, HarvRESt seeks to identify, understand, and overcome the existing barriers hindering the widespread adoption of this innovative approach. Current initiatives often overlook the complex interactions and factors within the farming and RES context, resulting in ineffective support for decision-making based on accurate projections, estimations, and forecasts. HarvRESt will therefore consolidate and enhance existing knowledge, creating an Agricultural Virtual Power Plant capable of running diverse scenarios and farm configurations. This tool will determine the best operational procedures for a given RES solution, providing valuable data to a decision support system. This system will weigh trade-offs and key indicators, offering tailor-made recommendations to farmers and policymakers.

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