Ref. Ares(2023)6624226 - 30/09/2023

AGRO FOSSIL FREE

Report on identified policy gaps and policy guidelines

Del 3.7.

Type: Report, Deliverable Title: Report on identified policy gaps and policy guidelines

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement ID 101000496

Document Summary

Document Title: **Report on identified policy gaps and policy guidelines**

Version: **1.0**

Document Lead: **RESCOOP.eu**

Related Work package: **WP3**

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Contributor(s): **All Consortium**

Communication level: **Public (PU)**

Project Number: **101000496**

Grant Agreement Number: **101000496**

Programme: **AgroFossilFree**

Start date of Project: **October 1st, 2020**

Duration: **36 months**

Project coordinator: **Thanos Balafoutis - CERTH**

Abstract

This document provides policy recommendations on how Fossil-Energy-Free Technologies and Strategies (FEFTS) can be adopted in European farming to defossilised agricultural activities and the respective products.

After introducing the project objective, the description of the methodology to extract the information from all project's activities was provided. The combination of the literature review of current energy status in EU agriculture, a survey with farmers and experts about FEFTS adoption, the online AgEnergy Platform content, and the interactive innovation processes through workshops in national and transnational level provided the policy recommendations on how agricultural defossilisation could be achieved faster and easier.

19 Policy Recommendations/Briefs are provided, highlighting the challenge they need to overcome, the identified policy gaps and recommendations and the impact for policy makers to consider.

The developed policy guidelines on regional and EU level are proposed to be addressed by the future Common Agricultural Policy, Renewable Energy Directive, Green Deal and Farm-to-Fork strategy and upcoming legal initiatives (national and EU level) in relation to establishing a Green Europe.

In the Annex, 19 one-page Policy Briefs of the AgroFossilFree project are given for dissemination and communication reasons.

Contents

1. INTRODUCTION

AgroFossilFree is a Horizon 2020 CSA project whose main objective is to create a framework under which all core stakeholders will cooperate to evaluate and promote the currently available fossil-energy-free technologies and strategies (FEFTS) in EU agriculture to decrease in the short term and eliminate in the long run the use of fossil energy in open-field crop production and controlled environment agricultural constructions from cradle to farm gate, while maintaining yield and quality of the end product offered to consumers in a cost efficient manner. Such a framework will contribute to bridging the gap between the available novel high-end clean energy solutions and the everyday European agricultural practices by capturing grassroots-level needs and ideas, promoting effective exchange of information, and investigating the possible financing opportunities for any de-fossilizing activity between the farming and related industry community. Ultimately, it will facilitate farmers to find solutions for their specific needs contributing towards fossil-free farming.

AgroFossilFree activated and ran for 36 months an effective exchange between research, industry, extension services and the farming community so that direct applicable research and commercial solutions on FEFTS are widely disseminated and grassroots level needs and innovative ideas thoroughly captured.

Using the EIP-AGRI “multi-actor approach”, AgroFossilFree has gathered insights on the barriers and incentives for the adoption and better uptake of novel FEFTS as well as on the needs from end-users and other stakeholders in the value chain, such as researchers, industry, and advisors. These findings were used to produce a set of policy recommendations to assist the fast adoption of FEFTS in European agriculture, which are presented in this Deliverable. In order to make these recommendations easier and faster to be read, they are given in this deliverable in policy briefs that can be widely disseminated within the agricultural community and policy makers.

The Deliverable is divided into six Chapters:

Chapter 1 – Introduction: Short overview of the project objective, the approach selected, and the results obtained.

Chapter 2 – Methodology: Description of all steps to extract the information from all project’s activities (literature review of current energy status in EU agriculture, a survey with farmers and experts about FEFTS adoption, the online AgEnergy Platform content, and interactive innovation processes through workshops in national and transnational level) and provide the policy recommendations on how agricultural defossilisation could be achieved faster and easier.

Chapter 3 – Summary of AgroFossilFree outcomes considered to produce the Policy Recommendations: Main results that contributed to identify policy gaps and respective solutions on regional and EU level, which should be addressed by the future Common Agricultural Policy, Renewable Energy Directive, Green Deal and Farm-to-Fork strategy and upcoming legal initiatives (national and EU level) in relation to establishing a Green Europe.

Chapter 4 – Policy Recommendations/Briefs: Summary of main policy recommendations for FEFTS integration in European agriculture, highlighting the challenge they need to overcome, the identified policy gaps and recommendations and the impact for policy makers to consider.

Chapter 5 – Conclusions

Chapter 6 – Annexes

2. METHODOLOGY

Process for the integration of results

AgroFossilFree is a Horizon 2020 project following the "multi-actor approach" set from EIP-AGRI, engaging stakeholders around the agricultural and energy sectors. The project applies an interactive innovation model, based on a bottom-up approach, using information gathered through surveys and workshops at the grassroots level (national) and EU level. The methodology selected to identify the policy gaps and compile policy recommendations in briefs was built on the outcomes of the project's different activities and tasks:

1. Assessment and evaluation of the current energy use status in EU agriculture through an extensive literature review.
2. Identification of existing needs and interests for the future farm energy profile by identifying factors influencing FEFTS adoption in view of regional specificities by conducting a survey with 470 farmers and 41 experts from the 8 EU participating countries.
3. Assessment of successful innovation processes in existing FEFTS.
4. Identification and registration of available and directly applicable FEFTS from applied research results to market solutions, training material and existing financing tools for defossilising activities.
5. Collaboration with relevant stakeholders in thematic groups using interactive physical and online workshops to produce community-based ideas for FEFTS integration in agricultural systems in a regional, national and EU level.
6. Creation of the AgEnergy Platform to showcase in an easy way all available FEFTS and development of a Decision Support Toolkit to propose FEFTS interventions and accompanied financing tools for the farm needs of the platform's users.

Selecting the policy guidelines that AgroFossilFree provides to agricultural and energy stakeholders was a result of all the above steps, considering the technological and socioeconomic maturity of the available FEFTS that were derived from the scientific and grey literature, the research projects run in the EU, the existing financing mechanisms in the EU for FEFTS, the market availability of FEFTS and the direct interests and ideas from the survey (511 stakeholders) and the series of workshops in national (998 stakeholders) and transnational (140 stakeholders) levels about FEFTS in European farming.

The sequence of activities and results of AgroFossilFree and their interrelation to achieve the final goal of the project to propose policies to support agricultural defossilisation is graphically depicted in Figures 2.1 and 2.2.

Figure 2.1 shows the structure of the activities (in green boxes) and the respected results (in orange bubbles) primarily on a national level and secondly on an EU level, even if all these activities were conducted in many cases simultaneously. It can be shown that the survey (WP1) to farmers and experts was conducted on a national level in the 8 participating countries and resulted in the identification of the farm energy related needs that farmers and experts have expressed, while the barriers that hinder FEFTS adoption and the respective incentives to assist defossilisation in EU agriculture were also provided (see Deliverable 1.2 and 1.3). In the meantime, on a national level the project has identified specific successful innovation processes of private or public entities that resulted in the defossilisation of agricultural practices (WP1). This activity assisted the consortium to find the reasons that even if barriers exist, these specific cases managed to overcome them and applied FEFTS in farms (see Deliverable 1.4). The last activity on a national level was the organisation of 24 regional (national) workshops (3 per country) within WP3 using a common methodology to extract more information about the needs, barriers and incentives requirements from stakeholders' point of view in different countries, assess specific popular FEFTS based on local needs and identify gaps in existing policies and incentives (see Deliverable 3.3). Moving to the EU level, AgroFossilFree project reviewed within WP1 the current status of energy use in EU farms of all kinds (open-field, livestock and greenhouses) and identified the trends of energy consumption and technologies today (see Deliverable 1.1), in order to know which is the starting point for agricultural defossilisation. In addition, the AgEnergy Platform was created (WP4) and filled with inventoried FEFTS (WP2) of all categories, based on the methodology and standards set from the beginning (see Deliverable 2.1). The content of the AgEnergy Platform refers to popular FEFTS spanning from low TRL solutions derived from scientific papers and research projects up to mature commercial technologies that can be applied directly in EU farms. Furthermore, a series of training materials about FEFTS and financing mechanisms to support the adoption of such technologies and strategies are given in the AgEnergy Platform. Finally, 3 transnational workshops (WP3) were conducted per agricultural production system category (open-field, livestock, greenhouses), in order to validate the needs, barriers and incentives discussed in the regional workshops and provide ideas on new policies and incentives suggestions to increase FEFTS adoption.

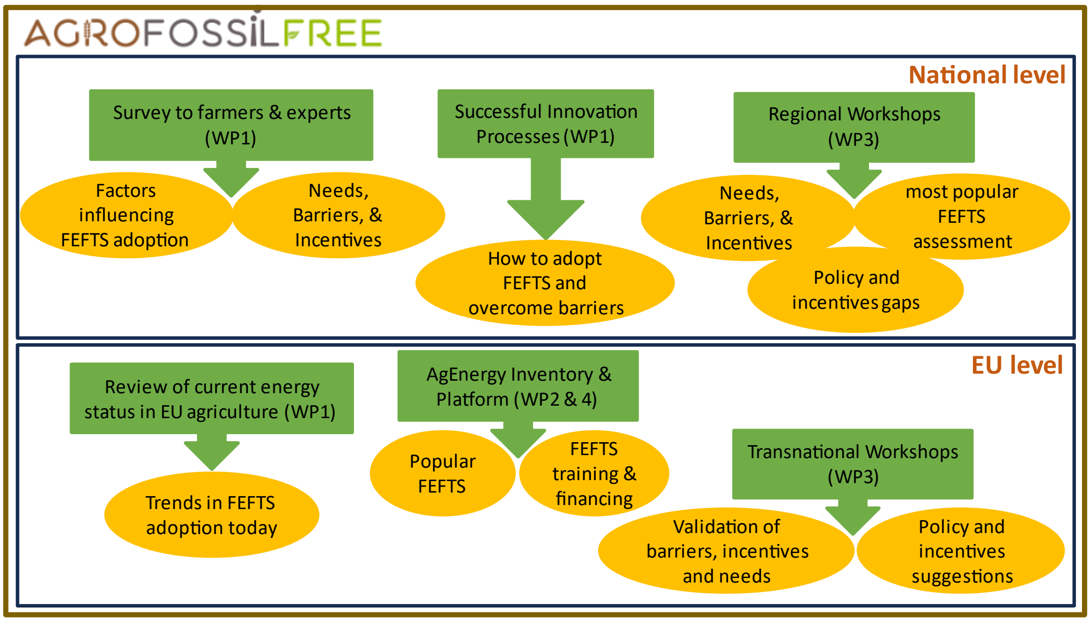

Figure 2.1. Project results that have been considered to produce the recommendations. (Above, activities and respective results at national level. Below, activities and respective results at EU level. Green boxes represent activities and orange bubbles represent results).

Figure 2.2 presents the flow of integration of project results (in orange bubbles) leading to the production of the policy recommendations and briefs. As shown, the factors influencing FEFTS adoption together with the trends of FEFTS adoption today provides a combinatory overview of the energy status in EU farms and the reasons for limited FEFTS integration currently. Both these factors provide us with the necessary background and basis for the development of impactful policy recommendations. From this, the assessment of FEFTS in regional workshops and the extensive list of FEFTS, training material and financing mechanisms in the AgEnergy Platform helped the consortium to define which technologies and strategies are considered more interesting and important for agricultural stakeholders and understand the reasons behind this selection. The recognized needs, barriers and incentives for FEFTS adoption and the ways proposed by successful cases to overcome the existing problems fed the transnational workshops' validation process and provided a mature list of actions to be included in the policy recommendations. Finally, the policy and incentives gaps identified during the regional workshops were used in the transnational workshops as the basis for suggestions from the stakeholders for new policies and incentives to defossilised agriculture.

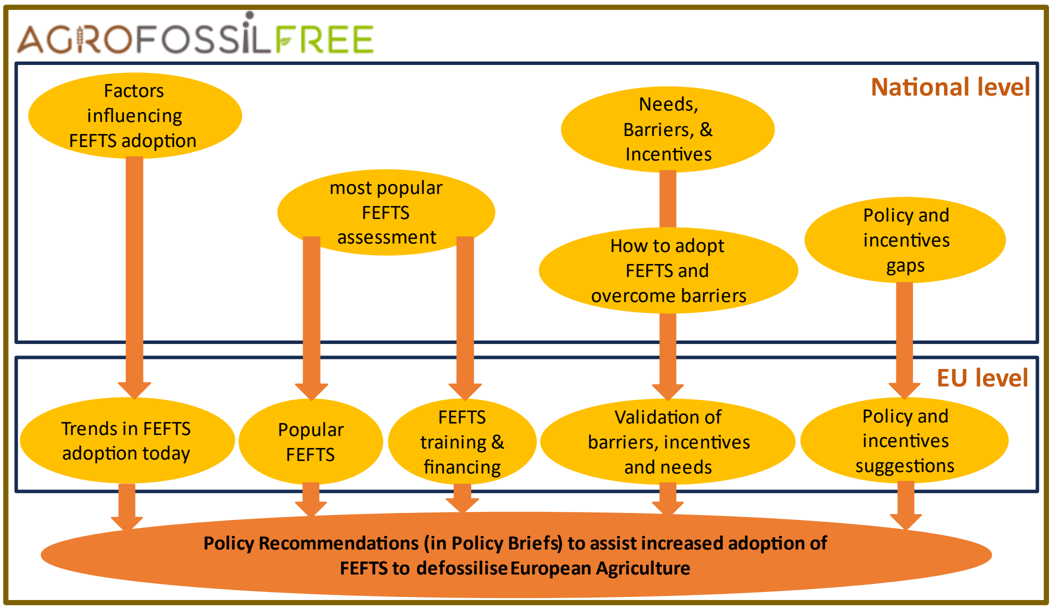

Figure 2.2. Flow of integration of project results leading to the production of the recommendations and policy briefs. (Above, project results at national level. Below, project results at EU level).

The following sections present in brief the project's outcomes that have been considered to produce the policy recommendations. For details on the methodology used to produce the individual outcomes and results, the reader is referred to the individual Deliverables.

3. SUMMARY OF AGROFOSSILFREE OUTCOMES CONSIDERED TO PRODUCE THE POLICY RECOMMENDATIONS

3.1. Current energy status in EU agriculture

AgroFossilFree has applied an operational definition of energy use in agriculture and attempted to include all operational energy use that is covered by agricultural activities and uses, both directly and indirectly. The system boundary was cradle to farm-gate and included all energy consumption up until the farm gate. Direct energy use refers to all energy inputs consumed for: on farm operations, transportation, heating and cooling, lighting, electrical equipment, machinery, automation processes, farm management and irrigation. While the main direct energy uses vary depending on the production system, in our study it was allocated according to three sectors: open-field agriculture, livestock and greenhouses. The main energy uses that the study focused on for each category were:

- Open-field agriculture (sowing, planting, tillage, application of inputs, harvesting, machinery use, irrigation and threshing, storage, grain drying).
- Livestock (crop processing and feeding, milking processes, manure handling, heating, cooling, dehumidifying and ventilation, machinery use, water heating and pumping and lighting).
- Greenhouses (on farm operations, heating and cooling, lighting, and irrigation).

Indirect energy use refers to all the energy used for the production of agricultural inputs. These inputs account for energy use that can be assigned to the agricultural sector but prior to reaching farms, including energy used in the:

- production of fertilizers (raw materials, manufacturing, transport)
- production of pesticides (raw materials, manufacturing, transport)
- production of animal feed (includes all the energy use to produce animal feed, including its raw materials)
- pumping of water to the agricultural holding
- production, storage and transportation of seeding materials

The results of this extended metanalysis of information coming from different sources of scientific literature and statistics (see Deliverable 1.1.) showed the following:

Energy use in EU agriculture is **significant and fossil fuel dependent**. According to Eurostat, agriculture accounts for 3.2% of total energy consumption, 56% of which is derived directly from crude oil and petroleum products, 17% from electricity, 14% from gas and 9% from renewables and biofuels. However, our results suggest that if indirect energy use associated with the production and transport of fertilizers and pesticides is included the proportion of energy use in the EU-27 would be **62% higher overall**.

Our results also show that energy use, its concentrations and breakdown, **vary significantly per production system** (open-field, livestock, greenhouses). According to our estimates, of the crops and production systems included in our study, the annual energy inputs for arable agriculture are 1227 PJ, for orchards and vineyards are 208 PJ, for meat production systems are 501 PJ, for dairy production systems are 543 PJ.

For open-field agriculture, our study finds that the **production and use of fertilizer is the largest energy consuming activity in EU agriculture, accounting for around 50% of all energy inputs**. On farm diesel use accounts for 30%, while electricity (for irrigation, storage and drying) accounts for 8%. Pesticides and seeds each account for 5% of total energy inputs. In all livestock systems, except for beef production systems, **animal feed is the main energy input accounting for around three quarters of all energy requirements**. The production of animal feed consumes around 60% of the cereal production in the EU and requires significant high-protein imports. On farm electricity use, which currently mainly comes from fossil sources, is also significant but varies considerably depending on the production system. In high yielding and high-energy intensive greenhouses energy use is dominated by **heating and cooling**. By contrast, lower yielding and less energy-intensive systems use little to no heating/cooling and instead energy use is mainly associated with **fertilizers, diesel use for machinery, irrigation** and other activities.

The above illustrate that for the EU to achieve the goals outlined in the Green Deal and Farm to Fork strategy, it is likely that the **adoption of non-fossil energy sources, and improvements in energy efficiency** and the further development and adoption of related technologies for agriculture is required. In addition to this, a **transition to more sustainable agricultural practices and farming systems is required**. For instance, our chapter on conservation agriculture, as an indicative example of a FEFTS, highlights that scaling of conservation agriculture can significantly reduce on farm energy use and carbon emissions as well as sequester considerable amounts of carbon (**up to 190M tonnes per year**) and improve the overall climate resilience of the agricultural sector.

This work has produced a series of recommendations on how missing information could be obtained soon:

- Immediate **increase of RES powering agricultural facilities** is necessary to overcome the clear domination of non-renewable sources use for their energy needs in the EU agricultural systems.
- Drastic **improvement of the energy efficiency** across the agricultural sector is required to accompany RES integration to primarily reduce the energy needs before covering them with non-fossil sources.
- **Unification of small holdings** (either by acquisition from larger farms or by applying modern cooperative systems between small farmers) seems necessary, as there is a general positive correlation between larger farms and energy input per hectare, while due to economies of scale, these farms are more likely to be earlier adopters of newer, more energy efficient technologies.
- **Shifting to non-conventional systems** (organic, conservation) does not necessarily mean that energy use will be reduced, but they use more sustainable energy sources.
- **Reduction of chemical fertiliser use** (mainly nitrogen) and non-locally produced **animal feed** is vital for energy (indirect) use decline in EU agriculture.

Open-field agriculture

- The use of FEFTS, such as increasing the use of **organic fertilizers** (from agricultural and other organic wastes/feedstocks) and transitioning to lower input and more sustainable production systems (such as **agroforestry**, **no-tillage,** or **conservation agriculture**) and high-tech application systems (**precision agriculture**), can reduce the fossil energy use associated with fertilizer use.
- Reduction of pesticides (accounts for 5% of the total energy inputs), could be achieved by minimising the consumption of manufactured pesticides, increasing their use efficiencies, transitioning to more sustainable production systems, and increasing the share of locally produced organic pesticides.
- On-farm diesel use is the largest direct energy carrier in open-field agriculture related mainly to soil tillage, harvesting and sowing. Using more **efficient tractor/implement combinations**, switching to **tractors powered by on-farm produced RES** (e.g., biofuels like biomethane from manure and waste residues or locally produced electricity from RES), adopting **agricultural**

practices that minimise tillage and improve farm management efficiencies, could have a large impact on overall diesel use.

- **Switching to electricity powered systems** for on-farm operations could significantly reduce the share of fossil fuels in direct energy consumption, as the EU electricity systems are rapidly transitioning to RES (reaching 34% in 2019). In addition, in many cases, electric powered systems are **more efficient** than fossil fuel powered systems.

Greenhouses

- High tech greenhouses (mainly in northern / central Europe) should focus predominantly on energy for **heating** that is dominated from fossil fuels. Sustainable sources of heat, mainly **geothermal**, have been growing rapidly, while **heat pumps** could shift heating from fossil fuels to electricity increasing efficiency and renewability through RES derived electricity.
- Low tech greenhouses (mainly in southern Europe) should mainly focus on agricultural input (fertilisers, pesticides, water) reduction to decrease their energy profile, as in open-field agriculture. These could include **reducing fertilizer and pesticide use and increasing their use efficiency**, increasing the share of RES for other energy uses (lighting, ventilation, irrigation pumping, etc.) and adopting efficient practices that minimize their use.

Livestock

- Reduction of the reliance on animal feed, **especially imported animal feed**, and decrease of the energy intensity of animal feed would reduce overall energy use.
- Further increase of the already **increased production in EU-grown soy and other protein sources** to cover the still existing significant deficit in high-protein feed.
- Possible reduction of animal product consumption through substitution with other sources of protein.
- **Finding other feedstocks for feed** other than cereals and oilseeds, which consumes high energy amounts, could reduce the energy intensity of feed (e.g., an EIP-AGRI Focus Group identified 5 new feed options - bakery products, green biomass (glass/clover), insects, micro-algae and single cell protein - for pig and poultry farming that would reduce the environmental footprint of animal feed[1]).
- Switching to more renewable electricity sources could invariably help **reduce the amount of fossil energy used for on-farm activities**, like housing (lighting, feeding and milking systems) and manure management.
- Take advantage of the potential of livestock manure as a **source of organic fertilizer** (according to the EC (2019), about 10 million tonnes of nitrogen and around 1.5 million tonnes of phosphorus are applied to EU fields through manure application), as well as for **renewable energy production** in the EU (biogas production using manure as main feedstock continuously increase and its upgrading into biomethane can realistically increase biomethane production by 18 billion m^3 across the EU in areas with high livestock densities[2]).

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[1] EIP-AGRI Focus Group. 2020. "New Feed for Pigs and Poultry Final Report.

[2] Scarlat, Nicolae, Fernando Fahl, Jean François Dallemand, Fabio Monforti, and Vicenzo Motola. 2018. "A Spatial Analysis of Biogas Potential from Manure in Europe." Renewable and Sustainable Energy Reviews 94 (October): 915–30. https://doi.org/10.1016/j.rser.2018.06.035.

3.2. Survey to farmers and experts

After the literature review analysed in Section 3.1, AgroFossilFree conducted a survey to farmers and experts to identify the needs regarding energy use in European farms, the barriers that occur when trying to shift to non-fossil practices and the required incentives to overcome the problems and cover the requirements of farming to achieve the goals of the Green Deal and the Farm-to-Fork strategy. Two questionnaires were produced based on extensive literature review (see Deliverable 1.2.) and they were used respectively to survey and interview **470 farmers** and **41 experts** (i.e., involved in agricultural technology development and innovation processes) from 8 EU countries. Farm size was the main criterion for selecting farmers to investigate the adoption (or not) of RES as well as of energy efficiency and carbon sequestration technologies and practices vis-à-vis the available innovation support systems (advisory/extension services, including training), policy dynamics, environmental limitations, and farmers' sociocultural and economic circumstances. Therefore, utilized agricultural area (UAA) or Livestock Units (LU) in each country was applied, using a first estimation of the sample (no. of farms/farmers per farm size per country) based on EUROSTAT 2013 data sets[3]. Attention was given to (a) include both adopters and non-adopters in the sample; and b) capture the different needs and priorities of farmers in relation to their different socio-economic characteristics.

As far as the experts' interviews are concerned, the target-group comprised keypersons from research, industry and practice while mainly focusing on advisors. The overall aim was to capture the wider societal environment (and processes) influencing the development, dissemination, and use of innovative FEFTS as well as to explore similarities and differences in the perception(s) of factors affecting such processes. The expert interviews were conducted face-to-face, via telephone or Skype, recorded and transcribed to produce computer-generated documents and analysed per topic[4].

The results of this extended survey are given in Deliverable 1.3., but a summary is given below:

Regarding RES, adopters said…

Out of those aware of RES 45% claimed that they *use RES* on their farms. **Solar energy is by far the most used RES on the farms** (76% of RES adopters/users), followed by **biomass/biofuels/biogas** (36%). Around two thirds of RES adopters said they had seen (**demonstration**/ other farmer) or tested the technology before getting/purchasing it. Adopters' most important source of information/ support on the *assessment* and *establishment and use* of RES are (>15% of farmers) their **own experience followed by manufacturers/dealers and private advisors**. The most common use of the energy produced with RES concerns the heating and cooling of buildings (72%) and lighting (66%) with the use of energy for farm machinery and vehicles and farming practices being considerably lower (31% and 24% respectively). Most adopters also sell energy to external consumers (62%).

More than half of the adopters said that they were motivated to use RES primarily for **economic reasons** (reduction of energy costs and price of energy sold to others/ outside the farm), this was the primary reason highlighted;; **reduction of environmental hazards** follows. Furthermore, more than two out of three adopters said that a specific subsidy gave them the opportunity to invest in RES on their farms. In general, adopters state that RES are easy to work with (82%), reliable (81%) and economically justified

[3] The analytical data concerning the size of all agricultural holdings per country, based on EUROSTAT 2013, were presented in Appendix 4, Deliverable 1.2

[4] Sarantakos, S. (2005). Social Research (3rd Edition). Basingstoke: Palgrave McMillan.

(79%). For RES maintenance and, when necessary, repairs farmers mainly rely on the manufacturer/ retailers (79%), their own experience (58%) and independent service providers (49%).

Regarding RES, non-adopters said…

Non-adopters assert that the main reason for not having/ using RES on their farms mainly owes to the fact that **they cannot afford it** (40%) followed by their consideration that the available technology is either **not the best fitting technology** for them or is **not compatible** with existing technology/ machinery/ equipment in their farm (19%). Furthermore, they claim that they would use RES if they would **get a subsidy** (90%) as well as relevant **training** (66%). They also said that the most important source of information they would trust before deciding to adopt/ use RES technology is (>10% of farmers) a **cost-benefit model** tailored to their farm, **official contacts** (with an advisor, official or someone paid for their service) and **personal trial**. Most non-adopters have seen other farms using RES and stated that this experience raised their interest in alternative energy production.

Regarding Energy Efficiency Technologies, adopters said…

60% of farmers claimed that they *use energy-saving technologies/practices* on their farms. Most adopters (59%) had seen (**demonstration**/ other farmer) or tested the technology or practice before getting/purchasing it. The most important farmers' source of information/ support on the *assessment* and *establishment and use* of these technologies/ practices are (>10% of farmers) farmers' **own experience**, national or regional agricultural (public, cooperative) **extension services**, **other farmers**, and **manufacturers/dealers**.

Economic reasons (i.e., the reduction of energy costs) was referred to as the main motivation of energy saving technologies/ practices' adopters (45%) followed by the **reduction of environmental impact** (23%) of the adopters. Only 1 out of 3 adopters said that a specific subsidy gave them the opportunity to invest in such technologies/ practices on their farm. In general, adopters state that energy efficient technologies/ practices are reliable (85%), easy to work with (82%) and economically justified (81%).

Regarding Energy Efficiency Technologies, non-adopters said…

The main reason for not having/ using energy saving technologies/ practices mainly owes to the fact that it is **not affordable** (27%), followed by their perception that the best, tailored to their situation/ production system, technology is **not available yet** (22%) and the **small farm size** (13%). Non-adopters claim that they would use energy efficient technologies/ practices if they would **get a subsidy** (96%) as well as **relevant training** (71%). According to non-adopters the most important source of information they would trust before deciding to adopt/ use energy efficient technologies/ practices are (>10% of farmers) a **cost-benefit model** tailored to their farm, **demonstrations**, and **official contacts** (with an advisor, official or someone paid for their service). Two thirds of non-adopters who have seen other farmers using energy efficient technologies/ practices claimed that this raised their interest.

Regarding Carbon Sequestration practices, adopters said…

More than 3 out of 4 of the interviewees (ca. 77%) said they utilize *manuring and fertilizing practices, cover crops and crop rotations, conservation tillage and crops residue management* with their main motivation being (>19% of farmers) the reduction of the **environmental impact** of farming, the reduction of **energy costs**, **"being a good steward of the countryside"** and the **utilization of farm by-products**. The great majority of the adopters (87%) maintained that they **did not utilize any specific external subsidy** to invest in/ apply such practices.

Regarding Carbon Sequestration practices, non-adopters said…

The main reasons for not adopting carbon sequestration practices are the **lack of appropriate/ best fitting technologies/ practices** (45%), **small farm size** and **non-affordability** (11%). Over 80% of them agreed that a subsidy and technical assistance would motivate them to apply carbon sequestration practices in their farms.

General characteristics of farmers towards new technologies…

According to the interviewed farmers, the most important RES and energy-efficiency technologies/ practices' characteristics that would make them more relevant to farmers' needs are (>80% of farmers) **long term reliability, price/ affordability, ease of use, operator safety and compatibility** with existing farm machinery.

Technology, according to the interviewees, can contribute to the **improvement of farming** (94%), assist farmers in **complying with the EU Regulations** (87%) and support the **recognition of their work** by the wider public (75%). In parallel, most of the interviewed farmers (70%) claim that they **experiment on their farms** (i.e., trying new technology or practices on the farm before they adopt it at full scale). Almost two thirds of the farmers said that they prefer to have **some experience with something before they buy** it; more than half claimed that they wait to buy new things, until they know that **others have positive experiences** with it. Nevertheless, just over 50% would buy new equipment even if their (social) environment would be negative on it.

Adopters vs non-Adopters in general…

Adopters and non-adopters of RES differ in terms of level of general and occupational education, digital skills and the frequency of Internet use, farm size, the existence of a successor, years in farming and participation in **collectives** (farmer cooperatives, association, unions, etc.). Furthermore, adopters are more likely to be full-time farmers, to have chosen agriculture as their profession (vs. family tradition), dependent in terms of the contribution of agriculture into the family income, to be more satisfied from farming as well as to be engaged in diversified on-farm activities, certification schemes and participate in CAP Pillar II projects. Additionally, adopters visit agricultural fairs, field days/demonstrations, or exhibitions more often than non-adopters. In parallel, adopters and non-adopters seem to consider different sources of awareness as being the most important to them.

Adopters put less emphasis than non-adopters in their evaluation of the importance of the characteristics of RES that would make them more relevant to farmers' needs. Although adopters are not stronger believers in technology, they are keener to experiment on their farms. Moreover, they are more likely to be the first in their social circle both to know about and buy new machinery/ technology and they would buy something new despite the negative attitude of their social environment and are not afraid of taking risks in farming.

The same differences hold also in the case of *adopters vs. non-adopters of energy efficiency technologies/ practices*. In this case, though, adopters seem to be stronger believers in technology (but not in its contribution to the recognition of farmers' work).

Most of these differences are found in the case of *adopters vs. non-adopters of carbon sequestration practices* as well. In this case though, adopters are younger, believe that technology supports the recognition of farmers' work and even if they are more likely to be the first in their social circle to know about new technology/ practices they are not the first to buy. Adopters and non-adopters do not differ in terms of farm size, occupational status (full-time vs. part-time farmers), the identification of a successor, the frequency of visits to agricultural fairs, field days/demonstrations or exhibitions, the sources of awareness as being the most important to them or their attitudes towards risk aversion.

Finally, it must be underlined that the adoption of RES, energy efficiency technologies/ practices and carbon sequestration practices are correlated.

What experts believe about RES…?

They argue in favour of RES and energy-saving technologies/ practices in facing the current problems of farming and the society at large. Experts agree that such technologies/ practices are beneficial to farmers in terms of both **economic viability** and **environmental sustainability** as well in improving the public image of farmers; they also assist in **farm diversification** and the **generation of employment in rural areas**. For the adoption of RES and energy saving technologies and practices in agriculture the relevant mix of **policies has to be reliable in the long-term** (i.e. not to change often as this creates insecurity to farmers), **provide sufficient financial incentives** (so that the investment will prove profitable) and take care of the dissemination of reliable information (including **extension/ advisory and educational/ training** services for farmers); **avoidance of cumbersome procedures** is also strongly recommended.

Overall, experts argue that while environmental and societal pressures may be important, it is **the economic advantage** (reduction of energy costs or energy sales to external consumers) which is the main driver for most farmers to adopt RES and energy saving technologies/ practices. On the other hand, experts agree that **high upfront/investment/installation costs** comprise the most important RES disadvantage along with the fact that **return on investment may take (depending on the technology used) a long time**. Therefore, there is need to financially support farmers, especially the **small and medium ones**. These opinions correlate with the findings from the farmer surveys.

Experts identified the same differences between adopters and non-adopters identified in the preceding (survey) analysis. Furthermore, they assert that despite the availability of RES and energy-saving technologies in the market, these need to be **further developed for farms' needs**. It is acknowledged that in most of the countries of AgroFossilFree, **farmers are largely neglected within the national AKIS**, while a **lack of functional AKIS/ innovation platform(s) in the field of RES** and energy efficient technologies/ practices has to be underlined.

This work has produced a series of recommendations about the needs of farms in terms of energy, the barriers hindering FEFTS adoption and the incentives that should be given to farms:

Needs of farms in terms of energy

- Most farms have continuous accessibility to energy carriers (electricity, fuels), but need renovation, as infrastructure and machinery are in many cases obsolete.
- Cost of energy carriers increase significantly over the years, pressing down the profit margin of farms.
- Dependency on external suppliers of energy carriers affects substantially the decisions of farms.
- Unsustainable energy use influences the "green" image of European farms.
- Conventional farming practices are fossil fuel dependent, leaving European farmers behind the future developments.
- Reduced agricultural practices and reuse of farms' by-products is necessary to assist soil fertility preservation and reduction of chemical agricultural inputs (indirect energy use), but also can bring farmers into the future carbon market, increasing their income in a sustainable manner.

- RES integration (especially solar and biomass/biofuel/biogas technologies) for local clean energy production (for self-consumption and/or sales to external customers) is needed to obtain independence from the fluctuations of the energy carriers' prices and become more environmentally friendly.
- Energy efficiency technologies and practices are essential, especially in old farms, to reduce the energy needs for farming, reducing simultaneously the production cost.
- The application of soil carbon sequestration practices is necessary to sustain farming for the years to come, reducing energy and input application without risking yield reduction.

Barriers hindering FEFTS adoption

- Economic reasons (high up-front investment and long pay-off period) are the most important barriers identified to apply FEFTS in European farms.
- Sustainability is served as priority to farmers, but the economic pressure, lack of knowledge and of specific incentives do not allow farmers to rank it first in their agenda.
- Training requirement to run and effectively use FEFTS is an obstacle.
- Advisory and extension services are not specialised in FEFTS, rather than in agronomy.
- FEFTS cost-benefit analysis for the specific conditions of the farm under discussion is not easy to obtain from state or companies (for free or low price).
- Lack of demonstration of FEFTS in real conditions in the vicinity of farmers, with regular open days for visitors to see their advantages, robustness and economic results and have a trial if possible.
- FEFTS providers (especially RES companies) see farms as customers and not as collaborators, making them reluctant to proceed to such investments.
- Most farms in Europe are very small to medium sized, reducing their capacity to shift to new technologies and practices due to economies of scale.
- FEFTS, in many cases, are not farming specific, but comes from other sectors, which make them incompatible with existing facilities.
- Policies are continuously changing, producing insecurity to farmers.
- Procedures are cumbersome in many countries (increased bureaucracy) making investment in FEFTS more difficult.

Incentives to increase FEFTS adoption.

- Specific subsidies for FEFTS use are the most mentioned incentives to increase FEFTS use.
- Sustainability and environmental concerns are the second reason to adopt FEFTS and they should be promoted by setting indicators and specific limits for farms to follow.
- Agricultural advisory all over Europe needs to be reshaped, incorporating also technological experts, to provide knowledge to farmers about FEFTS and assist them to select optimum technologies and practices for their farm's needs, always considering the size, crop or species, current infrastructure, and economic situation of the farm.
- Advisors should have a clear view of all financing instruments (public or private) available to provide the most advantageous solution.
- Develop "lighthouse" demo farms with multiple FEFTS applied all across the rural areas to act as best practice examples to farmers.
- Create specific policies to support very small to medium sized farms to integrate FEFTS in their activities, by either providing higher economic incentives or supporting them to cooperate and share the benefits of FEFTS.

- Develop policies for market transparency to protect farmers from misleading information coming from FEFTS providers to increase sales.
- Push FEFTS providers (with regulations and economic incentives) to tune their technologies specifically for farming conditions.
- Reduce bureaucracy and keep regulations steady for long periods to develop a transparent environment for farmers and their consultants to invest in FEFTS without considerable time consumption bureaucratic hurdles.

3.3. Successful innovation processes

9 existing cases of FEFTS applied in agriculture that comprise the whole innovation process, starting with the identified need and the origins of the innovative idea through to its implementation and finally its diffusion were identified and documented. Initially the identification of the 16 innovation cases (2 cases per country of AgroFossilFree) took place, accompanied by 4 additional case study stories from RESCOOP.eu. Then, 9 cases (1 case per country and 1 additional case from RESCOOP.eu) were selected to be further explored so that the cases would cover a wide range of innovation processes and innovations. The Spiral of Innovations was used that identifies seven stages in an innovation process, from the initial idea until the embedding stage of the innovation[5,6]. In each stage in the Spiral of Innovations there are different key activities to be performed, actors to be involved and typical pitfalls to be avoided.

1. **Initial idea:** Someone has an idea in response to a problem or an opportunity.
2. **Inspiration:** Others become inspired and form a “warm network” around the initiative.
3. **Planning:** The network of initiators is organised and negotiates space for experimentation.
4. **Development:** The initiators experiment new practices and show their effectiveness.
5. **Realisation:** The innovation is implemented in full scale.
6. **Dissemination:** Other people become interested and implement the innovation.
7. **Embedding:** The innovation becomes common practice/ is widely accepted and structures/ rules, etc. adapt to the new reality.

Primarily, we describe shortly the successful innovation processes of these 9 cases of specific FEFTS for rural areas. Then, we identified their characteristics that can assist the development of policy recommendations regarding:

1. Combined use of agrivoltaics, photovoltaics and biogas plant in one large farm (Italy)

This case describes a large farm (500 ha) that its original business was fattening 5000 cattle heads per year. Manure from cattle was used as fertiliser in the farm. In 2005, the farm initiated its interest on biogas after visiting German farms that already were using this technology. The opportunity to produce biogas and then electricity from manure and use the digestate as fertiliser seemed very positive. After consulting CONFAGRICOLTURA (General Confederation of Italian Agriculture) and becoming informed about a **new policy on “Green Farms”** in 2007, the farm started the procedure of licensing and funding until 2009 when the installation of a biogas plant and a photovoltaics park were realized. The capacity of the biogas system was initially 500 kW, while today it is 1 MW and is accompanied by an **underground piping system for direct digestate distribution** in all 500 ha of the farm and a **local district heating system** that provides heat to all buildings of the farm (houses, offices, workshop, etc.). By 2030, an addition of biogas upgrading

[5] Wielinga, H.E., Zaalmink, B.W., Bergevoet, R.H.M., Geerling-Eiff, F.A., Holster, H., Hoogerwerf, L. and Vrolijk, M. (2008). Networks with free actors: encouraging sustainable innovations in animal husbandry by using the FAN approach. Wageningen University and Research, Wageningen.
[6] Wielinga, E., Koutsouris, A., Knierim, A. and Guichaoua, A. (2017). Generating space for innovations in agriculture: the AgriSpin project. Studies in Agricultural Economics 119, pp. 26-33. https://doi.org/10.7896/j.1043

into biomethane will be realized for either injection into natural gas pipe system and/or direct use by local vehicles. As for the photovoltaic parks, the farm owns one stationary system (2010) and one with tracking system (2018) above a **grassland that can be used for sheep grazing** from an external farmer. The park will be expanded in land area by 2025. This investment has **increased the revenue** of the farm and allowed **the replacement of old machinery** with the latest generation machinery adding also smart agriculture components (GNSS, soil fertility controllers, weather stations). **Private bank financing** was used, avoiding public funding that compensates for the product sold only when the investment is finished.

- ✓ Main FEFTS identified: Biogas to electricity facility, biofertilisation system, waste heat district heating system, Agrivoltaics in grassland, smart agriculture technologies.
- ✓ Future FEFTS identified: biogas to biomethane for network injection or direct vehicle use.
- ✓ Main characteristic that made this case successful is the combination of energy production with sustainable management of agricultural land.
- ✓ The implementation of a new policy (i.e., “Green Farms” Policy) made it possible for the farm to adopt two different FEFTS (biogas to electricity installation and photovoltaics parks).
- ✓ Combination of energy production with optimum organic fertilisation (underground piping for digestate distribution) and free heating for the farm infrastructure makes the investment more profitable in the long run.
- ✓ Tracking photovoltaics (agrivoltaics) can be combined with animal grazing allowing the use of land for both activities and increase profit without jeopardising sustainability.
- ✓ Developing a multi-business model for farms, including energy provision, can assist further investment in the core of farming.
- ✓ In many cases, a cost benefit analysis can prove that private funding can be also a good solution, avoiding difficulties derived from the regulatory.

2. Agrivoltaics with Brite Solar (Greece)

This case describes Brite solar, a nanotechnology company that develops semi-transparent photovoltaics for agricultural use, to mainly reduce electricity costs for farms, especially greenhouses, where it can reach 28% of total operating costs. The idea is that the greenhouse roof can be occupied by such photovoltaic panels and therefore in 2009 in **collaboration with the University of Peloponnese**, the company started investigating the production of these panels. However, they were found to be very expensive and difficult to install, and it was noticed that it reduced the agricultural production due to shading from the photovoltaic modules. In 2013, a pilot testing of the product in experimental greenhouse cultivating tomato **reduced yield by 20% that led Brite Solar to change radically the design of the panels produced**. The new panels have innovative nanostructured coatings that absorb UV light which is not used by plants and retransmit it to the red and green region of the spectrum that are used for photosynthesis. This technology can be also used in conventional glass to increase photosynthesis in greenhouses. In 2019, the new panels were ready and have been applied in different **pilot use cases in greenhouses (e.g., 0.1 ha glass greenhouse covering vineyards) and open-field farms (agrivoltaics)**, changing the density of photovoltaic modules on the glass according to the crop photosynthetic needs.

- ✓ Main FEFTS identified: agrivoltaics in greenhouses, semi-transparent glass photovoltaics, nanomaterial coatings.
- ✓ Semi-transparency in glass photovoltaic panels, if successful, can convert any agricultural land into a combined energy and food/feed production system.
- ✓ Ideas coordinated by private entities in collaboration with public research entities (i.e., University in this case) can be easier implemented.

- ✓ Real pilot farm application of FEFTS prototypes can highlight any negative result and assist in shifting to minor or even radical changes in the design of an innovative FEFTS.
- ✓ Demonstration sites are vital for an innovative technology to be optimised and disseminated.

3. The New Holland T6 methane tractor (Germany)

This case describes an agricultural tractor that runs on methane that was designed as part of the company's clean energy strategy that started in 2006 providing environmental and economic benefits. The company used components **coming from a sister automotive company** and optimised the required software to achieve this transition. The company received **funding from the UK government** from the Advanced Propulsion Centre (APC), that assisted on the completion of the product development. **Collaboration with other companies** through the APC especially on the exhaust system was critical for the final product quality. Another collaboration with a company through APC brought the idea of **capturing, cleaning, production, and use of gas on farm** as a circular solution for livestock manure management. The tractor saves fossil fuels, without jeopardising the ability of the **vehicle to overcome all challenges that conventional diesel tractors** of the same size face.

- ✓ Main FEFTS identified: methane powered tractor, heat protection materials, use of manure for biogas to biomethane production for direct use in farm tractors, energy independent farms.
- ✓ Using FEFTS from other industry in agricultural purposes is key for the fast FEFTS adoption from farms.
- ✓ New material might be needed to make FEFTS compatible for farming.
- ✓ Government funding is assistive, even for large companies, to develop novel FEFTS.
- ✓ Collaboration with companies with specific expertise can help accelerate and improve product development.
- ✓ Producing alternative fuel powered tractors and other FEFTS does not mean that quality of work will be reduced.

4. GB Hybrid - strip-till and subsoiler (Poland)

This case describes an agricultural implement that applied strip-till combined with a subsoiler to loosen and mix soil without inversion and also apply fertilisation in deep soil (in two different depths). This technology allows plants to grow their root deeper to absorb nutrient and find available water, reducing the need for irrigation. The implement allows minimal soil cultivation, and fertilisation with a single pass, while with an addition of a drilling machine it can also sow directly. This implement **reduces the number of passes in the field**, hence also **fuel use** (direct energy use) and **fertilisation dose** (indirect energy use) due to the subsoil application method. The implement was designed by a farmer/agricultural engineer that has a farm located in slopes, where soil erosion, leaching and silting are common problems. Another problem he faces is water deficiency for plants during summer draughts. These problems direct him to design this implement. GB Hybrid collaborates closely with the University of Warsaw and conduct experiments together.

- ✓ Main FEFTS identified: strip-till, direct subsoil fertilisation application.
- ✓ Main future FEFTS identified: combined direct seeding.
- ✓ This innovation is based on minimum soil disturbance and direct application of fertilisers (and seeding) that reduces fuel use and as fertilisers application.
- ✓ Farmers can be a part (or the core) of innovation, as they have a full image of the problems faced in agriculture, as necessity is mother of innovation.
- ✓ Farmers of high educational level can assist in new advances in agriculture that reduces energy use.

- ✓ Collaboration with research entities (University in this case) is key to optimise new FEFTS.

5. Conservation agriculture (Spain)

This case describes Conservation agriculture, an auxiliary but extremely effective, practice to compensate carbon through soil sequestration, minimise greenhouse gas emissions and reduce significantly soil erosion. It consists of 3 main pillars:

1) minimal soil disturbance;
2) permanent soil coverage; and
3) crop rotation.

This practice is applied already in 7 million hectares in Europe. In 1995, a Spanish use case farm in Andalucia that had high soil erosion problem has been investigating different solutions and in 2001, this farm has purchased its first direct seeding machine to apply conservation agriculture and has seen benefits in reduced fuel use, low soil erosion, carbon sequestration in soil. Weed management is still a problem that needs to be overcome by pesticides, however crop rotation reduces this problem significantly. An olive producer in the same province has also started applying conservation agriculture using continuous soil coverage in 2017 and has observed the increase of soil carbon stock, increased organic matter, less agricultural input use (indirect energy use), less direct energy use in total (e.g., diesel use) and higher yield. Similar farmers have established a union that went under the umbrella of the Spanish Conservation Agriculture Association and has participated in numerous research project on this topic. In 2018, both farmers participated in a European research project, LIFE Agromitica and attempted to disseminate and convince more farmers to follow conservation agriculture.

- ✓ Main FEFTS identified: Conservation agriculture, carbon farming, carbon sequestration.
- ✓ Conservation agriculture has proven its ability to contribute to climate change mitigation by sequestering carbon in soil and reducing the use of fertilisers (indirect energy use) and the use of fuels (direct energy use) for ploughing that consumes the largest portion of fuels of all agricultural practices.
- ✓ Shifting to non-conventional practices is difficult for farmers, but farmers' word of mouth plays significant role, when the change is successful.
- ✓ Farmers' associations/unions are a very efficient tool for them to handle a common problem together.
- ✓ Participating in European, national, or even private research project is very useful for farmers to get involved with all the AKIS community (research, extension services, industry and other farmers), learn more, and become more open minded. In addition, they can receive financial compensation to apply new practices and observe the impact with minimum income effect.

6. Green Protein, an alternative to soya (Denmark)

This case describes a new product named "green protein" that acts as an alternative to soya feed provided today to livestock across Europe. Soya is mostly imported from distant countries from Europe and partly produced in land that used to be rainforest. In Denmark, **research through development projects** (innovation centres, universities, feed industry and agricultural associations involved) on how clover grass could replace soya has been active since 2012, especially under organic farming rotation schemes (first in poultry and then in swine). After successful initial research, two prototype plants were built to produce grass protein. The grass is first crushed and then pressed to remove the juice from which the protein is extracted after heating, centrifugation and drying. The **residues (grass fibres and brown juice) are used as an input in biogas plants**, where due to their previous processing, they are more valuable inputs than the full grass. The digestate from the biogas plant returns to the field as nutrients. The residues can also be given as feed to cattle. Clover grass has another benefit; it sequesters more soil carbon from most crops. Due to the technology's maturity, subsidies are given for new installations.

- ✓ Main FEFTS identified: alternative feed production with local resources, biogas production, biofertilisation with residues, carbon sequestration.
- ✓ Collaboration between farmers' associations/unions, innovation centres and universities are an efficient way to develop FEFTS to substitute existing unsustainable solutions.
- ✓ Using existing products in another way to produce sustainable FEFTS (feed in this case) should be considered, while positive side effects might occur.
- ✓ Industrial symbiosis can be a solution to increase the output when treating crops and their residues.
- ✓ Pilot large scale installations are needed to optimise a technology before it becomes fully commercial.
- ✓ Subsidies are needed to grow the FEFTS market, especially is brand new technologies, but always provided after the selected FEFTS has proven its efficiency.

7. Biomass Heat Solutions Limited (Ireland)

This case describes a fluidised bed combustion technology using poultry manure as fuel that can either produce heat for poultry sheds or electricity. The technology is combined with Building Management Systems (BMS) to improve climatic conditions in sheds, optimise ventilation, enhance feed conversion ratio, increase biosecurity by moving manure out of the shed and produce new income streams for the farm. The idea was conceived in late 1990s, due to the **EU policy on nitrates directive** that made poultry manure spreading in fields impossible, due to high levels of phosphorus. Hence, the local **association of poultry growers** decided to **collaborate with the University of Limerick** to develop a farm-based solution for power production from poultry manure combustion. After making contact with the **environmental agency of Ireland**, in the early 2000s the first pilot was funded and using the experience of the UK, in 2004 the first system was developed and installed in two farms. Having two running systems, allowed for a company to be established, attract investors, and install a larger system in another farm. In 2010, the company attracted the interest of UK farmers and started exporting. In 2014, the collaboration of the company with the environmental agency of Ireland and ministry of agriculture managed to **convince the EU through DG SANTE to create a new regulation moving poultry manure from the waste category to the fuels category for onsite farm use**.

- ✓ Main FEFTS identified: fluidised bed combustion technology using poultry manure as fuel, BMS.
- ✓ The example of the nitrates directive impact on the design and application of this technology shows the wide influence of EU policies to grow FEFTS adoption.
- ✓ Using local by-products or waste for onsite energy production is a circular rural bioeconomy solution that makes farms more efficient and resilient.
- ✓ Collaboration of farmers within associations brings faster solutions in common problems.
- ✓ Collaboration of farmers with research entities (University in this case) assists in optimising the technical solution.
- ✓ The assistance of governmental agencies (technical and financial) is vital for an idea to become a product. In addition, member state agencies can directly influence the EU regulations, when their petition produces benefits for all EU member states.

8. Sustainable storage barn 'Bewaarschuur van de toekomst' (the Netherlands)

The case describes a farm of 250 ha growing potatoes, onions, cereals, sugar beet, carrots, and peas that in 2014 decided to develop a sustainable storage burn with the **collaboration of a very experienced**

construction company. The facility has box storages, a track and trace system, and technologies to keep **high energy efficiency** (i.e., 5000 solar panels of 1.8 MW, novel double insulation shell to reduce working time of ventilation, heating and cooling with heat pumps, protected doors not facing the sun, water storage under the whole shed filled in winter by draining all facility and used for humidification of potatoes in hot periods, production of hydrogen using excessive PV electricity through electrolysis, and clean all farm's machinery, smart system with 24 h prediction for selecting to either sell or use internally the electricity produced, etc.).

- ✓ Main FEFTS identified: track and trace system, roof photovoltaics, novel double insulation shell, heat pumps, production of hydrogen, Building and energy management system.
- ✓ Collaboration of farmers with experienced private companies working on other sectors (industry, commercial and residential buildings) assists in optimising FEFTS specifically for the farm's needs.
- ✓ Combination of different technologies of RES and energy efficiency when designing and constructing new agricultural facilities is significant to develop fossil-free farms in the future.

9. Combined fossil-energy-free agriculture and citizen-led energy transition (Belgium)

This case describes two successful RES related use cases that show how agriculture can be combined with sustainability. **The application of agrivoltaics above a pear orchard can possibly combine agricultural production with electricity production**. Yield reduction due to shading is an issue to be investigated, but crop protection from extreme climatic changes (e.g., hail) could play a role in deciding in favour of such installations, if the positive energy impact is also considered. **The district heating of public schools using biomass (wood chips) from hedgerow management combines substitution of heating fossil fuels (natural gas and diesel) with developing denser hedgerows of agricultural roads.** Heating public buildings using local biomass significantly reduces their cost of operation (especially in northern Europe), while the hedgerow management develops natural wind shields against fierce winds that decrease agricultural land soil erosion, and simultaneously increases rural sustainability by creating optimum conditions for bird nests and animal shelters and reducing temperature beside the hedgerows during hot summer days.

- ✓ Main FEFTS identified: agrivoltaics in orchards, hedgerow management for biomass district heating, community energy systems.
- ✓ The main characteristic that made these two cases successful is the combination of energy production with sustainable management of agricultural sites.
- ✓ Pilot testing of FEFTS (agrivoltaics in this case) is crucial to observe their impact on agricultural and energy production.
- ✓ Community energy systems can assist both the cost of leaving in rural areas, but also can upgrade them in terms of sustainability and biodiversity.

3.4. AgEnergy Inventory and Platform

AgroFossilFree project has developed a methodology to classify the different FEFTS categories (see Deliverable 1.1.). As FEFTS refer to the tools required to address cleaner and more efficient energy production and use in agriculture, we primarily need to **identify the energy user/consumer** within the farming processes, namely the **agricultural technology application** that the specific FEFTS is used for. Then, FEFTS can be classified based on either they supply:

- **Clean Energy** to substitute fossil energy.
- **Energy Efficiency** Improvement in comparison to conventional technologies/ practices.

- **Soil Carbon Sequestration** (auxiliary category) mainly a Greenhouse Gas (GHG) compensation role rather than a fossil fuel reduction strategy.

In detail, the Energy Use categorisation refers to the applications of the agricultural technologies that are related to energy, while the Clean Energy Supply is relevant with the sources, types, technologies and storage of energy used in agriculture. The Energy Efficiency Improvement categorisation refers to the methods and tools that are used to increase energy use efficiency during farming activities, while Soil Carbon Sequestration is focused on the methods that can be applied in agriculture to reduce the impact of fossil energy use by enabling Carbon storage in the soil pool. The main FEFTS categories are presented in Table 3.1, while all subcategories can be found in Deliverable 1.1.

Table 3.1. FEFTS categories and level 1 and level 2 subcategories.

FEFTS category	Level 1 sub-category	Level 2 sub-category
Energy User/Consumer	**Agricultural technology applications**	heating and cooling of buildings
		process heat/cold
		lighting
		agricultural field practices
		vehicles
		tools
		energy sales to external consumers
Clean Energy Supply	**Renewable Energy Sources**	solar
		wind
		hydro
		geothermal
		bioenergy
		free energy
	Energy types	heating
		cooling
		electricity
		mechanical energy
		chemical energy
	Energy Technologies	photovoltaics
		solar thermal
		windmills
		hydropower
		heat pumps
		geothermal
		solid biomass conversion
		biogas / biomethane production
		liquid biofuels production
	Energy Storages	heat storage
		electricity storage
		cold storage
		intermediate bioenergy carriers
Energy Efficiency Improvement	**Energy savings**	efficient buildings
		efficient vehicles
		efficient tools
		precision agriculture
		precision livestock farming
		conservation agriculture

Carbon sequestration	**Carbon sequestration**	soil organic cover
		tillage (Conservation Agriculture + CTF)
		nutrient management
		crop diversification
		soil and water conservation techniques
		fire management
		grassland management

Based on the inventory categories above, an **online toolkit** was developed, named **AgEnergy Platform**[7] that acts as a permanent networking facility for the collaboration between the end-users and the FEFTS providers, showcasing different types of FEFTS. Each FEFTS record in the platform is presented in a mock-up card with 4 tabs that presents the main information about the FEFTS. Any registered member can create new records of FEFTS (and update them if needed) and assess them using an online questionnaire (if they want). Nonregistered users of the platform can freely browse the content of the platform.

Finally, the platform contains a **Decision Support Toolkit (DST)**[8] based on Artificial Intelligence that provides the ability to address coherently qualitative and quantitative variables mimicking the consultation process of energy and agriculture experts.

The final number of published FEFTS is 1959, with all FEFTS categories represented in the platform and divided in five main information types (scientific papers: 977; research projects: 180; commercial products: 542; training material: 131; financing mechanisms: 129). For more details, see Deliverables 2.4, 2.7, 2.10, 2.13, 2.16.

Based on the assessment of all FEFTS using specific questions and a Likert scale (Strongly disagree, Disagree, Neutral, Agree and Strongly Disagree), it was possible to rank all FEFTS by reducing this qualitative scale to numerical (-2, -1, 0, 1, 2) and add the answers to an aggregated score (max score: 16; min score: -16). Results were sorted and the category for each FEFTS (see Table 3.1.) was attributed to them. FEFTS assessed below a certain score (Papers: ≥14; Projects: ≥10; Products: ≥14) were not considered as they were not the most popular ones. The categories found were summed and presented ranked by popularity in the table below. This procedure was executed in the list of scientific papers, research projects and commercial products and the auxiliary information types (training material and financing mechanisms) were not used in this analysis.

Table 3.2. FEFTS categories identified in the content of AgEnergy Platform.

Papers (≥14)	Projects (≥10)	Products (≥14)
solar	solar	precision agriculture
photovoltaics (agrivoltaics)	photovoltaics (agrivoltaics)	solar
bioenergy	precision agriculture	conservation agriculture
biogas / biomethane production	conservation agriculture	wind/windmills
conservation agriculture	bioenergy	electricity storage
nutrient management	wind/windmills	efficient buildings
heat pumps	heat pumps	bioenergy
wind/windmills	hydropower	biogas / biomethane production
		liquid biofuels production
		efficient vehicles

[7] https://platform.agrofossilfree.eu/en
[8] https://dst.agrofossilfree.eu/

		heat pumps
		hydropower
Additional categories found:		
community energy	community energy	insulation
Biochar	Biochar	Building management systems

3.5. Regional Workshops

The central tool for information exchange in the regional hubs was the three multi-actor workshops per hub, bringing together research, extension, industry and farmers within and outside the AgroFossilFree project. Twenty-four multi-actor workshops were conducted covering the Northern, Western, Southern and Central/Eastern regions of Europe. The workshops captured stakeholder's innovation ideas and needs on a regional level.

Based on the guidelines (see Deliverable 3.3.), several FEFTS were presented at the starting point of the workshops to initiate discussion. The list of FEFTS presented reflects across themes (open-field, greenhouses, livestock), covering all RES for agricultural use (i.e., biomass, solar energy, wind energy, geothermal energy), alternative power supply for agricultural vehicles (i.e., biofuels, electrification), storage of excess energy (i.e., as fuel, as heat, or as electricity) and HVAC solutions (i.e., heat pumps, biomass boiler, CHPs, BMSs). Tools to measure and guide operations, as well as management tools for agricultural practices and input application which are constantly based on the latest knowledge, are also common topics across the three themes. Conservation agriculture related FEFTS were also shown to participants. Combined or complete systems for efficient heating/cooling, lightning, and ventilation were also presented for greenhouse and livestock farming.

After this presentation, the discussion between stakeholders was initiated with a certain series of questions. The analysis regarding the policy recommendations derived by this conversation is sorted by themes.

3.5.1. Open-field agriculture

The main discussion issues were (i) the needs of the farms in terms of energy in a technical, financing and knowledge sharing level; (ii) the barriers hindering adoption of FEFTS and (iii) the incentives needed to increase FEFTS adoption.

3.5.1.1. Needs of farms in terms of energy.

<u>**Technical**</u>

- Need to **increase energy intensity** (energy used to produce a given level of output).
- Development of cheap electric or hydrogen powered tractors with **increased batteries capacity and fast recharging**.
- Fleets of electric agricultural robots could substitute tractors, but there is **need of optimised battery technology and incorporation of photovoltaics** on them.
- If RES are adopted in farms, **energy storage systems** (hydrogen, optimised batteries, Pumped-storage hydroelectricity) using the excessive electricity are required. RES manufacturers should provide both solutions.
- Easy calculation of the **right sizing in machinery and the right energy carrier**, based on the farm size.

- Use of **nitrification inhibitors** and impact on CO2 compared to the impact of fossil fuel alternatives/green energy for open field agriculture.
- **High conversion rates of biomass or sun/wind into fuels**, so that loss of energy is avoided.
- **Local energy production and consumption** on one farm or joint farms (wind, biogas, etc.) to avoid burdening the distribution networks.
- Need for **agricultural machinery analysis and decision support** (reduce idle effects to consumption that can reach 20% of tractor uptime, optimised driving patterns and field/road transport).
- Easy calculation of **saving potential by comparing different technologies**, implementing them in real conditions, study the whole value chain to identify the highest impacts in the whole energy circle, find whether "The hen made the egg or the opposite".
- **Reduction of the electricity consumption** for irrigation (mainly in southern countries), drying processes (mainly in northern countries).
- **Precision agricultural techniques** should gradually take over conventional methods.
- Easy renting of equipment to **try it out** on own farm.
- **Crop rotation must be enforced and enriched**, as it is a comprehensive approach allowing savings through restoration of soil fertility and humus content resulting in better use of nutrients, lower production costs, lower fuel and fertiliser consumption, and higher yields.
- **Biogas production market is still untapped**, with farmers selling part of their production or by-products as substrates and in return use the digestate as fertiliser.
- **Green certificates** that help the implementation of carbon sequestration practices by farmers and reduce the negative effect of fertilisation through better use of fertilisers.
- Technologies for the **transportation of waste by the biomass plants** should be enhanced (e.g., in Italy they are almost non-existing).
- **Change cultivation practices**, but the transition should be done considering the situation of the farmers and in stages.
- **Need to cover a shortage of labour**, this also determines technological development.

Financial

- RES should be available in **reasonable / affordable prices**.
- **High equipment prices** for precision agriculture.
- Energy prices should be **fluctuating smoothly** to allow farmers to react.
- Agricultural land should be **protected from current opportunities to lease** their land to solar, wind and energy storage developers.
- Solar PV and energy efficiency technologies **should proof their businesses to farmers** before adoption increase.

Knowledge / Information / Awareness

- **Technical support** is needed for farmers showing the benefits of FEFTS with practical cases and advising.
- Use **cooperatives as a driver of knowledge transfer** and provide them with the necessary support for all issues of technology adoption and bureaucratic issues.
- **Pilot tests** for crop diversification, adaptation to climate change, and food sovereignty.
- **Training and financial support** to implement FEFTS.
- Development of **energy communities for optimum exploitation** of local energy sources.

- State consultancies are often not sufficiently prepared for transferring innovative FEFTS solutions - there is a need for **specialised consultancy units**.
- Need for a **compendium of FEFTS knowledge** and workshops to show good examples of FEFTS on **demonstration** farms (in the country or abroad).
- The agricultural sector is dramatically ageing; older farmers are often not interested in FEFTS, while young farmers **need information and training to afford them**.

3.5.1.2. Barriers hindering FEFTS adoption.

- Precision farming solutions and no-till practices can reduce the use of fossil fuels, but they are **risky investments in such uncertain times**, considering that there is no guarantee of the sale of agricultural products.
- There is **no synchronized system of data gathering and processing**, producing non-coherent data that cannot be applied correctly in precision agriculture.
- Lack of **knowledge** of modern technology.
- Lack of **FEFTS demo sites**.
- Lack of **valuable studies and access to reliable information** on FEFTS.
- Existence of **many applications and internet platforms** related to agricultural production is difficult to be processed by most farmers, making them reluctant to use them.
- **Difficult to acquire independent information** regarding certain FEFTS (e.g., PV).
- The **constant change of politics** related to the sector.
- The **permanent scarcity of raw materials/operating materials** for this sector.
- **Waiting for 2nd generation biofuels** for the last 15 years, does not allow political directions to focus on available FEFTS.
- Decision making process of politicians regarding the promotion of FEFTS is **slow**.
- Business as usual **prevents opening new horizons** on energy use.
- **Potential of alternatives to diesel fuel** for agricultural machinery is not widely known.
- There is an impression to farmers that **niche arable productions might have higher energy consumption** than conventional systems.
- Farmers do **not have enough time for searching financing channels** in the sector.
- For conservation agriculture implementation, it takes **time and resources to learn** the way to do successfully, which make it even more difficult for small farmers.
- **Lack of financial incentives** (or knowledge about it).
- Complicated **bureaucracy**. Lack of trust towards regulations (volatility).
- **Lack of advisory and extension services** as well as guidance regarding FEFTS use.
- **Fragmentation of farms** into multiple small plots in some countries.
- **Limited function of collaborative schemes** (i.e., cooperatives, groups) in some countries.
- Sustainable energy production on farm **cannot go without energy storage on site**.
- Electrical or hydrogen powered tractors are too **expensive and unsure expenses** to be currently considered.
- Knowledge gap about suitable **alternatives to mineral fertilizers**.
- **Growing prices** and uncertainty of energy carriers.
- Uncertainty about agricultural products sales makes it tricky to make costly investments.
- Advisors are **not sufficiently knowledgeable** in terms of FEFTS technology.

- **Unfavourable, volatile legal regulations and strict procedures** related to FEFTS does not assist further adoption, while the priorities of agricultural policy are not always in line with the real needs of agriculture and not adapted to local needs (probably due to member state application).
- Outdated and inefficient equipment combined with the **attraction** of some farmers (especially elder ones) **to traditional farming methods**.
- Farmers **unwillingness to implement or even test** new FEFTS.
- **Grid connection** and **local authority planning restrictions** also act as barriers for FEFTS.
- The **scale of the challenge in meeting emission reduction targets** in agriculture is not communicated enough.
- Consideration that fossil free agriculture as **an unreachable miracle**.
- FEFTS are considered a **privilege of bigger agricultural companies** and unbearable for a lower income reality.

3.5.1.3. Incentives to increase FEFTS adoption.

- **Specific subsidies for FEFTS** are the most mentioned incentives to increase FEFTS use. Financial incentives should be based on the **use of 'hard' measures from enterprise data** (general on enterprise levels or specific on individual enterprise). **Validation of the effect of different measures** should accompany the subsidies given.
- **Economic and technical support** to introduce elements of modern FEFTS step by step.
- **Enforce continuous support** after receiving aid or purchasing new equipment.
- Support **biogas systems using open-field products as feedstock** across the EU.
- Need for political statements on **climate labelling**.
- Assistance to **use nitrification inhibitors** to reduce CO_2 in farming.
- Support **change of cultivation practices** (e.g., conservation agriculture) in stages with soft transitions.
- The market/mechanisms for carbon credits may well be opaque, but it can be the **financial incentive to initiate new cultivation practices**.
- Support with subsidies energy efficiency technologies and measures to **increase energy intensity** in agriculture and not only subsidising hardware for RES.
- Change policies to help **agriculture produce fuels itself**, as an exchange with diesel, e.g. biogas in exchange for diesel.
- Assist the **link between cooperatives and research centres, governmental stakeholders, and commercial representatives** to become closer and more extensive so that cooperatives can transmit knowledge. Also, cooperatives should be assisted to generate their own information and investigations to help farmers.
- Even if public administration has the rural development plan and other tools to support FEFTS adoption (e.g., training courses, project generation, advisory and research areas), it depends on whether the state or region **has enough resources to bring these tools to the farmers**, which are often **limited or may not exist at all**.
- **Engage sole farmers** into energy communities, cooperatives, joint ventures, participation in research projects to make them truthfully incentivized and interested in participation, knowledge transfer, and finally FEFTS adoption, as today farmers do not have time outside their daily field work and do not find value in such activities.
- The **CAP should support the practices of Conservation Agriculture** to promote its use. The Regional Rural Development Plans in the framework of the EAFDR should include measures to support

activities contributing to the Green Deal. It seems there is a **missing link between Green Deal and CAP**.

- **Combined training, financial aid, advisory/extension services, and networking** should be provided to local farmers.
- Support **further Integration of precision agriculture combined with conservation agriculture** after further research.
- Offer subsidies to farms that achieve a **positive balance of organic matter** using appropriate **crop rotation and balanced fertilisation**.
- **Use farmers' views and needs** in designing legal regulations or technological solutions.
- In many countries, it is **unjustified for small farms to buy expensive technologies** just because it is required to receive subsidies (waste of money and energy)- there is no premium for basic equipment, while expensive equipment is not used well enough.
- Support **standardisation of farm data format** to be used in various applications.
- Policies should include **small scale solutions** to save energy in farms, not associated with large financial outlays, and be not overly complicated and labour intensive.
- Assistance to **introduce precision agriculture, keeping tradition in action** to avoid losing the knowledge gained by farmers in centuries.
- Offer motivations to **use the untapped raw material left in farms** to develop RES in rural areas.
- Deployment of renewable energy technologies and energy efficiency in agriculture must be stimulated through **ongoing energy policy**. Needs for a clear Government strategy to facilitate grid connections for farmers and to support the installation of rooftop solar and other key infrastructure.
- The **new CAP should assist FEFTS adoption** by supplying financial aid and structured policies, allowing smooth modernization of the agricultural domain and mitigating simultaneously **any negative economic side effect for the farmers**, which may derive from the transition. Ensure that **farmers are central players** in the national energy transition.
- Establishment of energy communities for the optimum exploitation of existing energy sources is needed. Actions to increase energy efficiency could help to **balance some energy demand growth**.
- Promote **farm independent energy auditing services** by the Government accompanied by propositions of FEFTS.
- **Carbon audit services for farms** could assist agriculture to play a major role in the EU decarbonisation strategy.
- Keep national and EU **legislation clear, not volatile nor subject to misleading** interpretations.
- Consultation able to carve out **tailor-made technological solutions** for each farm.

3.5.2. Livestock

The main discussion issues were as mentioned in the previous section; (i) the needs of the farms in terms of energy in a technical, financing and knowledge sharing level; (ii) the barriers hindering adoption of FEFTS and (iii) the incentives needed to increase FEFTS adoption.

3.5.2.1. Needs of farms in terms of energy.

Technical

- Implement **decentralized and intelligent energy distribution**, especially on the improved integration of RES to increase security of supply and provide added value for the farmer.

- Environmentally friendly design of agricultural production processes with **increased automation and electrification of machines and use of self-produced energy** from RES.
- **ESG GREEN tool** for Danish agriculture could be further developed and used in other countries and compare technologies between application areas regarding the CO_2 impact.
- About **70% of production cost is related to feeding** and this needs to be reduced with any means.
- Focusing on the livestock building, the cost of **heating and cooling** need to be reduced significantly.
- **Filtering systems** have a high energy consumption that has to be decreased.
- **Distribution grid upgrading** for energy trading opportunities to grow is necessary.
- **Precision livestock** in a need due to its significant impact on reducing energy, labour and therefore financial resources spent on milk production. Herd management based on precision technology optimises feeding, reproduction, early detection of health problems and electronic identification of animals.
- **Water retention** based on aboveground and underground tanks storing rainwater from the roofs of livestock buildings is a good solution to the high demand for water from cattle and the current meteorological conditions.
- **Heat pumps need to be combined with solar PV and battery capacity** to cover many uses on livestock farms, including milk cooling process, heating of washing water, hot water and steam sterilisation systems.
- Integration of **heat pumps with energy management system including battery and PV** for cooling and heating at the same time.
- Livestock sector needs to count the **availability of agricultural products and by-products, land and roof surfaces** that can be conveniently used for energy production from FEFTS.
- **Circular energy independent livestock farms** are a major need for the resilience of farms.
- Need to shift to FEFTS, such as **electrical automatic fodder distribution systems in combination with PV**, **pre-cooling of the milk with production of lukewarm water**, **heat recovery from the milk refrigeration tank**, production of **domestic hot water using a solar thermal system**, always in conjunction with a complementary water heating system.
- Design of milk rooms to **ensure good internal ventilation** and keep low internal temperature to reduce the energy consumption of the milk tank.
- Need for adoption of **automatic mechanical fodder and manure lane cleaning systems**, that spend less energy than the scraping blades carried by a tractor or wheel loader.
- Correct use of tractors, **limiting their idle time** as much as possible and adopting a **low consumption/fuel efficient driving mode**.
- Good **internal organization** of the building and storage facilities and arable fields, with limitation of non-productive routes of mechanical means.
- Need for **verification of FEFTS technologies** (e.g., under Environmental Technology Verification (ETV) programme) and **certification of integration of FEFTS**.
- There is a need to **close old subsidy programs** and move finances to new areas more targeted towards climate.

<u>Financial</u>

- **Local circumstances and finances are not sufficient yet** to enforce pioneering FEFTS to livestock growers.
- Pioneering farmers should be **financially supported and guided** in the use of FEFTS and reward them for their intention to start producing more sustainably.

- **Right supports and placement for loans** to make heat pump integration possible.
- **Reduce electricity costs** for heat pumps.
- Identify **alternative sources of income** and/or the possibility of reducing production costs, to cope with the recurring crises of the agricultural market and the global economic crisis.

Knowledge / Information / Awareness

- Better practical advisory on solar power (agrivoltaics).
- **"Transfer centres"** are key to foster knowledge dissemination and innovation adoption. The agriculture sector is eager to adopt changes. New technologies are not an issue. Information websites are valued. Support the word of mouth (practical experience) and demonstrations.
- Pioneer users who seek FEFTS out of personal interest and motivations represent 5-10% of farmers. The **vast majority follows** the technology or practice becomes economically and operationally viable.
- Enhance **training of farmers, advisory services, and installers** with technical assistance, providing standard solutions as much as possible.
- Need for **simple communication** on how and why, what costs and savings achievable.
- **Feedback** for improving the FEFTS or adjusting them.
- Need for **free consultation**.
- Dissemination of information through **farm organisations**.
- Photovoltaics are deemed very popular in the market but there is **lack of awareness** or understanding for their operation. The same counts for heat pumps.

3.5.2.2. Barriers hindering FEFTS adoption.

- Agricultural sector is remote and **lack grid interconnection to transfer energy surplus.**
- Lack of **proper buildings' insulation** in most livestock facilities for reducing energy consumption.
- The actual agricultural and energy **policies are not suitable** to make agriculture carbon neutral. The energy policies alone are suitable to minor extent.
- For many livestock farming branches, **meat and milk prices remained rather stable** in the last 30 years, whereas input prices or electricity increased significantly. This is a large challenge for many farmers.
- **High animal feed prices** reduce the income and that might delay FEFTS implementation.
- **Most FEFTS are not verified** for their results, putting farmers in a defence position.
- In some countries, there is a barrier against PV integration in buildings, because of **rules on construction of buildings**, leading farmers to build solar farms on good farmland instead due to high fees. However, this leads to competition on land for food/feed.
- **Lack of specific FEFTS knowledge** of (local) technicians on installing and maintenance.
- The livestock sector is often **"disconnected" from** the technicians, the government, and other livestock farmers, while working intensively.
- Opportunities might be lost due to the **lack of information about how to proceed**.
- Correlation between old people and reluctance to connect to new technologies.
- **Low subsidies for biogas** in some countries, where livestock farms could get more involved on this FEFTS, in comparison to the subsidies for solar photovoltaic or wind.
- Small farmers **miss the contact with more structured farms** for knowledge-sharing.
- As livestock farmers operate in tight profit margins, **investment in FEFTS gets uncertain**, because there are doubts about maintenance, optimization and lifecycle costs.

- **Missing proper guidance** for achieving the optimum FEFTS integration, and of simplification of bureaucratic procedures related to FEFTS licensing.
- **Difficulty to form groups** (energy communities, cooperatives etc.) for FEFTS adoption.
- Local rural energy grids are **not capable of receiving RES derived energy.**
- Farmers do **not feel confident to invest in unique hardware** for which current mechanical workshop services would be far away.
- With energy prices currently on the rise, the installations of RES in dairy farms seem reasonable, but the investment cost becomes **risky due to unstable milk prices**.
- Farmers report barriers in using computer applications, which in the case of herd monitoring systems is a necessary condition for using these tools.
- **Constantly changing environmental, legal and management** conditions.
- There are large gaps in the system of policy, grant aid and implementation at farm level.
- Modernisation schemes for farms **set upper ceiling limits** on expenditure that seem limiting for potential investment in FEFTS.
- There should be **insurance against failure of projects**, probably as member state government support.

3.5.2.3. Incentives to increase FEFTS adoption.

- **Integration of heat pumps with PV panels** could be better explained and sold as an integrated system on farms.
- Remove **grid connection costs** and provide **lower electricity tariffs for heat pumps**.
- **Geothermal suitability maps** should be used to assess ground source heat pumps (GSHPs) resource for any farm or location.
- **Stimulation of awareness, and simplification of legislation** would enable FEFTS integration.
- Promote and understand **best practice examples of FEFTS integration** in livestock farms at political level.
- **Financing for young livestock farmers** could be improved.
- Promote **higher prices on product from farms of low carbon footprint**, as a key to future FEFTS success.
- **FEFTS integration certification** could be a new possibility for financing.
- Support farmers to participate in energy communities, cooperatives and European projects. **Biogas management in collective schemes** should be pursued.
- Assist the creation of **"transfer centres/centre of excellence"** to bridge the gap between farmers and research, so that research findings on FEFTS can be applied faster on farm level.
- Offer **clear understanding about the return on investment of FEFTS**, as livestock businesses operate on **tight profit margins** and financial planning is a vital activity.
- Promote **plug and play FEFTS with low maintenance and ease of operation**, to avoid spending farmers' time dedicated to managing their exploitation.
- Develop **demonstration/pilot farm applications of functioning FEFTS** wherein the offset, storage, delivery, economically sound and safe use of selected FEFTS tested and presented to the agricultural sector and society and it will spread quickly through word of mouth.
- A **protection framework is necessary against the uncertainty** that the investment in FEFTS will bring to farmers.

- In some countries, there is overlapping between national and local policies. Therefore, **national governments should legislate considering the reality in the local dimension** not to cancel local government's ability to help farmers based on their exact needs.
- Develop a **cascade definition of policies** coming from the EU, national, and regional/local levels to make it clearer to farmers.
- Optimisation of **advisory services** to be FEFTS literal for livestock applications.
- **Simplification of legislation and licensing procedures** with energy contractors.
- Raise **awareness and training** in new FEFTS technologies.
- Provide **reduced interest rate loans** for FEFTS integration.
- Develop **certification of integration of FEFTS** in livestock facilities.
- Formation of **energy communities as well as cooperatives** is very significant, especially to coordinate large scale community projects.
- **Waste management of livestock facilities** should be more directed to energy production and then production of biofertilisers for direct local use.
- **Industrial symbiosis** should be strengthened between livestock and other facilities.
- Promote **labelling of food** produced in a more sustainable way, or a reduction in the prices of leasing farmland.
- Consensus that new CAP could assist the adoption of FEFTS, but there are **insufficient FEFTS related subsidies** in CAP. **Trusted funding stream** could be another step in CAP evolution. **Special funding schemes for early adopters**. FEFTS could be used in an **agri-environmental scheme** (e.g., Similar to low emission slurry spreading as an option in IRL GLAS initiative).
- Identify **best systems of operation** in terms of energy efficiency, using real data to inform decisions on what's happening on farms.
- Support proper backup in terms of **servicing the FEFTS** over the years after installation.
- Develop a joined-up policy to meet target of **400.000 heat pumps by 2030 in Ireland**.
- Recognition of the **benefits of heat pumps for lowering demand on the grid**, perhaps tax breaks. Deploy smart grids to support this.
- Support farm **self-sufficiency** and high energy efficiency for livestock farms.
- Provide local livestock entrepreneurs with basic training, financial aid, advisory and extension services and **networking** for this transition.
- Support consultants who can **carve out tailor-made technological solutions** for farms.

3.5.3. Greenhouses

The main discussion issues were as mentioned in the previous section; (i) the needs of the farms in terms of energy in a technical, financing and knowledge sharing level; (ii) the barriers hindering adoption of FEFTS and (iii) the incentives needed to increase FEFTS adoption.

3.5.3.1. Needs of farms in terms of energy.

Technical

- **Agri PV** or greenhouses with transparent solar modules could reduce the energy needs.
- Reduction of the electricity consumption, water management, self-consumption, pumping, mobility, farm temperature and lightning, emission reduction, minimize production costs.
- FEFTS should be **compatible** with the rest of the greenhouse activities.
- **Energy communities** are key, where energy is distributed among users within a radius of 50 km, can help with the use of energy when someone does not need to self-consume.

- The needs of greenhouses that can be covered by local energy production from RES are mainly **heating and cooling of buildings**, **lighting**, **agricultural field practices**, and **vehicles**, using solar, heat pumps, and solid biomass conversion technologies.
- Energy storage must become more worthwhile, and **hydrogen powered energy storage** seems to be a near-future solution with less risks on depreciation and malfunctioning in comparison to conventional battery systems.
- **Geothermal heat pumps** for climate control to extend growing season in greenhouses has great potential. Attach to current geothermal boreholes for localised crop heating to start the season earlier in tunnel or cold glass horticulture. Integrate with solar adoption and use reverse metering.
- New technology for **CO_2 extraction from the atmosphere** for crops could blend with heat pumps where both heat and CO_2 are needed.
- RES based glasshouse heating solutions needed and underfloor heating for production nursery and plant propagation.
- **Green labelling** is needed to gain extra profit to cover the investment cost of FEFTS.
- Integrating of **biomass technologies** in greenhouses provide an option to decarbonise the heat sector in a rural context, especially if farmers grow the used biomass.
- Burning of **straw for energy** needs is another option.
- **Pyrolysis for combined heat and biochar production** could be a solution for heating needs in greenhouses.
- **Bioplastics** to substitute plastic cover of greenhouses or technologies capable to reduce the impact of these plastics after the completion of their lifespan (mainly south countries).
- **Photovoltaics and biomass/biogas** are the most used FEFTS in greenhouses.

Financial

- **Cooperation** between greenhouse growers on FEFTS topics could create new **opportunities to invest** in sustainable energy production and storage, as many entrepreneurs would bundle their effort and form a stronger voice in society and for policy makers.
- The need to ensure **reasonable energy prices** throughout the whole year makes production of energy a financially sound option, if competitive and compatible.
- FEFTS Integration is possible in greenhouses with the right supports and place for loans.
- Favour the emergence of the lowest cost FEFTS solutions.

Knowledge / Information / Awareness

- Need for technical assistance.
- Enhance knowledge on digitalisation.
- More knowledge on pros and cons between different kinds on pellets that can be used as heating fuel in greenhouses.
- More workshops like AgroFossilFree provides.
- Need for advisory services to provide to farmers proper guidance for selecting and using correctly the optimum FEFTS.
- Request for enhanced knowledge on digitalization and automation, provide more FEFTS education to greenhouse managers, but also to advisors and the financial sector.
- There is a need for advice/training about the use of produced energy regarding their later demands for energy and fluctuations in production due to weather conditions.

3.5.3.2. Barriers hindering FEFTS adoption.

- The incentives for moving to FEFTS adoption are not sufficient in plastic greenhouses, mainly because the **income is low and does not justify the expense**.
- Uncertainty of **future energy costs and fluctuations** to implement FEFTS economically.
- Even if greenhouses are within agriculture, **specific funding options are scarce and complicated**.
- Feeling that there is an **energy monopoly**, and the farming community is **helpless**.
- The main issue to develop solar PV in Spain is the change of land use that is required.
- In most countries, local authorities **advisory and provision of capital expenditure grants are limited**.
- Lack of **financial incentives** (or knowledge about it)
- Lack of **trust towards regulations** (volatility) and **complicated bureaucracy** (simplification of licensing procedures).
- **Hesitation to undergo vast changes** and adopt innovative solutions due to the elevated cost that might be unbearable for greenhouse production units.
- **Lack of experts** to guide greenhouse growers to see in practice the real benefits of adopting FEFTS.
- Product prices are relatively low with respect to the production costs, which leaves a **small profit margin**, always depending on the production unit's scale size.
- Fear about the **constantly increasing cost of fertilizers** due to the global economic instability.
- Lack of results' **demonstrations** and efficiency proofs.
- There is **a lot of unknowns** associated with decision making regarding all the different RES energy production and storage, with specific reflection to the farm of interest.
- There are different subsidy policies by different government bodies, but there is **no clarity on which are best for the farmers circumstances**, requesting a lot of time from farmers to select.
- Greenhouse farmers feel that other priorities regarding **regular business operations are more important on the short term** than investing in FEFTS that in most cases it is a way to reduce costs of production rather than earning money from producing energy.
- **Inefficient administration** of supports and **bureaucratic obstacles** to FEFTS adoption.
- **Underdeveloped grid connection** capacity**.**
- **Cost of investment is still high**, when compared with returns from market.
- There are gaps in the system of policy, grant aid and implementation at farm level.
- Funding models extended to large scale users.
- The **schedule of energy consumption is not in favour of the greenhouse industry** in relation to the currently variable energy costs.
- For each hectare of greenhouse 13 hectares of solar PV system are needed, so farmers are often **unable to meet their needs or resell the energy**.

3.5.3.3. Incentives to increase FEFTS adoption.

- Integrating of biomass technologies on suitable greenhouses can be done well if the right economic incentives are in place for farmers to **grow their own biomass**.
- Missing incentives to **combine** the advantages of **inter-regional**, central energy generation with the advantages of **regional, decentralized energy generation**.
- Let **political decisions be taken at regional level** and make long term plans (for business security reasons). The resulting experiences should then be bundled with suitable tools. Then they should be mirrored back into the regions to adjust at the inter-regional level.

- More **reliability of politics - currently changing directions constantly**. Remember that FEFTS which are good today maybe will be out/replaced by new technology tomorrow.
- Protect climate-neutral pioneers from the **ever-changing opinions from the outside** (e.g., government, advisors, innovation brokers, FEFTS providers).
- Promotion of improvements to **existing greenhouse production sites** with targeted and simple funding/incentive/support solutions. Also consider **small structures** and **niche farms** when it comes to funding opportunities.
- Regionally produced products should have a higher value or the import of products that can also be produced in the country should be taxed higher.
- **Priority for geothermal energy and heat networks**.
- Agri PV problem for EU arable land subsidy can be lost, this must be changed politically.
- Support economically **injection of exhaust gases (CO_2) into greenhouses** and provide permits for it.
- Development of **energy communities and clusters of innovative FEFTS solutions**.
- Support **demonstrative pilot projects of FEFTS** in greenhouses.
- Better involvement of **research centres**, development of organizations for producers and consumers and **collaboration** among neighbouring farmers.
- **Simplification of administrative requirements** for FEFTS implementation by setting common/standard criteria among the different governmental departments.
- Offer **knowledge and training** on the technical side of FEFTS for both advisors and farmers.
- Lower costs of FEFTS and enhance subsidy implementation especially for **small production units**.
- Assist **plug and play FEFTS solutions** with easy operation and maintenance to be available in the market.
- Support **energy audits to understand the energy pain points** of the greenhouse.
- Reduce bureaucracy.
- Support **cash injection, long-term subsidies, and credits**.
- Connect **CAP with Green Deal**, increase **operative funds**, and **improve knowledge** about CAP from farmers.
- CAP should have a specific **line for agrivoltaics development**.
- Give more **weight to ecological agriculture and green policies**. Merge **energy efficiency and agri-food** policies.
- Support **national advisory services with fast reflexes** to achieve maximum engagement and lead to knowledge transfer from research to the field and further incorporation of FEFTS in the daily agricultural practices.
- **Mitigate the shortcoming of knowledge and advice on FEFTS** for agricultural entrepreneurs. Even when farmers would have their own production facilities and storage systems, there would exist a need for **advice on the management of these systems** (energy production expectations, need of storage capacity, moment to sell energy to customers, need to store energy for peak moments for use with own greenhouse production).
- New **opportunities for commercial advisory companies** to incorporate these subjects in their services besides the regular advice regarding the crop production.
- Improve incentives to encourage the **use of bioenergy** on greenhouse farms.
- Need for development of **support schemes for renewable heat and power**, such as the Irish Support Scheme for Renewable Heat (SSRH)
- **Explicit rule set in funding mechanisms** to remove any uncertainties.

- **Certification of FEFTS** for greenhouse use.
- Shift **budget of CAP from other priorities to FEFTS** or increase the total budget to include them too (as there is already pressure to address existing priorities without adding more new/alternative funding needed).
- **Biomass energy training** is needed for farmers, especially mushroom producers.
- Support **carbon audits** for greenhouses with influxes of CO_2.
- Coordinated approach to farms with multiple opportunities/as **part of district heating**.
- To save resources, incentives should no longer be sent to simple photovoltaics, but to **agrivoltaics**.

3.6. Transnational Workshops

After the conclusion of the series of 24 Regional Innovation Workshops covering the 3 production systems of agriculture, namely open-field, greenhouses and livestock, 3 Transnational Innovation Workshops per theme were organized aiming to bring together relevant agricultural stakeholders to:

1. provide an overview of and discuss energy consumption in EU agricultural production as well as the factors affecting the adoption of innovative strategies and technologies.
2. present and discuss the main and current European agricultural industry solutions and associated policies as well as discussing future developments regarding energy efficiency improvements and renewable energy sources for agricultural production.
3. present and evaluate past and current research results of specific agriculture related FEFTS and to identify needed research direction, collaboration schemes, cross-border and educational efforts.

In each workshop, participants were split in two working groups each with stakeholders with a variety of expertise, from across the EU, allowing to receive important relevant insights and outputs for policy. The detailed results of these workshops are given in Deliverable 3.4.

3.6.1. Open-field agriculture

The main ideas for new policies from the transnational workshop for open-field agriculture were:

General Policies:

- Policies should mainly focus on solutions for **energy efficiency**. Currently, many farmers are unable to afford investment in new technologies, therefore they should focus on efficient use of the resources they already have.
- Since most participants did not know the significance of fertilisers (as indirect energy carrier) to the energy profile of open-field farms, a communication campaign on this matter should be started and sharing methods (temporal and spatial precision application, biofertilisers as substitutes of synthetic types) to reduce synthetic fertiliser use.
- Solutions for **carbon storage:** Participants of the discussion would like to see greater attention in terms of policies, given to conservation agriculture and carbon farming.
- There is a large interest in **alternative fuels to power agricultural machinery**.
- **Precision agriculture**: Greater attention should be given to precision agriculture, since it may be the best solution for the time being to reduce indirectly energy consumption.
- **Financial incentives** for those who introduce climate-friendly measures should be included as a driver for change.
- **Reduce taxes on energy** when the energy used is provided from RES (especially for alternative fuels).
- Apply policies to **promote self-sufficiency** through:

- ✓ biomass fuels production and consumption.
- ✓ biofertilizer use or/and production (i.e., composting/biofertilizer production/farm scale biogas plants).
- ✓ electricity production and consumption on farm level.
- ✓ incentives for self-sufficiency of feed protein from sustainable protein crop cultivation on an EU level.

- **Carbon taxes** could be a policy to assist FEFTS to grow, but according to some participants they are complicated and make things difficult, as it is quite tricky to effectively measure carbon sequestration. **Carbon credit schemes** should be expanded in agriculture to support efforts of soil carbon sequestration, like conservation agriculture.
- Policies or incentives to improve **education and knowledge sharing of FEFTS.**
- **Develop grants specifically for agriculture** and **ease the application** to invest in FEFTS for agricultural use.
- **Regulations should not complicate** the FEFTS implementation (e.g., simplification of agricultural photovoltaic connection to grid, allowance of self-sufficiency of internally produced biofuels).
- **Upgrading of the electricity grid** in rural areas to be prepared for RES influxes.
- **Biogas plant installations to be more subsidised where capacity exists**; in Denmark it has really helped doubling the biomethane production (during 2022) to cover all natural gas needs by 2035.
- **Policies promoting measurable/result-based subsidy financing of FEFTS**, where the subsidy extent is correlated to the national or regional level of independence on fossil fuel.

Must have technologies:

- **Cover Crop Mixes:** means (strategy) to manage nutrients circulation and allow reductions in the use of fertilisers.
- **Agrivoltaics:** allow for renewable energy production, without taking the land devoted for agricultural production, therefore it seems a good option for incorporating renewable energy.
- **Biogas** and **bio-methane-fuelled agricultural machinery:** holistic approach of the energy production/consumption problem in farms and especially suitable for mixed farms (open-field crop and livestock production). These two solutions were considered as closely related, and both FEFTS are even more interesting when combined. It was mentioned that it may be easier for big companies to set up such kind of renewable energy plants than it is for a single farmer.
- **No-till planters:** solutions for reduced energy consumption during field operations (reduced fuel consumption) that also enhance soil carbon sequestration.
- **Crop sensors:** optimised application of fertilisers and pesticides achieved through precision farming technologies and methodologies.

Reluctance observed for specific technologies:

It is noteworthy that the participants did not consider **investments in wind turbines** as a must have for the near future open field agriculture, due to the required large size to be cost effective and ensure a fast return of investment, a reality that does not fit well with small European agricultural holdings.

It was also mentioned that it may be **easier for big companies to set up a renewable energy plant than it is for a single farmer**, since the prices offered to energy producers tend to differ.

Participants were generally reluctant concerning the potential of the adoption of **electric tractors**, which may be related to the technological difficulties (mainly battery related) associated with producing effective electric tractors and depicts a perspective that refers to a transnational pan-European level and the case may be different in certain countries.

Hydrogen production combined with RES was also not so interesting for the participating stakeholder, as it seems very advanced based on the existing farm needs.

Ways (in national or EU level) that would help farmers familiarise with FEFTS:

- **Practical trainings** and **demonstrations on pilot platforms and farms**, showing how particular FEFTS can be used in practice and how they are successfully used by pioneering farmers.
- Need for **innovation brokers** and more support to pioneering farmers was pointed out.
- More **effective dissemination** of the available information that has been produced about FEFTS in agriculture.
- **Direct interaction with farmers** and possibility of consulting their doubts with actual FEFTS users would be appreciated.
- Another suitable method of educating on FEFTS would be spreading information through **extension services** and **agricultural advisors**, who should receive an appropriate prior technical training in the specific subject (as they are mainly of agronomic background).
- Transition intentions need to be implemented in the CAP and related subsidy eco-schemes as well. **Subsidy schemes should prompt farmers to realise** that application of FEFTS can improve income and sustainability simultaneously (for instance thanks to fuel saving from no-tilling and other conservation agriculture practices that increase soil organic matter through carbon sequestration) **and shift them from the current energy consuming strategy.**
- **Need to train advisors adequately about implementation of energy efficiency measures**, as they receive a lot of questions about it and often find they don't have the answers. Of course, it is also significant to train farmers that will become ambassadors of FEFTS (other farmers tend to mimic). It should be built into education curriculums.
- State advisory systems across Europe span from very well-structured (e.g., in Denmark one advisor assists about 40 customers/farmers), to well-structured (e.g., in Ireland this proportion is about 1 to 300) to no formal integration of the advisor into the agricultural system (e.g., Greece). It is proposed that **member states should fund organised advisory systems**.

3.6.2. Livestock

The main ideas for new policies from the transnational workshop for livestock systems were:

General Policies:

- **Replace existing feed with alternatives**, as it is the main energy consuming category for livestock meat, poultry, and dairy production and is often neglected as energy carrier.
- **Increase feed efficiency** in the barn.
- Changing feed types will allow **reduction of the 60% of agricultural land** that is used for animal feed production.
- **Supply chain of feed should be improved** to reduce cost of transport.
- In some countries, the production cost in livestock is connected to fuel and electricity by only 5-10%, so direct energy is not the main pain for farmers. Hence, higher energy prices are not a major driver for FEFTS investments.
- Rooftop solar and biogas have been already installed in farms having the economic strength for FEFTS investments. Farms with **limited finances need public assistance**.

- Small farms seem to go out of business due to high overall production costs, due to **expensive heating and feed** and need support.
- Livestock farmers do not make investments to reduce energy consumption, mainly due to uncertainty coming from economics and rising energy costs, but also from other related policies (e.g., the new nitrogen legislation in the Netherlands).
- Offer support to farms to become **sustainable and self-sufficient regarding feed and energy**, to make them resilient to change.
- **Biogas at farm level** would be a good solution, but regulations should assist this application in livestock farms.
- Incentives focusing on the **production of biomethane** might increase livestock farms income.
- Provide **aid to smallholders** that are about to decide to step out of business.
- Enforcing the energy profile of livestock farms will assist animal product prices to **remain in acceptable levels**. On the other hand, the price for milk and meat can be considered low (e.g., in Germany), leading consumers to ignore the real production cost.
- Increase in **industrial symbiosis** for energy production of livestock facilities with other sectors might help the sector.
- Stimulation of **circular economy** through the new CAP and encouraging increased collaboration to overcome the situation.
- **Bureaucracy needs to be reduced** to adopt FEFTS.
- **Energy saving technologies should be prioritised** (e.g., pumping and transport of manure, ventilation of stables, lightning, precision farming, conservation agriculture in mixed farms).
- Manure handling and spreading to obtain **utilisation of organic fertilizers** should be assisted.
- Farmers **should measure energy consumption** in different places at the farm to see where they stand and take measures in the most consuming practices.
- Promote **building management systems** that also measure energy consumption for all livestock buildings.
- Promote **annual keeping records** to analyse the energy use and reduce costs.
- Alternative feedstock for biogas production might be **already used for other purposes** (e.g., straw need for bedding or district heating).
- Photovoltaic installations that have an operational lifetime of many years could help both small and large farms to overcome the rising costs of electricity.
- LED lightning, efficient insulation of buildings, efficient heating systems and climate control, fuel efficient machinery (variable transmission etc.), biofuel driven tractors.
- **Renew ventilation systems in poultry production** that consumes most electricity.
- For dairy, irrigation, farm machines and milking (incl. cooling) consume most electricity.
- **Milking robots** may not always be the right solution, but they might be if electricity comes from RES locally installed at the farm.
- Support **cooperation between livestock stakeholders** to obtain better prices both on products and FEFTS investments.
- **Change crop rotation** towards more diversity of farm products, for instance growing energy crops and growing your own protein.
- **Ease processes for installing RES** to produce energy for self-consumption.
- **Decouple the pricing of electricity from natural gas**.
- **Remove taxes** on the transport of renewable energy related goods.

- Develop **more advanced business models** (e.g., about biomethane, selling RES) to clear the situation for farmers.
- **CO_2 emission taxes** on agricultural production could be reinvested for subsequent investment/subsidies for FEFTS.
- An **off-road vehicles tax system** could be integrated for agricultural machinery of all types to promote substitution.
- Rethink **priorities/focus areas for the second pillar** of the Rural Development Programme to support FEFTS investment to the farms.
- **Enabling policies of spatial planning** for agreed areas to set up specific technologies (e.g., PV, wind, biogas, etc.).
- Policies that **combine animal welfare with energy savings** to support sustainable livestock farming.
- Policy about renewables with very strong financial support providing specific **category towards livestock**.
- **Labelling livestock products as green**, based on a well-established system to avoid green washing, could promote FEFTS adoption.
- **Different investment support** for new and sometimes less proven FEFTS technologies should be provided.
- **Differentiation of regulations between EU countries** are necessary to take into account their geographical differences and climate, and differentiate policies based on the size of the farms, and last but not least to promote family businesses rooted in specific regions.

Must have technologies:

- Biogas plants.
- PV integration in rooftops of livestock building.
- Alternative (biomethane) machinery.
- Feed production/efficiency independent of livestock production type.
- Smart manure handling from stable to storage.
- Poultry and Swine (new technology for heat treatment of feed, cooling of eggs at storage, and heating/cooling of buildings).
- Heat exchanger/heat recovery systems.
- Biomass boilers/heaters.
- Heat pumps.

Reluctance observed for specific technologies:

- No interest in wind turbines.

Ways (in national or EU level) that would help farmers familiarise with FEFTS:

- **Practical as well as on-line trainings and demonstrations** on pilot platforms and farms, showing how particular FEFTS can be used in practice and how they are successfully used by pioneers.
- Governments could **participate in fairs** to promote FEFTS, something they rarely do.
- **Extension services and advisors** should get in the frontline of promoting FEFTS.
- **State advisory systems** could assist farmers of low income.
- Advisors should be provided with **facts and numbers** to disseminate FEFTS to farmers followed by **information campaigns**, for instance by social media and **workshops** with presentations of successfully implemented FEFTS.

- **Livestock associations or national federations** should promote transparent information about FEFTS solutions to their members.
- Cover the **gap between academics, advisors and farmers** with national development programs.
- Make FEFTS related **business cases clearer** for the actual national situation. FEFTS implementation with full scale farms for construction of practical platforms for farmers to show positive examples with proven effects (demo) on a national level.
- Place an **EU level approved graphic/logo/sticker** for use with FEFTS for any technology that is actually defined as a FEFTS, based on certain criteria.

3.6.3. Greenhouses

The main ideas for new policies from the transnational workshop on greenhouses were:

General Policies:

- Energy carriers for greenhouse use (especially in high-tech facilities) should be **shifted to towards alternative RES** to compensate the cost rise from fossil fuels price increase.
- **Energy efficiency measures need to be promoted and supported** to reduce energy needs of greenhouses (especially in high-tech facilities), as the combination of conventional energy price increases and improvements in Energy efficiency technologies will drive adoption of such measures.
- **Standardisation of the framework for protected crop production on EU level** including energy efficiency improvement goals are key factors for increased sustainable production.
- Economic support for the transition to FEFTS use is necessary to **avoid scrolling of cost increase to final food** (horticultural products) prices.
- **Focus on sustainable and more specialised "protected under covered structures" crop production** in the EU, due to increased demand for locally produced products, increased focus on environmental sustainability and optimised production systems, high costs of logistics, failures meeting EU sustainability guidelines for imported crops.
- Need for the **development of effective energy measurement method** such as **energy audits** for greenhouses. Strong policy on this way will help any difficulty in effectively measuring energy use today and stimulate practices similar to energy labelling on products in the EU.
- Avoid making the greenhouse sector **responsible for something they cannot control** and for what it is complicated to measure/audit.
- Introduce greenhouse sector to **carbon neutrality per unit of cultivated crops**, which is becoming increasingly important to retailers and consumers.
- **Optimise building envelope design** in new greenhouses to avoid high energy demand.
- **Heating, Ventilation and Air Conditioning (HVAC) together with irrigation and lighting** are the most wasteful energy parameters and novel FEFTS should be applied to optimise them.
- Greenhouse stakeholders have different opinions on where energy is 'wasted', so **FEFTS prioritisation is challenging** to support a green transition in the EU greenhouse sector.
- **Shift measures of the new CAP** towards FEFTS in greenhouses.
- Use **CO_2 tax (CO_2 reduction rewards)** in favour of **green production** in greenhouses.
- Develop **targeted modernisation schemes** (for instance, in Ireland a grant exists for the purchase of RES equipment, similarly, in the Netherlands there is a national scheme subsidising the adoption of heat pumps) and **tax deduction of investment in FEFTS**.
- **Clear and long-term national strategies** are key factors to encourage investments in new FEFTS technologies.
- Policies that **support returns on investment** are generally more effective.

- **Minimal price for agricultural produce** can reduce risk for farmers to implement FEFTS.
- Specific economic **support for small** greenhouse holders.
- Phasing out of fossil fuel boilers by **supporting green heating systems**.

Must have technologies:

- **Building Management Systems (BMS):** Greenhouses are complicated facilities that require detailed knowledge of climatic conditions and plant status to obtain high yields with low cost. Modern BMS using multiple data inputs from different sensors that processes them to produce valuable information to run optimised practices in the greenhouse can make a huge difference for growers.
- **(Semi-) transparent or conventional PVs:** Greenhouses cover large surfaces that if covered with PV technology that allows plants to photosynthesize could develop self-sufficient farms with ability to sell electricity. Regular PV can also be applied mainly in external land that the greenhouse uses for auxiliary work.
- **Heat pumps:** heating and cooling are the main energy consuming activity of a greenhouse (mainly in northern Europe) and heat pumps seem to be a technology that could reduce this energy pain for growers.

Reluctance observed for specific technologies:

- No interest in wind turbines.

Ways (in national or EU level) that would help farmers familiarise with FEFTS:

- Development of a **new vocational specialisation** on FEFTS.
- **Funds for farmer education**.
- Advisors **stimulating awareness** of relevant FEFTS technologies.
- More **effective dissemination strategies** from different entities (governmental bodies, advisory/extension services, cooperatives, innovation brokers, etc.)
- Economic **subsidies for adoption** of FEFTS in greenhouses.
- Development and adoption of a **FEFTS label** to upgrade the fame of greenhouses using FEFTS.
- Provide **paid farmer trainings**, so to increase interest.
- Knowledge transfer under the headline "how to!" with training content on **latest EU developments, energy savings strategies, specific RES technology trainings, and how to access subsidies** using summer schools, workshops, case study presentations, practical trainings, webinars, virtual tools, presentations of experimental demos and site visits.

3.7. Final List of Policy Recommendations/Briefs

The methodology presented in Chapter 2 has allowed us to extract policy recommendations at different levels (technical, financial, regulatory, knowledge sharing) that in detail has been presented in Subchapters 3.1-3.6. However, the AgroFossilFree consortium has identified the most crucial recommendations that would be ideal to be presented to stakeholders in Europe to assist in FEFTS adoption and smooth defossilisation of the agricultural sector. The policy recommendations that AgroFossilFree has come up with are separated in 3 main categories:

- **Horizontal Policy Recommendations:** These proposed policies are about energy related issues in farming that can be applied to any type of farm and FEFTS; therefore, they have a horizontal application capacity and can be used to assist all other specific policies to be adopted easier by farmers.

- **Specific to agricultural production system Policy Recommendations:** These policies can assist specific FEFTS to be applied in farms of certain production systems (open-field, livestock, greenhouses); hence, this document indicates the necessary steps required for them to be adopted by farmers.
- **Generic Policy Recommendations:** This category refers to policies that are completely necessary to be taken for any innovation towards green growth in EU farming, including FEFTS integration.

The list of the AgroFossilFree Policy Recommendations/Briefs are given in the table below:

Table 3.3. FEFTS categories identified in the content of AgEnergy Platform.

Policy Brief No	Policy Brief Title
Horizontal Policy Recommendations	
1	Enabling the creation and growth of energy communities in rural areas
2	Farm Energy Audits
3	European Low Energy/Carbon Label of Agricultural Products
Specific to agricultural production system Policy Recommendations	
4	Agrivoltaics for open field agriculture
5	Alternative Fuels for Agricultural Machinery
6	Precision Agriculture as energy consumption reduction strategy
7	Carbon Farming for Carbon Removals
8	Conservation Agriculture to enhance soil carbon stock and reduce GHG emissions in European Agriculture
9	Alternative crop nutrient providers (Green Fertilisers / Biofertilisers, biostimulants / Biochar)
10	Building Management Systems (BMS) for Agricultural Constructions
11	Heat pumps for HVAC of agricultural constructions
12	Photovoltaics (PV) and Photovoltaic Thermal (PVT) Collectors and Systems for agricultural constructions rooftops
13	Biogas production from agricultural waste and other innovative feedstock / Biomethane upgrading for local consumption or grid injection
14	Facilitating the development of energy independent farming in Livestock
15	Livestock building energy upgrading/renovation
16	The use of thermochemical fluids for energy saving and storage in agriculture
Generic Policy Recommendations	
17	Financial Support to Fossil Energy Free Technologies and Strategies
18	Regulatory support to Fossil Energy Free Technologies and Strategies
19	Technology, Knowledge Transfer, and Awareness Building provisions to support Fossil Energy Free Technologies and Strategies diffusion

3.8. Consultation with EC actors

The selected 19 Policy Recommendations/Briefs were shared with Policy Officers from the associated DGs of the European Commission and on May 25th, 2023 an online consultation meeting was conducted to present and discuss the Policy Briefs for further optimisation following valuable feedback from the experts. A total of 41 people participated in the online event and the revised versions of the Policy Recommendations/Briefs are presented in the next chapter.

4. POLICY RECOMMENDATIONS/BRIEFS

Each policy recommendation starts with the statement of the challenge that must be overcome, followed by the policy gaps and recommendations proposed and closing with the expected impact after its implementation.

4.1. HORIZONTAL POLICY RECOMMENDATIONS

4.1.1. Enabling the creation and growth of energy communities in rural areas

What is the challenge?

Policy measures at all political levels should be taken so that energy communities in rural areas, composed of citizens, and other local actors willing to co-operate, like farmers, other local SMEs, and the municipality, can grow in number and size and promote the local energy transition.

Such measures, constituting the enabling framework required by the Renewable Energy Directive (REDII) and the Electricity Market Directive (IEMD), should support communities across the EU to engage with, participate in and benefit from the energy transition to a fossil fuel free agriculture, economy, and society by 2050.

The prospect of an enabling framework and the unclarity of the definition of energy communities in the RED II and IEMD Directives, however, is currently leading in several Member States to the hijacking of the concept by private and public, incumbent, and new big players in the energy market, like in Flanders (BE).

Policy Recommendations

EU Level:

- Align both definitions of energy communities (REC/CEC) with each other and make sure that they guarantee citizen participation and special support to citizen driven initiatives.

Member state Level:

- Introduction of specific definitions of energy communities at the national legislation in line with the EU legislation, explaining the criteria around what constitutes an energy community as a bottom-up initiative with the EU-citizen at its core. See the Transposition tracker REC and CEC definitions[9], or the Policy Database of the Energy Communities Repository (DG Energy)[10], where you can follow up on how the transposition and implementation is going on in all EU member states. Each Member State should do an assessment of barriers and potential for the development of energy communities at the national level and the findings of such an assessment should be used for the design of a complete enabling framework for them to be able to participate in the market without discrimination compared to other market actors.

[9] Transposition tracker energy community definitions: https://www.rescoop.eu/transposition-tracker

[10] Policy Database of the energy Communities Repository: https://energy-communities-repository.ec.europa.eu/energy-communities-repository-legal-frameworks/energy-communities-repository-policy-database_en

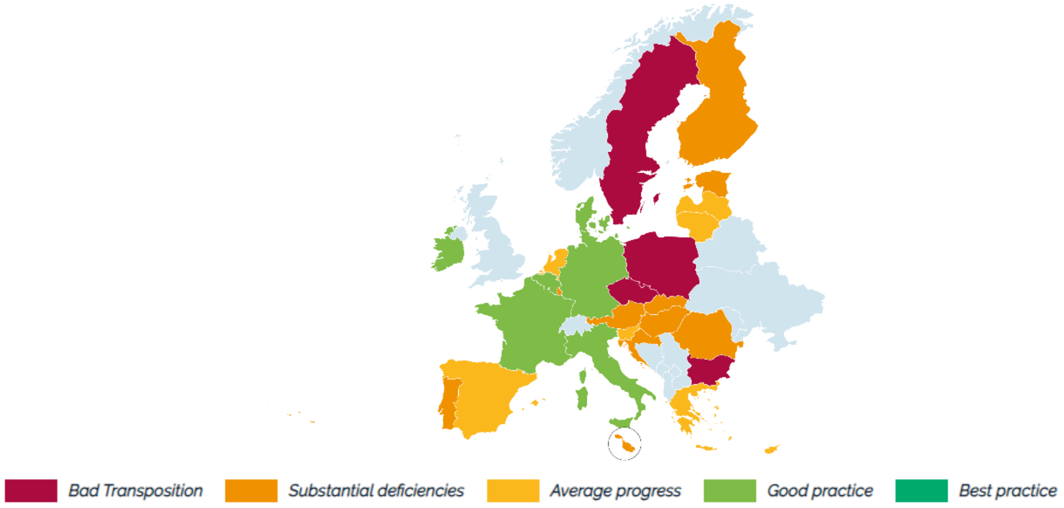

Figure 3: Transposition of definitions of REC and CEC in the different EU member states end of 2022.

- An ambitious community energy sub-target within the renewable energy target (like in Scotland[11], the Netherlands[12] and Wallonia[13] – see in impacts section) should be set by all Member States.
- Specific allocation and targeting of development programs and EU public funds[14] (Recovery and Resilience Funds, Cohesion & Regional Development Funds, Modernisation Fund) for energy communities at a national, regional, and local level.
- The share of total funds allocated to energy communities should be proportional to the development stage of the community energy movement and the ambitious community energy sub-target of each Member State.
- Tailored community building support, legal, financial, and technical advice for energy communities make up an essential element of the enabling framework. There should be a holistic strategy to provide financing and advice across different levels of project development:
  - ✓ Tailored financing tools for energy communities should be available, including grants, but also low interest loans, guarantees, blended financing mechanisms, etc.
  - ✓ There should be a link between energy communities, building renovation and energy efficiency schemes of all Member States.
  - ✓ Energy communities should be recognised under multiple objectives (e.g., green and/or circular economy), promoting renewable energy, tackling energy poverty, etc.
  - ✓ The design and communication of the schemes and measures supporting energy communities should be transparent.
  - ✓ The selection criteria and the prioritisation of various social components should be given to potential energy communities clearly and in detail.
- Member States should consider the specificities of renewable energy communities when designing their support schemes for renewables. Tendering processes by authorities should be decentralised to allow and assist local actors to run energy communities.
- Procedures to facilitate the participation of energy communities in open calls (e.g., capacity building workshops/ working with network and intermediary organisations) should exist to boost access in

[11] Scotland: https://www.gov.scot/publications/local-energy-policy-statement/pages/4/
[12] Netherlands: https://www.klimaatakkoord.nl/participatie/handreiking-participatie-duurzame-energie
[13] Wallonie: Pax Eolienica: https://www.wallonie.be/fr/actualites/eolien-wallon-un-plan-ambitieux-simplifie-et-plus-participatif-pour-2030
[14] Tracker how EU public funds (Recovery and Resilience Funds, Cohesion & Regional Development Funds, Modernisation Fund), are being used by Member States to support energy communities: https://www.rescoop.eu/financing-tracker

available public funds.

- The funding programmes should be stable and predictable through time, keeping the process transparent and consistent in its structure and the investment policy and maintaining constant disbursement cycles.
- Member States should follow the good example of Austria which has introduced and supports a national coordination office for energy communities (Österreichische Koordinationsstelle für Energiegemeinschaften; https://energiegemeinschaften.gv.at/) to support the creation of new energy communities and the support of existing ones.
- Online information gateways for energy communities could be implemented in European countries and should be supported. A blueprint of such gateways was developed by the project SHARES[15]
- Examples of working enabling frameworks[16]
- Greece has established a robust regulatory and legal framework over the past decade, having at the heart of this journey the Law 4513/2018, which serves as a cornerstone in promoting decentralized energy production and fostering Energy Communities. Farmers in Thessaly, taking cues from this enabling environment, were quick to adapt and harness the advantages offered by Energy Communities to mitigate cultivation costs by leveraging community-driven energy production initiatives. The energy produced is primarily utilized for irrigation, which is a significant factor in the region's agricultural success.
- In Italy, the National Recovery and Resilience Plan (Pnrr) allocates 2.2 billion euros for the promotion of energy communities in municipalities with fewer than five thousand inhabitants, to relaunch their development and mitigate situations of economic vulnerability. The goal - but the process has yet to start - is to reach June 2026 with at least 2,000 MW of installed renewable capacity and a production of 2,500 GWh. According to the latest quarterly report Energy and climate in Italy by the GSE, published in May 2023, at the end of 2022 there were forty-six configurations of collective self-consumption and twenty-one renewable energy communities, for a power of 1.4 MW. These numbers are still small compared to the targets and ambitions, but it is expected that they will grow a lot once the European authorities have finished evaluating the decree presented by the government on February 2023. The text not only provides for economic support, but provides energy communities with a clearer and more complete regulatory arrangement that is currently lacking. Among other things, the power limit for each incentive plant is raised to 1 MW - it is possible to associate more, provided they do not exceed this capacity -, in order to enable renewable technologies other than photovoltaic ones, which in any case remain the simplest to place.

Expected Impacts

- With a well-designed enabling framework, the community energy sector can grow substantially[17] as the examples of Scotland with its CARES scheme[18] and the Netherlands with the Post Code Rose mechanism[19] illustrate. In the Netherlands, the number of citizen-led initiatives grew from about 70 to 700 in 7 years.

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[15] https://sharerenewables.eu/; Example of a national gateway in Germany: https://erneuerbare-energie-gemeinschaften.de/

[16] Report on enabling frameworks: https://www.rescoop.eu/toolbox/enabling-frameworks-for-renewable-energy-communities-report-on-good-practices

[17] Study potential community energy: https://www.ce.nl/publicatie/the_potential_of_energy_citizens_in_the_european_union/1845

[18] Scotland: https://localenergy.scot/funding/

[19] Netherlands: https://www.rvo.nl/subsidies-financiering/sce

- When the windfarms and solar parks in the rural areas are owned or co-owned by the farmers and their neighbours and the returns also stay local, this will boost the local economy[20] and give young people opportunities to stay in their rural area.
- It will boost social acceptance[21] for the energy transition.

4.1.2. Farm Energy Audits

What is the challenge?

Nowadays, most EU farms do not conduct energy audits as farmers are not familiar both with the procedure and the benefits gained from it. On the other hand, energy audits are mandatory for residential and commercial buildings to determine their energy efficiency.

Today, the energy audits provide a complete electricity consumption and energy efficiency assessment, obtaining important information regarding the building's energy usage and Energy Star rating from the audit report. Based on this information, any energy usage issues are identified and can then be corrected to cut electricity costs. The results of this procedure are evident in the report "**A Study on Energy Efficiency in Enterprises: Energy Audits and Energy Management Systems"** published by the EC in 2016. In this document it can be seen that SME's who have created networks, identified energy saving measures and then implemented them, succeeded the minimization of their energy needs. **For example, the 30 Pilot Networks project, which is a part of the Learning Energy Efficiency Networks (LEEN), identified 7030 measures out of which 3580 were profitable, resulting in energy saving potential of 2670 MWh/year**. As the project is still ongoing, **for the time being, 207 measures have been applied and 98.5 MWh/year energy savings have been achieved**.

For the case of **farmers, such networks and measures have not been set yet**. Farms have specific characteristics on the way they operate and setting a unified methodology is not as easy as for residential and commercial buildings. For example, they may use different energy carriers and have multiple energy use categories both in open-field categories and buildings. This is an issue that has not been yet properly addressed in the CAP, however based on the CAP funded advice the necessary knowledge exchange is expected to increase.

Therefore, **the challenge is to create a universal system in which energy audits for farms will be easily conducted**. At the same time a complete methodology will have to be set in order to help farmers realise the privileges gained from conducting such procedure as the cost of maintenance of their farms will decrease, dependence of fossil fuels in agriculture will be reduced and at the same time it will contribute to the adaptation and mitigation of climate change.

Policy Recommendations

EU Level:

- **Promote the advantages of conducting farm energy audits** on national level towards minimization of the energy consumption combined with farm operational cost reductions.
- **Create a uniform methodology** that will be followed for conducting energy audits across EU.

[20] Germany: https://www.uni-kassel.de/fb07/index.php?eID=dumpFile&t=f&f=2280&token=7dbdd77657ce15e67e933920a04e4c52dd105aeb and France: https://energie-partagee.org/wp-content/uploads/2019/12/Note-technique-Etude-Retombees-eco-Energie-Partagee.pdf
[21] Study social acceptance community energy: https://www.rescoop.eu/news-and-events/news/european-citizens-want-ownership-of-wind-and-solar-projects-in-their-neighborhood

Member States Level:

- Create a platform which farmers and their advisors can easily customize to their needs and **do the energy audit effortlessly**.
- Ensure that the existing energy audit processes for commercial, industrial, and residential buildings are adapted and followed for farms of all types. Initially, **keep the audit procedure optional and then move to mandatory certificate of completion** for farms to be able to operate.
- Farmers who have done an energy audit on their farm could be **eligible for financing aid programs** that will help with upgrading their energy consuming equipment based on the results of the audit.
- Promote farmers who conduct energy audits in their farms and apply energy efficiency measures by **increasing the product's price towards the buyer**. These products could be promoted as eco-friendly and greener (see Policy Brief "European Low Carbon Label of Agricultural Products").
- In Poland there is a need to create a concrete methodology first, and then it will become possible to promote audits.
- Support farmers in conducting energy audits as, for instance, is done in Ireland where a €2,000 Energy Audit voucher is available to all businesses including agriculture who have an annual energy spend more than €10,000.
- Farm energy audits in Greece are regulated by the national law 4342/2015, which transposes the EU Energy Efficiency Directive (EED) into the Greek legislative framework. The law requires large industrial consumers, including farms, to either conduct an energy audit every four years or implement an energy or environmental management system. The law also provides a framework for promoting energy efficiency measures and sets the institutional framework for carrying out energy audits. The law also includes the criteria based on which an audit is obligatory or not. Energy audits include a physical inspection of agricultural buildings and equipment, as well as a measurement and analysis of the energy flows and performance indicators and conclude with recommendations for implementing the most cost-effective and technically viable measures. Certified energy auditors are registered in a national registry of the Ministry of Environment and Energy.
- In Italy, the Guidelines for the energy certification of buildings, introduced by the Ministry of Economic Development with effect from 1 October 2015 (Ministerial Decree of 26 June 2015), do not concern agricultural or rural non-residential buildings, **without air conditioning systems**, being excluded from the obligation to supply the energy performance certificate (Ape).

Expected Impacts

- **Reduction of energy consumption and related emissions in agriculture** through changes to be applied by farmers for the energy optimization of their farms (expected savings up to 35% of the total energy consumption).
- Increased farm profitability, as **costs related to energy use will be significantly reduced** while maintaining the same incomes per production, favouring rural population maintenance or increase.
- **Possibility for the conduction of targeted research** in areas required since the results of all farm energy audits will be gathered to create a unified database.
- Acquisition of knowledge regarding the EU farms energy status by **creating a registry that will provide to policy makers the information necessary to focus their policies** for energy consumption reduction in the agricultural domain.

4.1.3. European Low Energy/Carbon Label of Agricultural Products

What is the challenge?

The European Union has set labelling in agriculture, such as the organic logo that gives a coherent visual identity to organic products produced in the EU. The reason to produce distinctive labels showing a specific characteristic of agricultural products is to make it **easier for consumers to identify these products** and at the same time help **farmers to market them across the entire EU, potentially receive better prices and economic aid**, acting as an incentive to move to more sustainable products.

Such labelling can only be used on products that have been certified for their specific characteristic (e.g., organic) by an **authorised control agency or body**, using a certain methodology to check the fulfilment of strict conditions in the production system. In case of successful certification, the label can be awarded accompanied by a display of a code number of the control body and the place of farming.

The EU does not have a label referring to the sustainable direct and indirect energy use during agricultural production that could lead farmers to greener energy use in all the processes involved. A **defossilisation labelling system for agricultural products** to be applied EU-widely in all member-states could act as an **official certification scheme for products that have been produced with sustainable direct and indirect energy use practices** that lead to greenhouse gas (GHG) emissions reductions and removals and other environmental and socioeconomic benefits, such as reduced water resources contamination and maintenance of rural population.

Policy Recommendations

<u>EU Level:</u>

The policies that should be followed to make the label successful are:

- The official certification scheme for direct and indirect energy use reduction (with respective GHG reduction and/or carbon sequestration) during an agricultural production should provide **clear rules and transparency to the grocery market actors** by introducing a framework for monitoring, reporting and verification of greenhouse gas emissions reductions or removals to encourage farmers to include their business in this process.
- The label should be based on the **energy use reduction level and the GHG emissions reductions or carbon removal methodologies** (based on a Life Cycle Assessment format) approved by an official authority of the EU.
- Several companies have labelled their products with **own low and zero emission labels** without scientific evidence and proof about the positive impact. This leads to consumer deception. In Germany, consumer associations[22] and the Federal Ministry for the Environment and Consumer Protection condemn these practices. **Suitable legislation is needed** to avoid this practice.
- The certified energy use reduction and GHG emissions reductions or removals of an agricultural product should be **registered in an official registry to prevent double-counting and avoid green-washing** of certain products that were not sustainably produced.
- The certification framework should be initially set from the EU's responsible authority (**top-down approach**) but should also follow a **bottom-up approach** allowing stakeholders and experts to propose certification methodologies for specific agricultural products, considering geographical and pedoclimatic conditions of the production site, also counting the Protected Designation of Origin

[22] https://www.verbraucherzentrale.de/wissen/umwelt-haushalt/nachhaltigkeit/klimaneutrale-produkte-nachhaltig-sinnvoll-oder-cleveres-marketing-79835

(PDO) and Protected Geographical Indication (PGI) framework. The proposed methodologies should be reviewed by a specialised committee and, **if approved, they could be a part of the official certification scheme**.

- **Third-party auditors could also play the role of verification and certification bodies** assisting the official EU body to reach a verdict for an agricultural product's ability to receive the label.
- Labelling agricultural products that use low or zero fossil energy should be of **low cost for farmers (especially small holders)** and simultaneously the products should receive **higher prices in the market and specific CAP support** to attract farmers into sustainable energy use and increased efficiency.
- In case of developing this label, extension services, private advisors and innovation brokers should **inform farmers about such frameworks** and provide services such as preparing the necessary paperwork to receive this label to **promote these products in a fast pace to consumers**.

Member States Level:

- Following the controversial inclusion of traffic light labels proposed by the EU, in Italy some studies carried out by the Milan Centre for Food Law and Policy and with the scientific know-how of the State University of Milan have developed a labelling system that provides a score summary relating to the quality of food products according to a holistic and multidisciplinary logic. This model goes beyond the limit of the traffic light label (green, yellow and red) which necessarily implies an implicit evaluation of consumption "authorisation", corresponding to green, and vice versa of a "prohibition", when the score falls in the red spectrum. An approach that risks triggering unwanted mechanisms of possible excessive consumption in the first case and renunciation in the second, when instead a healthy diet corresponds to a balanced consumption of a wide variety of products. The label thus conceived combines nutrition and sustainability for conscious food choices, and gives the consumer a clear, complete and multifactorial reading on the environmental, economic and social sustainability of the products.

Expected Impacts

- **Increased interest of customers** in low energy input agricultural products.
- Farmers' **shift from conventional energy use** in agricultural production to more sustainable energy use.
- **Higher prices** of labelled agricultural products.
- **Reduced energy and carbon footprint** of farming activities.
- **More rural employment**, but also **new business creation** in the certification domain, improving population indices in these areas.

4.2. SPECIFIC TO AGRICULTURAL PRODUCTION SYSTEM POLICY RECOMMENDATIONS

4.2.1. Agrivoltaics for open field agriculture

What is the challenge?

Achieving the EU's medium- and long-term objectives for transitioning away from fossil fuels necessitates the large-scale implementation of renewable energy sources. Photovoltaic (PV) systems are expected to contribute significantly to this endeavour. As reported by Solar Power Europe, there is a need to roll out an impressive 870 GW of solar energy across the EU by 2030 to pave the most cost-effective path toward achieving carbon neutrality by 2050.[23] This aligns with the global shift towards cleaner energy sources to combat climate change.

While rooftop PV systems can serve as an alternative, their scalability is insufficient to meet the massive renewable energy demands for the EU’s decarbonization efforts. Consequently, the focus turns to the expansion of ground-mounted PV systems. Nevertheless, this approach can create a conflict between food and energy production, posing potential unintended socio-environmental repercussions.

Agrivoltaics (APV), the synergy of agriculture with solar photovoltaics, emerges as an innovative solution to preserve agricultural land while concurrently generating solar energy. The concept involves integration of solar panels with crop cultivation, ensuring dual land utilization. The HyPerFarm H2020 project conducted a study, identifying prospective APV sites throughout the EU. Astonishingly, the potential capacity for APV systems in Europe is estimated at 51 TW, which could yield approximately 71,500 TWh of electricity annually.[24]

Furthermore, climate change poses an imminent threat to agricultural productivity within the EU, with studies indicating a projected decline in crop yields. In this regard, APV systems can prove to be invaluable. The thoughtful incorporation of solar panels in agricultural fields can shield crops from extreme weather conditions and create microclimates that are conducive to agricultural productivity.

However, the path towards APV maturity is filled with challenges, including optimisation of agricultural yields in tandem with solar energy production, building a robust APV business model, and developing supportive regulatory and policy frameworks for APV systems. Moreover, the EU’s Common Agricultural Policy (CAP) and national policies should consider supporting APV systems as a sustainable practice, encouraging adoption by farmers.[25]

APV systems are particularly viable for orchards, vineyards, greenhouses, and arable crops, albeit with varying complexities. For many farmers, investing in agrivoltaics is a leap of faith due to the lack of supporting infrastructures and unfamiliarity with the multifaceted benefits of the technology. Most farmers have yet to embrace the dual role of being an energy producer while farming. Hence, the establishment of demonstration sites, such as those under the HyPErFarm project,[26] is crucial for illustrating APV efficacy. Moreover, the development and deployment of intuitive tools for assessing the performance of agrivoltaic systems are imperative.[27] There is also a need for additional pilot projects to examine the influence of APV on crop behaviour under diverse climatic conditions and to ascertain the optimal balance between shading and electricity generation.

Lastly, even with positive results from pilot projects, farmers must critically assess various aspects such as the positioning of APV systems on their farms, energy management strategies (including consumption, surplus sales, and on-site storage), and the current and anticipated levels of farm electrification. Comprehensive educational programs, financial incentives, and agricultural extension services can facilitate the seamless integration of Agrivoltaics into existing farming practices and contribute substantially towards the EU's defossilization and climate neutrality goals.

[23] SolarPower Europe (2021): EU Market Outlook for Solar Power 2021-2025
[24] Niazi, K.A.K, Victoria,M. (2023). Comparative analysis of PV configurations for agrivoltaic systems in Europe. Under review. Accessible via Deliverable 5.1, HyPErFarm project (URL)
[25] European Commission. Common Agricultural Policy (URL)
[26] HyPErFarm project. Pilot plants (URL)
[27] Agrivoltaics webtool (URL)

Policy Recommendations

EU Level:

- **Set specific standards on what qualifies as an APV system**: Currently, there is no universally accepted definition of Agri-PV in Europe. The frontrunners in the field of Agri-PV within the EU are Germany, France, and Italy, which have taken the initiative in developing standardization protocols and guidelines for Agri-PV implementations.[28,29,30] Taking inspiration from their efforts, the first steppingstone toward encouraging the widespread adoption of APV systems should be the establishment of a clear and stringent definition of what constitutes an APV system (taking into account EU related policies). Development of a Quality Standard, monitored by a third-party entity is also a requirement. This is imperative to prevent conventional PV projects from encroaching on fertile agricultural lands under the guise of APV systems. Ensuring that agricultural yields are not compromised should be a central consideration in these standards. Consequently, a project could be classified as APV if it meets certain benchmarks, such as maintaining a stipulated minimum percentage of crop yield in comparison to the yield in the absence of APV. Japan serves as a noteworthy example in this regard, where the Ministry of Agriculture, Forestry and Fisheries (MAFF) has enacted regulations stipulating that an agrivoltaic system can only be installed if the crop yield is maintained at a minimum of 80% of its original production levels.
- **Targeted financial support of APV**: For initiatives that meet the criteria for genuine APV systems (as elaborated in the point above), it is imperative that financial support be extended for a designated period. This approach mirrors the support historically provided to emerging sustainable technologies, including conventional PV systems. The infrastructure necessary for the dual utilization of land in APV systems diverges from that of traditional PV projects and may encompass elements like elevated mounting frameworks and semi-transparent solar modules. As the production of these components is yet to achieve economies of scale, their implementation is associated with higher costs compared to conventional PV systems. Consequently, the involvement of public institutions can be invaluable during the nascent stages of extensive APV deployment. This support can materialize in various forms, such as direct contributions via subsidized electricity tariffs or indirect incentives like tax reliefs linked to project investment costs and preferential loan conditions for such ventures. Such backing would substantially facilitate the initial phase of APV adoption until the technology evolves to become more cost-effective.
- **Streamlining regulatory and permitting processes**: The implementation of APV systems should not be stymied by inflexible regulatory protocols, such as onerous construction permitting procedures. Measures should be taken to expedite these processes, for instance, by creating catalogues of pre-approved system designs, thereby facilitating a fast-track approach for construction permits. Furthermore, it is essential to proactively identify and mitigate other potential regulatory obstacles, such as the implications of land use designation alterations when APV systems are integrated with agriculture. To do so, identification / classification of potential agricultural land for Agri-PV deployment through spatial planning and categorisation of land in terms of suitability that takes into consideration policies related to energy, agriculture, environment and biodiversity at EU and national level should be implemented. The processes for obtaining licenses and connecting to the electrical grid should be streamlined and expedited.

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[28] DIN SPEC 91434:2021-05 Agri-photovoltaic systems - Requirements for primary agricultural use (German Institute for standardization, 2022).
[29] Ministry of the Environment and Energy Security (MITE, 2022). “Guidelines on Agri-PV systems”
[30] Agency for the Ecological Transition (ADEME, 2021). “Characterizing solar PV projects on agricultural land and Agrivoltaism”

- **Avoiding conflicts with agricultural subsidies**: In the frame of the CAP measures, farmers receive agricultural subsidies, depending on their use of the land. Installing APV may negatively affect the farmer by not receiving the agricultural subsidies anymore. This needs to be avoided and framework conditions changed so that it is possible to install APV and still receive CAP subsidies.
- **Addressing access to grid issues**: Given that APV systems are intrinsically a highly decentralized form of electricity generation, their deployment is contingent upon access to the electrical grid. In instances where expanding the grid at the requisite pace proves unfeasible, alternative strategies warrant consideration. These alternatives may encompass incentives or support for decentralized energy conversion systems, such as converting electricity into green hydrogen, or fostering support for user cooperatives centred around extensive APV installations, which could include agro-industrial enterprises. This multifaceted approach ensures that the deployment of APV systems remains agile and adaptable, navigating the complex landscape of regulations and grid accessibility.
- **Promote APV innovation**: Fostering innovation in APV can be approached through a multitude of avenues at the EU level. This encompasses R&D grants to facilitate further research into APV systems, both at the farm level and in the realm of enabling technologies, such as advancements in photovoltaic technology, with the objective of optimizing the amalgamation of agriculture and solar energy generation. Additionally, support for domestic production of essential components can play a significant role.
  Up until the present, only a single specific call topic has been issued pertaining to the development of Agrivoltaic systems within the Horizon Europe research and innovation programme.[31] Moreover, the work programme for 2023 – 2024 does not encompass any call topics in relation to this subject. It is of paramount importance to create avenues for funding in order to catalyse the development of new APV pilot plants. This will pave the way for a more comprehensive understanding of the dynamics and performance of agricultural practices in conjunction with energy production through APV systems.
  The establishment of these pilot plants can serve as invaluable case studies, offering insights that can guide policymaking, support the creation of best practices, and ultimately contribute to the EU's goals for sustainable energy and climate action. Engagement with industry stakeholders, agricultural communities, and research institutions should also be prioritized to foster collaboration and knowledge sharing in the pursuit of refining and scaling of APV technology.
- **Awareness:** Raising awareness regarding the merits of APV systems should commence with the farming community at the foundational level and encompass all the stakeholders integral to the value chain, such as researchers, developers, manufacturers, and more. Aarhus University conducted a study through the HyPErFarm project where they created various "Personas" based on qualitative interviews to simply understand the key stakeholders' perceptions of Agrivoltaics, as well as their needs, goals, and frustrations. This insight helps in developing tailored strategies for encouraging acceptance and smooth integration of these innovations.[32]
- Furthermore, actively showcasing APV technology through pilot projects encompassing a diverse array of crops, coupled with the arrangement of educational visits, should be encouraged. Informational campaigns, workshops, and accessible guidelines delineating the advantages of APV systems ought to be disseminated to increase the curiosity and interest of farmers and agricultural associations. Establishing a knowledge-sharing framework is crucial to capitalize on acquired

[31] Novel Agro-Photovoltaic systems. TOPIC ID: HORIZON-CL5-2022-D3-01-06. (URL)
[32] Torma, G. & Aschemann-Witzel, J. (2023). Creating Personas: A Qualitative Multi-Stakeholder Approach to Explore Sustainable Innovation Perception. Accessible via HyPErFarm website (URL)

experience, steering the successful adoption of APVs.

- However, awareness-building initiatives should not be circumscribed to the farming community alone. It can prove equally fruitful to engage wholesale purchasers of agricultural produce, such as supermarket chains. These entities can craft innovative marketing strategies for products cultivated in tandem with APV systems. Moreover, educating consumers and fostering a predilection for produce associated with APV technology could catalyse market demand. Similar to how consumers have gravitated towards specialized products like organic foods, they can be encouraged to prefer and seek out products cultivated through sustainable APV systems. This multifaceted approach bridges the gap between technology, agriculture, commerce, and consumer preference, thus bolstering the ecosystem for APV adoption.

Member state Level:

- Dedicated capacity targets for Agri-PV systems in the Member State national plans and policies should be set from governments.
- Land use designation changes is sensitive, as some Member States are open and flexible, while for others landscape preservation is of primary importance and the framework is strict.
- In Greece, Agri-PV is regulated by the national law 4513/2018, according to which, Agri-PV can be implemented in two ways: (i) by installing semi-transparent or opaque PV modules on greenhouses or other agricultural buildings, which can generate electricity for self-consumption or feed-in to the grid. The PV modules can also provide shade, protection and microclimate control for the crops and (ii) by installing PV modules on farmland, which can generate electricity for self-consumption or feed-in to the grid. The PV modules can also allow for dual use of land, where crops can be cultivated under or between the modules. The law also provides financial incentives for Agri-PV projects, such as: (i) guaranteed feed-in tariff (FIT) for 20 years for projects up to 500 kWp; (ii) premium tariff for projects above 500 kWp that participate in the electricity market; (iii) reduced property tax for projects up to 1 MWp; (iv) reduced connection fee for projects up to 1 MWp.
- In Italy, based on the article 11 of the decree-law of 1 March 2022, n. 17, converted, with amendments, by law 27 April 2022, n. 34, after paragraph 1, the following is added: Photovoltaic plants located in agricultural areas, if located outside protected areas or belonging to the Natura 2000 network, subject to the definition of the suitable areas referred to in article 20, paragraph 1, of legislative decree 8 November 2021, n. 199, and within the limits allowed by any prescriptions where located in areas subject to direct or indirect landscape constraints, are considered artifacts instrumental to agricultural activity and are freely installable if they are made directly by agricultural entrepreneurs or by jointly owned companies with electricity producers to which the company or business branch is conferred by the same agricultural entrepreneurs to whom it is business management activities are reserved except for the technical aspects of plant operation and energy transfer and the following conditions are met: (i) The solar panels are placed above the plantations at a height equal to or greater than two meters from the ground, without concrete foundations or difficult to remove; (ii) The implementation methods provide for their effective compatibility and integration with agricultural activities as a support for the plants or for parcelled irrigation systems and protection or partial or mobile shading of the underlying crops for the purpose of the simultaneous creation of monitoring systems, to be implemented on the basis of guidelines adopted by the Council for agricultural research and analysis of the agricultural economy, in collaboration with the Energy Services Manager (GSE); (iii) The installation is in any case subject to the prior consent of the owner and of the farmer, in any capacity as long as it is onerous, of the fund".

Expected Impacts

- The APV concept could make a significant impact in different production systems, including protected agriculture in greenhouses and the open-field cultivation of a variety of crops. Primary interest would be the open-field cultivation of fruits and vegetables, as well as viticulture, due to factors such as their widespread presence in many regions, the good adaptability of several of them to partial shading, the high value of several of them, and the large losses they incur annually due to adverse weather phenomena (e.g., hail).
- The cultivated land in the EU devoted to these crops exceeds 6.5 M ha, of which we can consider 20% as available for APV deployment, owing to factors such as solar potential, capital availability, technical reasons, and farmer conservativeness. Rolling out APV systems on 8 k ha of agricultural land annually, with a capacity of 5.5 GWp, would conserve more than 5 k ha of land annually that would have to be devoted to single-use ground-mounted PV in order to install the same power; the capacity of 5.5 GWp could correspond to adding 6 TWh/yr of renewable energy to the EU energy system every year.
- Rather than only selling energy to the grid, APV systems could, through the support of self-consumption or direct-selling practices, assist in assist on avoiding utility grid overloading and improving its resilience. In addition, farm applications such as water pumping for irrigation, charging electric agricultural vehicles and tools, drying or cooling commodities equipment could be served. Also, supplying energy to adjacent buildings or electric loads (in agreement with the respective owners) to form a local microgrid and serving domestic and commercial energy needs of an energy community (potentially charge battery arrays for this purpose) could be another application of APV.
- Conventional PV panels or semi-transparent modules seem to have good potential to assist on simultaneous food and energy production. Open spaces between conventional PV systems could be cultivated with either annual or perennial crops to bring agricultural value to existing ground mounted PV systems. Conventional PVs could be also mounted on farmers' auxiliary buildings and warehouses, either on the rooftop (optimal inclination leading to maximum performance) or in the side surfaces.

4.2.2. Alternative Fuels for Agricultural Machinery

What is the challenge?

GHG emissions from burning fossil fuel in agricultural machinery during the normal course of operation is around 10% of the GHG emissions of agriculture in comparison, or ca. 1% of total EU-27 GHG emissions[33] As a result, **conventional fuel is not the most critical, but still a contributor to the overall agricultural carbon footprint.**

Many options exist for farmers to reduce their CO_2 footprint. Future farms could, for example, contribute to electricity production with solar panels, windmills, and biogas/biomethane plants on their ground. Consequently, **electrification with batteries (direct electricity storage) and fuel cells (electrification through hydrogen)** of the agricultural machine fleet seems a logical next step. However, its uptake will depend mainly on future technology development to solve the issues of weight, energy density, and fast refuelling of energy storage on-board for a sustainable, effective, and efficient operating range. As a result, for short and mid-term, **full electrification seems more feasible for small-sized agricultural**

[33] CO2 from fuel combustion of off-road vehicles and other machinery (from agricultural/forestry excluding stationary machines and fishery: https://di.unfccc.int/detailed_data_by_party

machines, while for medium- and large-sized ones and for high power applications there is no alternative to internal combustion engines (ICE). Technological progress in the coming decade will define the long-term potential of electrification. Therefore, for farmers fleet of machinery, even with state of the art and anticipated technology, the combustion engine remains relevant in the coming years.

Approaches to reduce the CO_2 footprint of agricultural machinery are multiple, ranging from efficiency gains in the agricultural production process using best practices model predictions, to the utilisation of alternative drives and fuels. Agricultural machinery is characterised by a high level of robustness and reliability, resulting in a long service life. The high average age of the agricultural machinery fleet with combustion engine needs to be considered for planning any transition of engine technologies and energy solutions. **Currently, there is no single technology or energy carrier capable of replacing fossil diesel and diesel technology entirely.** A mix of technologies and energy carriers, most suitable for a given sector, certain region, and farm conditions, will have to be identified and applied.

Policy Recommendations

EU Level:

Due to the characteristics of the agricultural machinery fleet and the work it must perform, we believe that internal combustion engines (ICE) remain a viable and suitable solution for the coming decade to deliver on the CO_2 reduction targets. We call on the promotion, production, and use of renewable and low-carbon fuels for agricultural machinery, whilst other technologies **(e.g., electrification or green hydrogen)** come to maturity. In more details, we strongly recommend:

- **Support** in raising awareness that combustion engines remain a necessary key energy converter for agricultural machinery in the long-term due to its specific type of use. Changes to existing designs will be financially impossible to realise with engine development in car and truck industry being halted.
- Agriculture should be **recognised as a key** sector for the use of e-fuels and Hydrotreated Vegetable Oil (HVO i.e., renewable diesel) as **drop-in replacement fuels**. The main reason is the agricultural practice being mainly in remote areas, and the need for storage within farms. Any fuel that can directly replace fossil diesel in the existing storage facilities, to be stored for longer periods of time, means reduced direct costs for farmers. This argument is less true for competing sectors. A **proper political framework** is needed for investment in the scale up and uptake of these fuels. This must facilitate the applicability of alternative fuels for agricultural purposes and grant the necessary financial support to farmers and contractors.
- For a proper adoption of the use of renewable and low-carbon fuels instead of conventional diesel, **a short- and long-term EU-wide strategy must be established** which would include feasible targets and specific taxation and incentives encouraging the use of biomass fuels (crop and waste based), hydrogen and e-fuels in agricultural industry. Public incentives and taxation should be proportional to the climate contribution of the various biomass fuels and e-fuels, calculated based on a life cycle assessment.
- The transformation to zero CO_2 emission must be seen and handled as an **investment with proper assignment of value**. This is certainly true for agriculture. The farmers, but also the industry, need a **clear perspective** to plan accordingly, as the development processes for new products have a certain lead time.
- To **promote CO_2 reduction** within the agriculture production, authorities should look at a well-to - wheel (well-to-crop for agriculture) and not tailpipe emission approach to enable a portfolio of options, as wide as possible, **to suit farmers' needs.**

- The European Commission should continue **to promote research in alternative biomass resources** for the production of advanced biomass fuels including by exploring sources for potential new feedstocks and by supporting the commercialisation of technologies to convert feedstocks available at scale, in particular wastes and residues, but also non-food crops from new production methods that serve for better carbon sequestration and increase of biodiversity.
- Within the **competition** between Fatty Acid Methyl Ester (FAME i.e. biodiesel) and HVO for feedstock in the form of waste streams such as used cooking oil and animal fat, **preference** should be given to HVO as a perfect drop-in replacement fuel.
- **Awareness raising** of farmers, contractors, advisers towards the state-of-the-art technologies/practices must be promoted. This could be a combination of providing proof of concept of innovative tools/practices through **demonstration farms**. This can be supported by the flagship eco-scheme precision farming.
- Fuels that can be **produced and used by the farmers themselves** should be promoted, such as biodiesel, pure plant oil (PPO) or biomethane. Tractors that can use these fuels were investigated and are used. The advantage of PPO and biodiesel is the simultaneous production of fuels and proteins (for food or feed, e.g., rapeseed cake), the advantage of biomethane is the simultaneous production of fuel and the conversion of agricultural residues such as manure into higher value fertilizers.

Member state Level:

- In Italy, during a meeting of 13 February 2023 attended by political parties and members of the relevant ministries of the Italian Government, the Technical Advisory Committee on Biofuels, for the purpose of carrying out the activities to which it is delegated, has expressed the need to investigate some issues relating to the world of biofuels through the preparation of a specific study, financed with the proceeds of the penalties for non-compliance with the legislation by the companies required to comply with the obligation to release biofuels for consumption. In this regard, the Committee signalled the need for in-depth analysis on issues relating to the potential and prospects for the production of bio-hydrogen (Steam Reforming) obtained from biomethane deriving from the biogas chain from sugary-starchy biomass. The study referred to in the tender must be carried out by November 2023; ad hoc policies will then be formulated by the ministries of reference for the matter in question.
- Mission booster is a special program in autumn 2022 with a focus on supporting the contribution of small and medium-sized enterprises (SMEs) to future solutions to the green challenges. The mission booster program specifically aims to support the creation of companies' innovative knowledge base for future solutions within green fuels for transport and industry (Power-to-X etc.).

Expected Impacts

For most of the EU agricultural machinery fleet to deliver a significant CO_2 reduction**, renewable and low-carbon fuels, notably liquid and gaseous biomass fuels, green hydrogen, and e-fuels will be an important source of energy**, by which internal combustion engine (ICE) remains a viable and suitable solution**.** There is the option for blending with fossil diesel and there is the option of hydrogen used directly in ICE, if uncertainties can be overcome on hydrogen production capacity, logistics and storage on-farm and on-vehicle. Sustainable biomass fuels can reduce GHG emissions at least by 60% and **biomethane** potentially even **by more than 200%,** in comparison to fossil diesel, when produced from waste and manure.

The higher cost of biomass fuels, hydrogen and e-fuels compared to fossil diesel, together with the lack of economic incentives for production and usage of these fuels in agricultural machines, along with **uncertainties around fuel taxation and subsidy regulations**, are among major risks for their broader uptake by EU farmers. The easy way to achieve the Green Deal targets in agriculture is to make these sustainable fuels a more attractive alternative. Therefore, each fuel should be taxed in accordance with its climate contribution and based on the same principle subsidy schemes targeting production, storage, and use of those fuels should be deployed. A long-term **alignment** between EU regulations and national initiatives around promotion of different fuels expected to be used in agriculture is also necessary.

Clear targets, taxation and incentives will encourage farmers to invest or participate, with good return of investment, into machinery running on biomass-based fuels, into local or regional production plants and farm or farms fuelling infrastructure.

Within a long-term EU vision and planning, well-targeted programs are needed to **financially support farmers' and contractors' investments into their machinery fleet and (re)fuelling infrastructure**, for accessing the best available CO_2 friendly technologies, and/or adjusting to harmonised practices for energy-optimised agricultural production. As there is no universal solution for all economic players, agricultural investment support programs must fit with the advancing developments of other sectors, the availability of energy carriers and technologies, and the specific energy needs of agricultural operations to maximise full potential benefit for every use case and end market.

We fully support the ambition to make European agriculture climate- and energy-neutral. Energy produced within short carbon cycles of circular agriculture – in a form of sustainable biomass fuels and valuable by-product proteins and organic fertilizers – **can play a significant role in ensuring European feed and food supply security and should be considered as unique assets of agriculture**. With self-supply of energy, **agriculture can become a prosumer as well as an energy supplier** for local communities, which would increase the economic health of rural communities, improve their energy security, and make them more resilient to climate change and energy market fluctuations. Primary food production will be more resilient by independence from fossil fuel. Within a circular agriculture, biomass fuel production can be sustainable within certain land use boundaries, whilst not compromising the food and feed demands. In the case of **biomethane produced from fugitive emissions from livestock manure**, it can also contribute to delivering a circular economy model for livestock agriculture and be part of solving the ammonia and methane emission problem. Risk of indirect GHG emissions from crop-based biomass fuels can be further diminished by focusing on low Indirect Land Use Change (ILUC) feedstock production. It can materialize, so that there is no conflict with existing crop production. For allocation of the ecological value of crop-based biomass fuels the substitution effects of co-products like digested biological material as an excellent natural fertilizer or protein source, should be taken into account as the Renewable Energy Directive (RED II) recommends for political decisions only. The co-product of high value animal feed can substitute imports from abroad. **As a result, biomass fuels are not necessarily a transition fuel till 2030 but also beyond.**

4.2.3. Precision Agriculture as energy consumption reduction strategy

What is the challenge?

Agricultural activities imply Greenhouse Gas emissions increase in both direct and indirect ways. Direct implications derive from fossil fuel consumption for agricultural machinery operations, while indirectly due to inputs application such as for fertilization and plant protection purposes.

The farming community can save a lot of cost and prevent further GHG emissions by applying Precision Agriculture (PA) techniques (i.e., guidance, recording, decision-making and reacting) that suggest **optimal routes** for less fuel consumption by agricultural vehicles (path planning) and **reduction of agricultural inputs** through site-specific application (target inputs to spatial and temporal needs of the field).

Applying PA strategy requires farm managers to use certain high-tech equipment most times, both in terms of hardware and software. In a PA concept, a lot of challenging agricultural operations are solved and optimally performed nowadays, but PA remains an active research topic yet, where solutions to problems such as early disease detection are still under development. Adopting current PA technologies can have a **positive impact on farm productivity and economics**, providing higher or equal yields with lower production cost than conventional practices.

PA can be applied to almost every category of open-field crop production (i.e., arable, orchards, vineyards, vegetables), but also to cultivations grown in controlled environments such as greenhouses. The necessary equipment used for PA purposes can be quite expensive in some cases. Exclusive ownership by single farmers may not be the most financially "attractive" idea for an investment sometimes, especially given the existing support framework for such technologies.

Policy Recommendations

EU Level:

The new Common Agricultural Policy (CAP) of the European Union (EU) has put PA on the list of eco-schemes practices eligible for funding and a total of 270 billion euros will be spent on EU farms introducing this practice until 2027[34]. However, certain policies that could be applied to promote PA implementation are:

- **Subsidies and incentives** should be given to farmers to acquire technologies that allow for precision input application. From remote sensing technologies to modern agricultural machinery (e.g., field robots or drones), the supporting technologies necessary to apply such agricultural practices should be affordable for farmers to accelerate their widespread adoption. Fortunately, the new CAP that started in 2023 is aligned with the concept of PA. One of the reforms is to provide financial incentives and, at the same time, support schemes for farmers to invest in PA technologies (e.g., precision fertilizer spreaders)[35]
- In case of very expensive equipment, the **concept of joint ownership or purchase by a group of farmers or agricultural associations** should be promoted and simplified.
- **Raise agricultural communities' awareness** regarding the aspects of PA is also a matter of the existing policies, as in most cases there is a need to support farmers on gaining knowledge on how to implement certain methods and what are the outcomes that they should expect. **Training programmes** are necessary to be organized by each member-state following a common standard that will be developed at EU-level.
- Farmers should be urged to record their inputs (annually) and join a program developed by the state to provide their data for monitoring/assessment purposes. If they also provide information about the respective yield, then a ratio could be formatted. Based on this ratio, farmers' footprint can easily be identified. Such a framework could be integrated into the **energy audits system** proposed (See Policy Brief "Farm Energy Audits"). Consequently, the member-state could either provide multiple rewards (for the successful cases) or recommendations from advisory services for further improvement.

[34] https://www.arc2020.eu/cap-beyond-the-eu-precision-agriculture/
[35] https://www.euractiv.com/section/science-policymaking/news/europe-entering-the-era-of-precision-agriculture/

- Farmers providing their **production data and energy audit information** showcasing their capacity for improvement of the direct and indirect energy consumption through PA application could be prioritized for respective incentives provision to **replace/upgrade the existing conventional agricultural equipment**.
- **Extension services should be trained adequately** to provide recommendations and technical support to farmers applying PA practices.

Member States Level:

- In Poland, the success of PA implementation requires an **operationally functional decision support system (DSS) dedicated directly to farmers**, which will power the on-board computers of agricultural machines controlling applications of variable doses of means of production or navigating agricultural machines. A coherent DSS should be responsible for supporting PA (at the national level), which will provide data using e-services and API services on spatial differentiation of production properties of fields, weather and its forecast, agrotechnical recommendations adapted to the current situation and crop phenology.
- In Italy, according to ENEA (National agency for new technologies, energy and sustainable economic development), the widespread application of good practices would be capable of generating energy savings of 25% in irrigation, 70% in the ventilation of industrial environments and 20% in agri-food production and processing. Confagricoltura will build a new model of sustainable agriculture 5.0, which looks to digital, the production of renewable energy, and more generally to green technologies, but capable of guaranteeing production levels and competitiveness.
- In Greece, Measure 4 of the Rural Development Programme (RDP) 2014–2020, which was co-funded by the European Agricultural Fund for Rural Development (EAFRD) and the Greek government, offered the opportunity to farmers to get 50% of their investment in smart farming technologies from an official list and shift their production to the new era, if selected for the upgrading of their farm.
- In the Netherlands, there is a policy that offers tax incentives for farmers that invest in climate smart applications (e.g., electricity driven drip irrigation systems). Farmers have the choice to: (i) deduct 75% of investment costs from their income on a self-chosen moment (a year with a high income) or (ii) deduct 27-45% of the investment as extra costs to lower their income in the year of investment.
- Mission booster is a special program in autumn 2022 with a focus on supporting the contribution of small and medium-sized enterprises (SMEs) to future solutions to the green challenges. The mission booster program specifically aims to support the creation of companies' innovative knowledge base for future solutions within Climate- and environment-friendly agriculture and food production.

Expected Impacts

- PA application will allow farmers to apply plant protection products (PPP), fertilizers, and water more precisely, reducing directly or indirectly cost and related negative environmental impact.
- Fuel consumption of agricultural machinery could decrease when agricultural machinery follows certain optimal routes to carry out agricultural activities.
- The enhancement of the ability of soils to operate as carbon stock reserve by reducing tillage and soil compaction from reduced traffic could positively contribute to GHG emission reduction.
- Remote sensing allows detailed field mapping to isolate areas of need.
- Sensor technology in conjunction with field mapping can replace blanket fertilizers’ and pesticides' application with targeted variable application.
- Regarding spraying, modern nozzle technologies combined with Pulse-width modulation systems

(PWM) can further reduce PPP use and waste.

- Variable rate nutrient application (VRNA) technologies can reduce the fertilizer quantities applied.
- Positive effect on farm productivity by optimizing agricultural inputs producing higher yields with lower cost than conventional practices.
- Assist food security and safety for human food consumption by reducing significantly the amount of inputs.
- End-users (farmers) will receive quantified information of the farm profit augmentation and the positive sustainability impact.

4.2.4. Carbon Farming for Carbon Removals

What is the challenge?

Carbon farming is a whole farm approach that aims to optimise carbon capture, through a range of practices, from the atmosphere to plant material and soil. Many farming techniques that support carbon farming (such as regenerative agriculture, conservation agriculture, agroforestry) exist, but are not practiced on a large scale in the EU. The land sector is currently a significant net emitter of CO_2, however due to its unique characteristics it has the potential to absorb large amounts of carbon and is key for reaching a climate-neutral agricultural sector and economy. For instance, the implementation of conservation agriculture practices in the EU can lead to carbon sequestration of approximately 137 Mt per year. In addition, organic carbon is essential for healthy soil and crop production.

To encourage the agricultural sector to deliver on climate action and contribute to the European Green Deal, it is necessary to create direct incentives for the adoption of climate-friendly practices through carbon farming, as currently, there is not yet a targeted policy tool (it is under development[36]) to significantly incentivise the increase and protection of carbon sinks for land managers.

Policy Recommendations

EU Level:

- Accelerate the development of tailored certification methodologies for the different types of carbon removal activities based on the QU.A.L.ITY criteria set out in Carbon Removal Certification Framework, CRCF) (Regulation COM (2022) 2022/0394(COD)).
- Support the work of the Carbon Removal Expert Group on the voluntary certification of carbon removals, that began in March 2023, and request an assessment of whether there is a functional EU **carbon farming tool** that accurately measures the impact of carbon sequestration that can be developed.
- Continue to develop the **standardisation of monitoring, reporting and verification methodologies** to provide a clear and reliable framework for carbon farming.
- Develop baseline soil testing that measures the carbon “sink” status of the current production system, so that a net carbon assessment can be computed that reflects carbon sequestered to date resulting from historical production processes.
- Explore the option of verifying carbon farming through secure, private digital ledgers.
- Continue to promote carbon farming practices through the CAP, for instance through 'good agricultural and environmental conditions’ (GAEC) standards, ‘eco-schemes’ and rural development agri-environmental and climate measures, and other EU policies.
- The recommendations of the Carbon Removal Expert Group on the voluntary certification of carbon

[36] https://climate.ec.europa.eu/eu-action/sustainable-carbon-cycles/carbon-farming_en

removals support the development, in the medium to long term, of an EU-wide carbon farming system, with supporting tools, that is based on best practices and integrates carbon farming credits that **allows farmers to get paid for adopting climate-friendly carbon farming practices**.

- Develop a range of **financial incentives** on a national and EU level that support the adoption of and transition to agricultural techniques that promote carbon farming including conservation agriculture practices (See Policy Brief "Adoption of Conservation Agriculture to increase the content of Organic Carbon in the European Soils), permaculture, regenerative agriculture and agroforestry. It is important that farmers are **supported in the first years** of their transition as there can be a yield dip in the first years of adoption.
- Continue to support R&D processes (like EJP SOIL) that attempt to **accurately measure the impacts** and life cycle of various carbon sequestration techniques.
- Develop **education and extension processes** that provide information to farmers on the long term environmental and economic benefits of using various carbon farming techniques.

Member state Level:

- In Italy, a public register of voluntary carbon credits in the agroforestry sector is about to be established; on 4 April 2023, the Senate Budget Commission in fact approved amendment 45.6 to bill 564 (Conversion into law of the decree-law containing urgent provisions for the implementation of the PNRR, as well as for the implementation of cohesion policies and of the CAP) which will set up the register at the Council for agricultural research and analysis of the agricultural economy (CREA). The measure - attributable to the implementation of the National Forestry Strategy - should allow for the coordination, accounting and monitoring at a central level of all those afforestation, reforestation and sustainable agricultural-forestry management activities that look at a new economic model linked to the absorption of atmospheric carbon in the soils.
- Mission booster is a special program in autumn 2022 with a focus on supporting the contribution of small and medium-sized enterprises (SMEs) to future solutions to the green challenges. The mission booster program specifically aims to support the creation of companies' innovative knowledge base for future solutions within capture and storage or use of CO_2.

Expected Impacts

- **Improved farm incomes:** Diversifying farm income streams through payments for sequestering carbon in their soils can improve farms' financial sustainability.
- **Enhanced resilience to climate change:** Higher carbon stocks in soils can support crop production while also providing protection to droughts and floods.
- **Increased carbon sequestration:** Providing payments for the implementation of carbon farming can incentivise farmers across the EU to adopt these practices and increase the carbon stock in their soils.
- **Enhanced biodiversity and soil health:** Increased carbon stock in soils can improve the overall soil health by improving soil fertility and water retention.
- **Positive environmental externalities:** The expansion of sustainable agricultural practices will support improvements in local environments.

4.2.5. Conservation Agriculture to enhance soil carbon stock and reduce GHG emissions in European Agriculture.

What is the challenge?

The land sector is currently a significant net emitter of GHG, while agriculture accounts for approximately 11% of GHG emissions in EU (EEA, 2021) and also considering that the current situation of organic carbon stocks in European agricultural soils is low or very low (EEA, 2012), mitigation action is clearly necessary to meet even the targets in terms of reducing the effects of Climate Change. However, due to its unique characteristics, the soil has the potential to absorb large amounts of carbon and is key for reaching a climate-neutral agricultural sector and economy.

'Carbon farming' is a whole farm approach that aims to optimise carbon capture, through a range of practices, from the atmosphere to plant material and soil. Carbon farming focuses on the management of carbon pools, flows and GHG fluxes at the farm level, with the purpose of mitigating climate change. The adoption of the principles of Conservation Agriculture (Minimum Mechanical Soil Disturbance; Permanent soil organic cover; Species diversification) increases 'carbon sequestration and storage in soils, as well as decreases GHG emissions from soil and machinery operations and should be considered to include them in the European policies to address the challenges that agriculture is facing due to Climate Change.

Policy Recommendations

EU Level:

- Promote carbon farming practices based on the principles of Conservation Agriculture through the CAP and other EU policies.
- Promote crop management under the principles of Conservation Agriculture that allow carbon fixation in the soil: No tillage and/or strip-till in arable crops and groundcover in woody crops.
- Create a harmonized European Label that certifies the farm contributes to mitigating Climate change by soil carbon sequestration and minimising emissions.
- Facilitate access to the information necessary for farmers to make the transition from conventional agriculture to conservation agriculture under expert supervision.
- Promote R&D policies to adapt the technique to all crops, especially horticultural crops.
- Promote direct payments to farmers who store carbon and reduce their carbon footprint by reducing direct and indirect fossil energy consumption. Integrate no-tillage, strip-tillage, groundcover in woody crops and cover/catch crops as suitable practices to achieve the objectives of the European Green Deal and the Farm to Fork strategy.
- Create a science-based protocol of sustainable crop management practices for inclusion in carbon farming, prioritising:
  - Incentivise by subsidies and aids the adoption of no-tillage as a low CO_2 emission practice, both in terms of fossil fuel use and soil emissions.
  - Encourage and promote the use of cover crops for carbon sequestration and weed control to avoid tillage and thus reduce CO_2 emissions from organic carbon mineralisation.
- Promote efficient communication to the EU citizens for giving knowledge and raising awareness on which are the truly sustainable tactics that favour the reduction of fossil fuel use, and carbon sequestration and, therefore, contribute to the mitigation of climate change.
- Analyse data from carbon farming pilots and assess whether a functional EU carbon farming tool that accurately measures the impact of carbon sequestration can be developed.

Member States Level:

- Facilitate farmers and agricultural service providers, through subsidy programmes, to acquire direct seeders, which is needed to establish No-till in the farmland.
- Encourage cooperation between farmers, promoting smallholder associations, and providing them with mechanisms facilitating access to machinery and economic support.
- Ensure access to the information necessary for farmers to make the transition from conventional agriculture to conservation agriculture under expert supervision.
- Promote and fund research projects that will enable access to these techniques to all farmers in all European regions, regardless of climatic conditions and crops.
- Create of training and advisory service for farmers that accompany them to implement these techniques on the farm.
- Promote training activities for farmers and advisors at national and regional levels, demonstrating in situ the benefits of adopting the principles of Conservation Agriculture in terms of carbon sequestration, soil health improvement, reduction of fossil energy consumption and reduction of production costs.
- Encourage and promote the use of cover crops for carbon sequestration and weed control to avoid tillage and thus reduce CO_2 emissions from organic carbon mineralisation.
- Develop a range of financial incentives that support the adoption and transition for farmers to agricultural techniques that conduct carbon farming including conservation agriculture, regenerative agriculture, and agroforestry. It is important that farmers are supported in the first years of their transition as there can be a yield dip in the first years of adoption.
- Measures to increase carbon absorption in the agricultural sector have recently been introduced into the Italian legal system (article 45, paragraph 2-quater-2-octies, Legislative Decree n. 13/2023). In order to enhance sustainable agricultural and forestry management practices, capable of improving the capacity to absorb atmospheric carbon, and additional to those prescribed by EU and national legislation on the management of agricultural and forestry surfaces, it is established at the CREATE the public register of carbon credits generated on a voluntary basis by the national agroforestry sector; the credits in question can be used in the context of a national voluntary market, in line with the provisions relating to the National Register of agro-forestry carbon sinks pursuant to Ministerial Decree Environment April 1, 2008 .

Expected Impacts

- Climate change mitigation through carbon sequestration and increase of carbon stock in the soil. Development of carbon sequestering farms, capable of storing more carbon than they emit, directly or indirectly.
- Reduction of direct emission from the soil.
- Improvement of soil health by increasing organic matter content, increasing biodiversity, and making farms more resilient to climate change, especially in the Mediterranean countries.
- Improvement of surface and groundwater quality, due to the reduction of runoff, erosion and leaching due to enhanced physical/chemical soil properties.
- Increased farm profitability, as costs are significantly reduced while maintaining the same incomes per production, favouring the fixation of the rural population.
- Change in the perception of European citizens about the role of agriculture in terms of the use of energies, sustainable production systems and climate change mitigation.
- Improved farm incomes through carbon farming, diversifying farm income streams through

payments for sequestering carbon in their soils can improve farms' financial sustainability.

4.2.6. Alternative crop nutrient providers

What is the challenge?

A full accounting of energy use in EU agriculture, according to recent research published in the framework of this project, suggests that around 50% of all energy used in EU agriculture is associated with the production and consumption of chemical fertilisers, in particular with nitrogen fertilisers. The production of these chemical fertilisers is based on fossil fuels, often natural gas. This illustrates that for the EU agricultural sector to move towards sustainable production systems a significant transformation is required in the production of fertilisers, and it is for the benefit of the EU to substitute them with alternative nutrient providers, preferably locally produced. Such products are green fertilisers, biofertilisers/biostimulants and biochar. Green fertilizers are nitrate-based mineral fertilizers with the same chemical and physical composition as fertilizers produced with fossil fuels (natural gas, coal, oil), but with a much lower carbon footprint because they are produced with renewable electricity (hydro, wind, solar) and renewable feedstocks (biomethane, green hydrogen). Hence, they are directly related to RES and reduce the indirect energy impact of farming, but also the impact on the environment. Biofertilizers are substances that contain microbes, which help in promoting the growth of plants and trees by increasing the supply of essential nutrients to the plants. They comprise living organisms which include mycorrhizal fungi, blue-green algae, and bacteria. Biochar is mainly used in agriculture to enhance soil fertility, improve plant growth, and provide crop nutrition. As a result, it improves the overall farming productivity. There is a series of policies to be implemented to proceed in the diffusion of such alternative nutrient providers.

Policy Recommendations

EU Level:

- Promote R&D processes that support the **replacement of fossil fuels** with RES in the production of chemical fertilisers.
- **Support industries**, through subsidies, that produce and/or shift their production processes to green fertilisers.
- Promote the use of **biomethane and green hydrogen as a substitute** of natural gas in the Haber-Bosch process.
- Through a range of market incentives, **ensure the long-term cost and price competitiveness of green fertilisers** as compared to fossil-based fertilisers.
- Develop **education and extension processes** that provide information to farmers on the benefits of using green fertilisers, biofertilizers, biostimulants and biochar in their production systems.
- Identify and support the development of products that improve the **quality of soils and support carbon sequestration** such as biochar and local biofertilisers.
- Promote further the use of alternative crop nutrient providers through the **Common Agricultural Policy (CAP).** Develop a long-term EU strategy that supports the **elimination of fossil fuel dependencies** in fertiliser production and use across the EU.
- Support the development of local networks that **prioritize the production of local biofertilizers** sourced from local feedstocks.
- Promote R&D processes that investigate the **long-term potential of biochar to improve soil fertility** and support the production of biochar.
- Promote **demonstration projects and pilots** that showcase to farmers how to use biofertilisers,

biostimulants and biochar and the respective applications.

- Provide a financial incentive to industry that uses **pyrolysis and gasification** technologies of agricultural biomass to produce biofuels or electricity and biochar as a by-product.

Member States Level:

- As already done in Poland, rational fertilisation practices can be achieved by an **obligation to carry out fertiliser plans** under the Rural Development Programme.
- Soil regeneration through **co-financing lime application in highly acidified soils** should be applied, as already done in Poland.
- Measuring water pollution by nitrates from over-fertilisation should be implemented in all countries (Greece, Poland and other countries has already done it) to set guidelines and conditions to minimise the risk of nitrogen losses to water reserves.
- In Poland, about 50% of soils are light. Increasing the supply of organic carbon to them in the form of biomass is an inefficient method for carbon sequestration because the supplied carbon cannot be effectively bound for a long period of time. An alternative is **the introduction of biocarbon** with a long residence time. Problems with taking steps in this direction include the **high cost** of certified biocarbon and the corresponding lack of interest among producers in agricultural applications. Economic support for farmers and producers is essential if biocarbon applications in practice are to grow. And we would like this to happen and for agriculture to have access to certified biocarbon. Instead, we would like to avoid scattered and uncontrolled biocarbon production by farmers for environmental reasons.
- In Italy, after 3 years from its drafting, on 16 July 2022 the New European Fertilizer Regulation 2019/1009 officially entered into force in Italy. It is called the New Regulation because it abrogates the EC Regulation n.2003/2003 which until now has regulated community mineral fertilisers. Furthermore, it modifies the EC Regulation n.1069/2009 laying down health rules relating to by-products of animal origin and derived products not intended for human consumption and the EC Regulation n.1107/2009 relating to the placing on the market of plant protection products. The types of fertilizers within the European Union multiply, and new types of fertilizing products are integrated such as organic fertilizers and biostimulants, which in Italy finally find a univocal and incontrovertible definition, finally establishing themselves as a valid and regulated reality, for a more sustainable agriculture.
- In the Netherlands, there is a policy that offers tax incentives for farmers that invest in climate smart applications (e.g., Recovery from N and P from organic manure, to use as alternative for artificial fertilisers). Farmers have the choice to: (i) deduct 75% of investment costs from their income on a self-chosen moment (a year with a high income) or (ii) deduct 27-45% of the investment as extra costs to lower their income in the year of investment.

Expected Impacts

- **Reduced greenhouse gas emissions:** The development of green fertilisers produced using RES can lead to significant GHGs reductions.
- **Enhanced biodiversity and soil health:** The use of locally produced biofertlisers and biochar can improve the quality and life of European soils.
- **Positive environmental externalities:** Reduced use of chemical fertilizers and increased use of biofertlisers can have positive environmental externalities such as reduced pollution and oxygen depletion in water bodies.
- **Improved public health:** Reduced use of chemical fertilizers and increased use of biofertlisers can help to reduce the risk of exposure to harmful chemicals, contributing to improved public health

outcomes.

- **Increased rural development:** The promotion of locally produced fertilisers from local feedstocks can support rural development, creating new jobs and business opportunities in rural areas.

4.2.7. Building Management Systems (BMS) for Agricultural Constructions

What is the challenge?

- Most agricultural constructions **lack advanced control systems**, leading to inefficient energy usage and high operating costs.
- Maintaining optimal environmental conditions for livestock facilities and greenhouses is a **major challenge without an appropriate monitoring and control system**.
- Barn environmental conditions impact the **livestock health and productivity**, while in greenhouses climate control plays also significant role for the **plant stress and final yield and quality**.
- **Excessive consumption of water** due to the lack of efficient water management strategies and technologies leads to waste and increased water scarcity concerns.
- Farmers often **lack real-time data insights** to optimize resource allocation, identify inefficiencies, and make informed decisions.
- **Lack of awareness** among the farmers regarding the benefits and potential cost savings associated with implementing BMS.
- Farmers are usually **reluctant towards installing BMS** and associated infrastructure due to the high upfront costs of implementing both a BMS and retrofitting outdated infrastructure.
- **Lack of technical expertise** is another challenge, as it is not readily available within the livestock industry, making it challenging for some facilities to adopt these systems.
- **Lack of regulations / incentives** that encourage the implementation of BMS in livestock facilities.

Policy Recommendations

Even though livestock facility owners rely on traditional practices and expertise acquired through years of experience, having set long-standing practices and cultural norms that prioritize manual operations over automated systems like BMS, the benefit of deploying efficient BMS for their facilities is significant. To tackle the existing challenges and increase the adoption of BMS we recommend:

- Provide incentives for farmers to install BMS in their livestock facility to have a **clear view of energy consumption in the current status**, assist in fast and precise **energy audits** (See Policy Brief “Farm Energy Audits”) and provide evidence of the impact on energy consumption of any intervention proposed by the auditor.
- Since most farms already have control systems in their agricultural facilities (e.g., irrigation systems, feeding systems, waste management systems), **incentives for integrating them into a holistic BMS** should be given for comprehensive and integrated control.
- Offer **financial incentives** (e.g., grants, subsidies, or tax benefits) to assist livestock facility owners with the required initial investment of installing BMS, in order to promote widespread adoption.
- Raise awareness through **training programs and campaigns** which educate livestock facility owners about the benefits of BMS, including energy savings, improved animal welfare, and reduced environmental impact.
- Develop and enforce **regulations mandating the implementation of BMS** in new livestock facility constructions or major renovations (e.g., establishing energy efficiency and environmental performance standards that include the use of BMS), incentivizing compliance through rewards.
- Allocate **funding for research and development** initiatives focused on developing and applying BMS

technologies in livestock facilities. More specifically, finance R&D for optimisation of existing BMSs for other uses (i.e., commercial and industrial buildings) to **cover the needs of agricultural buildings** that have specific characteristics (e.g. high humidity in both livestock facilities and greenhouses, significantly increased temperature during summer period, high amounts of dangerous gases and odours from waste for animals' well-being, different climatic needs for plants and animals based on the period of the season, etc.). In addition, finance R&D for **cheap sensors** needed for climate and well-being control that are not easily affected by high humidity, excessive heat, gases, and dust.

- Provision of **free governmental technical assistance and guidance** to livestock facility owners regarding the planning, installation, and operation phases of BMS through training workshops, consulting services, and access to expert advice to address any technical challenges or concerns.
- Foster partnerships between government agencies, industry associations, technology providers, and financial institutions to **create a supportive ecosystem for BMS adoption**, as a common workplace that allows sharing of best practices, case studies, and success stories that demonstrate the benefits and feasibility of implementing BMS in livestock facilities towards defossilisation in agriculture.

Expected Impacts

- BMS may optimize energy consumption in livestock facilities, resulting in **potential energy savings of up to 30%**.
- Precise monitoring and control of environmental conditions for livestock (e.g., temperature, humidity, hazardous gases) through control of Heating, Ventilation, Air Conditioning (HVAC) and creating optimal conditions for livestock, leading to **improved productivity and reduced mortality rates**.
- Possible **integration of BMS with waste management systems** could increase the profit of farmers, with simultaneous reduction of greenhouse gas emissions from the timely waste extraction and the optimum feed to anaerobic digesters.
- Implementation of **water management strategies through BMS utilisation**, including monitoring and using water-efficient equipment, minimizing water consumption and reducing reliance on fossil fuel-driven water pumping and treatment processes.
- Data-Driven Decision-Making utilizing data collected and analysed by the BMS would allow farmers to make **informed decisions, optimize resource allocation, and identify inefficiencies** for more sustainable practices.
- **Integration and maximization of RES** through the BMS (e.g., solar panels) would be possible, reducing reliance on fossil fuel-based electricity.

4.2.8. Heat pumps for Heating, Ventilation and Air Conditioning (HVAC) of agricultural constructions

What is the challenge?

- According to the European Commission, the agricultural sector accounts for about **10% of total Greenhouse Gas (GHG) emissions** in the European Union. Of the total energy demand for heating and cooling applications, agriculture **uses about 6%**.
- Modern Heating, Ventilation, and Air-Conditioning (HVAC) applications play a crucial role in agriculture where maintaining **optimal temperature and humidity levels is essential** for animal welfare (livestock facilities) and crop productivity (greenhouses).
- Barriers to adopting sustainable HVAC systems in agriculture include **high initial investment costs**, **limited technical knowledge**, and **lack of policy support (mainly the adoption of EU level policies**

to the national level). However, opportunities exist to overcome these barriers through technological advancements and supportive policies.

- **Heat pumps** offer a promising solution for agricultural HVAC applications with reduced GHG emissions. As a RES, heat pumps can provide efficient heating and cooling and dehumidification, while significantly lowering carbon emissions.

Policy Recommendations

EU Level:

Due to the fossil fuel dependence of European agriculture, as well as its potential for RES adoption, the EU can foster the widespread take-up of heat pumps in the agricultural sector, promoting sustainable farming practices, reducing GHG emissions, and enhancing energy efficiency. Based on the high efficiency of heat pumps (COP[37] > 4), we call on their promotion, further research, and development for HVAC applications in agricultural holdings. In more detail, we strongly recommend:

- **Assess the potential of heat pumps in different types of agricultural facilities to determine optimal systems for each location:**

Conduct feasibility studies and pilot projects to evaluate the efficiency and cost-effectiveness of heat pump installations in various agricultural contexts.

Via energy auditing, identify specific agricultural applications where heat pumps can provide the greatest energy savings and emission reductions, such as in livestock barns, poultry houses, and greenhouse operations.

- **Implement monitoring and evaluation systems to track performance and energy efficiency, providing feedback to farmers and technicians on optimizing their systems:**

Encourage the development and adoption of smart monitoring technologies that allow farmers to monitor heat pump performance, total energy consumption, and environmental conditions in real time.

Provide guidance on data analysis and interpretation, enabling farmers to identify areas for improvement and implement energy-saving measures accordingly.

- **Encourage the integration of heat pumps with other RES, such as solar or geothermal power, to elevate the COP, further reducing GHG emissions and energy costs:**

Promote the concept of hybrid, modular systems that combine heat pumps with other renewable energy technologies to maximize energy efficiency and minimize reliance on fossil fuels.

- **Support research and development efforts to design heat pump technologies specifically tailored for the agricultural sector, considering the unique challenges of high humidity in greenhouses and high humidity and corrosive environment in livestock buildings:**

Allocate funding for research institutions and industry collaborations to develop and test heat pump technologies that can withstand the harsh conditions commonly found in agricultural facilities[38].

[37] Coefficient of Performance: A higher COP indicates a more efficient system, as it can provide more cooling or heating while using less energy. If a heat pump has a COP of 4, it means that for every unit of electrical energy it consumes, it produces four units of thermal energy (heating or cooling).

[38] RES4LIVE and TheGreefa are ongoing Horizon 2020 projects, that can provide further insight by the end of 2024. Only a few

Encourage the development of innovative materials, coatings, and components that improve the durability and longevity of heat pumps in agricultural settings.

- **Foster partnerships and collaborations between heat pump manufacturers, agricultural stakeholders, and research institutions to drive innovation and knowledge transfer:**

Facilitate forums, workshops, and networking events to promote dialogue and collaboration among heat pump manufacturers, farmers, researchers, and agricultural associations.

Establish funding programs or grants to incentivize joint projects and knowledge-sharing initiatives aimed at advancing heat pump technology in the agricultural sector.

- **Establish guidelines and standards for the design, installation, and operation of heat pumps to ensure safety, reliability, and efficiency:**

Work with relevant stakeholders, including agricultural experts, heating and cooling professionals, and regulatory bodies, to develop “best practices” guidelines and standards specific to heat pump installations in agricultural constructions.

Address considerations such as system sizing, integration with existing infrastructure, noise levels, and environmental impact to ensure optimal performance and compliance.

- **Develop training programs and materials for farmers and technicians on the installation, operation, and maintenance of heat pump systems:**

Collaborate with agricultural organizations, industry associations, and educational institutions to design and deliver training programs that cover the technical aspects of heat pump operation and maintenance.

Provide educational material, such as manuals, videos, and online courses, to ensure accessibility and knowledge dissemination to a wide range of farmers and technicians.

- **Provide financial incentives and explore innovative financing models to offset initial investment costs[39] and incentivize farmers to adopt heat pump systems.**

<u>**Member States Level:**</u>

- An example is the Agroenergy Programme of Poland (subsidies for heat pumps and photovoltaics for farms from the Provincial Fund for Environmental Protection).
- In Italy, energy efficiency checks are mandatory only on heating systems higher than certain power: according to art. 8 of the state dpr concerns winter air conditioning systems with nominal useful thermal power starting from 10 kW and summer air conditioning systems with nominal useful thermal power starting from 12 kW. To check if you are above these thresholds and therefore subject to these checks, the MISE-7 faq contains two important clarifications: (i) for refrigerating machines and/or heat pumps, even if sometimes used for heating, the 12 kW threshold applies:

companies, such as INNO+, have started implementing heat pump solutions for specific applications in livestock buildings.

[39] Average manufacturing costs can vary quite broadly because of several factors, including the type of heat pump (such as air-source, ground-source, or water-source), its efficiency, capacity, and installation requirements. Additionally, prices may vary across different EU countries. For example, the cost of an air-source heat pump in Greece could range from ~300 to 700 €/kWth depending on the size and special characteristics of the facility (operation mode, installation location, etc.)

energy efficiency checks are mandatory if the useful power of the machine in one of the modes of use (winter air conditioning/ summer) is such or higher; (ii) b) in the case of the presence of several machines/generators, to check whether the power thresholds that involve the obligations relating to energy efficiency controls are exceeded, "the sum of the powers must be carried out only when the machines are at the service of the same subsystem of For individual appliances with power lower than the limit values shown in the aforementioned attachment A [10 kW for flame generators or those powered by district heating - 12 kW for refrigerating machines - 50 kW electrical for cogeneration plants] are not completed, therefore , energy efficiency audit reports".

- In the Netherlands, there are subsidies for stimulation sustainable/renewable energy production that include heating with heat pumps.
- In Denmark, subsidy for electrically powered heat pumps at basic amount plants outside the quota sector is supported by the Danish Energy Agency with DKK 23.4 million DKK in 2017 and 27.9 million DKK in 2018. The purpose is to counteract high heating price increases and to electrify heat supply. In addition, subsidy for individual heat pumps when scrapping oil, wood pellet and gas boilers (Scrap scheme) is provided aiming to phase out oil, wood pellet and gas boilers and instead promote the use of individual heat pumps for heating buildings and thus contribute to reducing Denmark's emissions of CO_2.

Expected Impacts

By implementing the recommended policies and supporting the widespread adoption of heat pumps in the EU agricultural sector, we can accelerate the transition towards sustainable farming practices, reducing GHG emissions, and promoting energy-efficient operations while ensuring the well-being of animals and crop productivity, as well as avoiding environmental degradation.

- Individual farmers can benefit from **reduced energy costs, improved energy efficiency, and lower carbon emissions**, resulting in long-term financial savings.
- The **EU agriculture sector can contribute to the overall reduction of GHG emissions**, helping to achieve climate change mitigation targets and promoting sustainable farming practices.
- Animals and plants in agricultural constructions can experience improved welfare and productivity through **precise temperature and humidity control**, enhancing their health and overall well-being.
- The energy produced within the short carbon cycles of circular agriculture can **make agriculture a prosumer** as well as an energy supplier for local communities, increasing the economic health of rural communities, improving their energy security, and making them more resilient to climate change and energy market fluctuations.

4.2.9. Photovoltaics (PV) and Photovoltaic Thermal (PVT) Collectors and Systems for agricultural constructions rooftops

What is the challenge?

- Agriculture has **high energy demands for heat and electricity**.
- Heat consists of 50% of the total energy consumption, while electricity only 20%. The costs of the energy consumption in greenhouses are up to 50% of the production costs and are the second largest operating cost.
- There is **little renewable energy penetration in agriculture**, as farms do not have the investment capability of modernizing their energy systems. Many still use oil, gas, and biomass as the main fuel.
- Fossil fuel costs are likely to rise in the future, and **electrification cannot be the only alternative to heating as this would overwhelm the grid**, especially with the inclusion of electric vehicles in the

future.

- Other renewable energy solutions are available such as wind, heat pumps, geothermal, etc. However, a mixed solution is necessary that will not depend on, and over saturate the electric grid.
- Solar photovoltaic (PV) panels and solar thermal collectors exist however both are necessary to deliver electricity and heat, consuming a lot of land and space.
- PVT technology is the **most efficient way to harness heat and electricity from the sun for a given space**. As land is abundant in agriculture, PVT fields are easily deployed on land and rooftops that may also provide benefit to the agricultural operation in some way such as to provide shading for crops or livestock. Complete electrification of heat will be a very difficult task as this would double the load on the current grid, which would require massive investment.
- Although PV technology is on the rise and costs are lowering due to policy incentives, there are **very few incentives for solar thermal and none for PVT**. PVT technology mostly cannot benefit from individual benefits for PV and solar thermal, even though the technology is the same.

Policy Recommendations

EU Level:

- PV systems should be expanded to all livestock and agricultural building rooftops that can support their installation in a net metering format to reduce electricity bills.
- **Impose stricter carbon tax** to fossil fuel usage to disincentivise its use and purchase.
- Establish **a short- and long-term EU-wide strategy for the adoption of renewable and low-carbon fuels in agriculture**, including feasible targets and specific taxation and incentives based on life cycle assessment processes.
- **Treat the transformation to zero CO_2 emissions as an investment with proper assignment of value**, allowing farmers and industry to plan accordingly, with a well-to-crop approach to enable a wide portfolio of options.
- **Promote research** that offers comprehensive reviews and studies on optimised PVT systems, along with supporting the correct solutions to market scale.
- **Awareness raising** of state-of-the-art PVT technologies among farmers, contractors, and advisers through demo farms and flagship eco-schemes.
- **Build capacity within the agricultural industry** around the use and opportunities of PV and PVT and share such research and innovation findings with key actors in the industry.

Member state Level:

- **Better recognise** PVT technology as a viable and efficient solution for renewable electricity and heat.
- **Facilitate support and subsidies** for PVT technology and solar thermal just like is being done for PV technology, along with favourable investment plans for those that wish to invest in a new system.
- **Incentivise SMEs and business** that are leading the conversation and implementation on renewable energy deployment and innovation.
- Incentivise agriculture by **supporting the renovation and purchase of renewable energy systems** such as PVT technology.
- **Promote and support local businesses** developing and manufacturing PV and PVT products to ensure supply chain is kept within the EU at a maximum.
- Incentivise agriculture by **supporting the renovation and purchase of renewable energy systems** such as PVT technology. For instance, in Ireland, The Solar Capital Investment Scheme (TAMS) provides an investment grant to farmers to improve the energy efficiency of farm buildings or their equipment. The investment grant can cover up to 60% of total installations costs for up to 62kWp

or smaller solar PV system.

- In Italy, the Ministerial Decree of 19 April 2023 to be financed under the PNRR, Mission 2, Component 1, Investment 2.2 "Parco Agrisolare" contains the procedures for submitting applications for access to the construction of photovoltaic systems to be installed on buildings for productive use in the agricultural, zootechnical and agro-industrial sectors. On 21 July 2023, the new Notice was issued pursuant to the Decree of the Minister of Agriculture, Food Sovereignty and Forests n. 211444 of 19 April 2023. The Notice relates to the financing of photovoltaic systems to be installed on buildings for productive use in the agricultural, livestock and agro-industrial sectors, with the residual resources of the PNRR measure M2C1 I 2.2 "Parco Agrisolare". The available resources amount to approximately 1 billion euros. Among the main innovations of the new tender: (i) increase in the maximum aid intensity up to 80% for companies involved in primary agricultural production and agricultural transformation into agriculture; (ii) introduction of the new case of shared self-consumption; (iii) participation of companies in aggregate form; (iv) possibility of creating photovoltaic systems on the roofs of agricultural buildings with power up to a maximum of 1,000 kWp per system; (v) doubling of the maximum admissible expenditure for accumulation systems up to 100,000 euros; (vi) doubling of the maximum eligible expenditure for recharging devices up to 30,000 euros; and (vii) maximum expenditure per beneficiary equal to 2,330,000 euros.
- In the Netherlands, there are subsidies for stimulation sustainable/renewable energy production that include PV installation in rooftops.

Expected Impacts

- Renewable heating and electricity from the sun has no operational carbon footprint, and if sourced locally, its **manufacturing carbon footprint is very low**.
- PVTs offer an **efficient (currently up to 80%) method** of harnessing heat and transferring it for domestic hot water use and space heating. Combining the production of heat and electricity in one panel, reduces the space used per energy output by half.
- If deployed on a large scale, PVTs can offer a levelized cost of heat of 0.02-0.05€/kWh which is a **big reduction compared to current electricity and fossil fuel prices**. Payback on investments can be as low as 2-6 years.
- There will be a decrease in **risk of price volatility and level** can remain at a constant, which is important as energy is a high share in agricultural costs.
- **Energy security for farms will increase**, as most energy will be produced locally.
- If the supply chain is kept local, then the capacity for renewable energy manufacturing and deployment within Europe will be enhanced.
- Investments in PVT will **likely pay off quicker** as prices for components and systems decrease, favouring the economy.
- PVT awareness will assist to **create a trend to invest in the technology**.
- Subsidies, support, and favourable financial schemes will accelerate market uptake of the PVT technology and allow for a quicker energy transition.

4.2.10. Biogas production from agricultural waste and other innovative feedstock / Biomethane upgrading for local consumption or grid injection.

What is the challenge?

Biogas production from livestock waste is a common practice today, but numerous livestock farms have not yet integrated such systems for technical, economic, and social reasons. Some farmers tend to be sceptical towards new methodologies as they are not sure about the advantages gained from doing a transition from already tested practices. Hence, national policies should be further promoted to educate and convince farmers to apply anaerobic digestion (AD), also known as biogas production, of their waste for energy and environmental reasons.

Besides livestock waste, also other feedstock types (e.g., straw, grass, etc.) can be used for biogas production, opening further opportunities for this sector to grow. Studies have shown that **using different feedstock types to produce biogas via the multi-feeding mode have worth mentioning advantages** when compared to the anaerobic digestion only of livestock waste. The most important one being, the **extended lifespan of the anaerobic digester** and the respective increase of the biogas production.

Biogas systems are mainly installed to run Combined Heat and Power (CHP) systems which feed in the electricity to the power grid. However, recently the upgrading of biogas to biomethane after cleaning the contained CO_2 and other non-useful gases is also a solution that can facilitate to cover the fuel demand of tractors and machinery of the farms with **independent energy, thus defossilising agricultural machineries** (see Policy Brief "Alternative Fuels for Agricultural Machinery" and "Facilitating the development of energy independent farming in Livestock"). The other option is to inject the biomethane into the natural gas grid and provide green energy to non-agricultural consumers. This enables, for example, to provide renewable energy to energy communities which would be beneficial to all participants (see Policy Brief "Enabling the creation and growth of energy communities in rural areas").

One of the most important countries of biogas development is Germany with nearly 10,000 biogas plants (2022)[40], which shows the feasibility and added value of the technology. Also in some other countries, there is considerable development of biogas plants which should be applied across whole Europe.

For instance, in Spain, there is a company named Biometagàs La Galera, which is owned by several cooperatives. **This company utilizes almost 150 tonnes of organic residues such as manure and olive tree residues. It produces biogas that is used to power the village in which the company is located.** According to their results they manage to **produce 50 GWh/year which is the medium consumption of 6300 houses in the area**. It should be mentioned that this was the first time in Spain that a private company made a biogas connection to supply nearby houses. **Before this, there was no regulation** and that was the main reason for a very long implementation time. Initially, the produced biogas from the company was used to power a fleet of buses that were serving as public transportation for the village. From this example the advantages of creating energy communities are evident, but at the same time, the lack of legislation for such cases still needs improvements.

Another successful example of biogas production and use is in Denmark where there are multiple schemes supporting biogas production**. The annual production of biogas in Denmark from 2012 to 2020, reached 15 PJ.** To date most of the produced biogas is used in electricity production. In the future it is expected that a greater share of the produced biogas will be upgraded and delivered to the natural gas grid. The Danish Energy Agency which is responsible for the rules and regulations regarding the support schemes and the criteria of sustainable biogas production is set on facilitating the advancement to more sustainable energy sources.

Therefore, the challenge is to **create a unified methodology/legislation on how this framework support can be implemented**. This methodology will have to highlight and promote the advantages gained from advancing to a greener more sustainable way of producing biogas to farmers. At the same time farmers and energy producers need to be **guided on how to implement the proposed changes and create**

[40] https://www.biogas.org/edcom/webfvb.nsf/id/DE_Branchenzahlen/$file/22-10-06_Biogas_Branchenzahlen-2021_Prognose-2022.pdf

productive energy communities which will contribute towards the reduction of the dependence and contribute to the adaptation and mitigation of climate change.

Policy Recommendations

EU Level:

- Promote R&D policies to **research and adapt new feedstocks** for biogas production.
- Ensure that the process is **transparent**, and that no energy provider abuses the financial aid or is taking advantage of the supporters of this procedure (i.e. farmers). The procedure should be consistent in its **structure and the investment policy** and at the same time maintain **constant disbursement cycles**.
- Facilitate access to the information necessary for farmers/energy providers to make the **transition from conventional biogas production to biogas production using multi-feeding mode**.
- Include **biogas production and use in the overall political strategies** as one important contributor to stabilize the overall (independent energy supply) and specific (e.g., for stabilizing the power grid) energy system.

Member state Level:

- Provide farmers with **financing aid** for the installation of new biogas plants.
- Encourage smallholders to **create associations/energy communities**, which will **build a common biogas plant or will sell feedstock to a nearby biogas production facility** to take advantage of the waste and residues produced from their farms in the highest possible profit. The biogas profit produced will be divided among the energy community members proportionally (see Policy Brief "Enabling the creation and growth of energy communities in rural areas").
- Encourage **cooperation between farmers** and provide them with mechanisms for access to equipment and economic support.
- Provide **financing incentives**, such as tax deduction, to farmers who install anaerobic digesters on their farms and incorporate new methodologies.
- Facilitate farmers and agricultural service providers, through **funding and subsidy programmes**, to acquire anaerobic digesters to produce biogas.
- Promote **training activities for farmers and advisors** at national and regional levels, **demonstrating in situ** the benefits of adopting new feedstocks for biogas production in terms of reduction of fossil energy consumption and substitution of fossil natural gas, and in terms of increase in anaerobic digester life-expectancy.
- **Encourage farmers to shift to mixed farms** so that both manure and crop residues can be used for biogas production. By doing this the farmer ensures the **continuous production of biogas** and that no residues and waste are left without being taken advantage of, while the remaining effluent **returns to the open-field land as organic fertiliser**.
- Promote the **direct use of biogas and biomethane** on the farms themselves, especially for their machines.
- EU Member States should prioritize the development of an indigenous biomethane industry, such as included in Ireland's Climate Action Plan, by supporting the construction of modern anaerobic digestion plants, and offering state aid with community ownership options.
- In Italy, on 13 January 2023, the Ministry of the Environment and Energy Security (the "MASE" formerly the Ministry of Ecological Transition) issued the decree approving the application rules drawn up with the support of the GSE (the "Application Rules") as required by previous Ministerial Decree n. 340 of 15 September 2022 published in the Official Gazette of 26 October 2022 and

entered into force the following day (the "New Biomethane Decree"). Based on this, (a) newly built plants fed by agricultural matrices and organic waste; and (b) plants to produce electricity from agricultural biogas subject to reconversion (so-called revamping) can get funding. The New Biomethane Decree operates in relation to the type of plant (agricultural or powered by organic waste), the category of intervention (for new construction or conversion intervention) and intended use of the biomethane produced by the plant (transport sector or other uses).

- In the Netherlands, there are subsidies for stimulation sustainable/renewable energy production that include biogas installations.

Expected Impacts

- **Climate change mitigation** using greener/alternative methodologies to produce biogas and biomethane, which will substitute fossil natural gas.
- Contribute to more **energy independence** at farm and national levels.
- **Increased farm profitability**, as the residues produced on farm are fully utilized and can then be used as a clean energy supply source to the farm/community itself.
- Significant **maintenance cost reductions** of the improved anaerobic digesters that use the multi-feeding mode and at the same time have increased life-expectancy.
- Increase the sense of community and cooperation among farmers and energy providers. This will lead towards the **creation of new synergies** where innovative ideas towards sustainable agriculture will emerge.
- **Local awareness of citizens** in renewable energy and a trend to invest in the technology.
- A **diverse portfolio of energy sources** that can be adapted based on the users' energy demand will enable the right system to be selected for any given usage.
- **Market uptake of the technology will be accelerated** through subsidies, technical support, and favourable financial schemes and will allow for a quicker energy transition.

4.2.11. Facilitating the development of energy independent farming in livestock

What is the challenge?

The agriculture sector accounts for **~10% of the total EU27 greenhouse gas (GHG) emissions** (from crops, livestock, and soils). Methane from slurry and ruminant animals is a large provider and livestock is on the line. Public opinions go from thinking that reducing meat consumption to reduce the number of farms, while solutions now exist. Thus, livestock farms have the greatest challenge of being high CO_2 equivalent emitters, while having among the highest profitability difficulties across Europe. Mostly hit are the smallest of these farms. European **400 000 livestock farms are below a 50ha average**. Most of dairy farms for instance have an average size **below 100 heads**, while smallest biogas plant needs a **minimal capacity for the equivalent of 1000 heads**.

Investments are often delayed as margins are uncertain and provide little visibility. Long term survival of these farms will depend more and more on their capability to make productivity gains while shifting to more sustainable farming models, without necessarily sharing the uplift in prices, and without any compromise on quality. Without subsidies to make them more profitable and at the same time more sustainable, many farms would disappear. Simultaneously, neighbourhoods are sensible to and smell or fear of diseases for the closest ones.

Solutions to capture methane from manure for small livestock farms are **on the way** to support these farmers into **producing and consuming their own energy on site**. In many cases, farmers would also be able to share/sell this energy either through fuel for machines or electricity or heating. Further additional benefits: Slurry covers enables to collect rainwater usable on farm or for irrigation purposes, thus reducing clean water consumption.

Proposed solutions include mobile upgrading biogas systems that can be shared among a cluster of farms in order to reduce the total investment per farmer. Digested material is an excellent natural fertilizer to restore organic matter in the soil instead of chemical fertilizers, that are expensive and normally produced with high consumption of fossil fuels.

The challenge is to make most of the small livestock farmers capture the fugitive methane and transform it into energy on site, cutting all logistics costs for material purchased and cutting external energy consumption, while providing the excess to the close neighbourhood.

Policy Recommendations

- Promote through farmers organizations such solutions, including advisory services.
- Enable farmers, through subsidy programs, to invest in biomethane emission capture solutions.
- Provide support by promoting any kilo of biomethane used for agricultural machinery or for transportation and replacing fossil fuel diesel.
- Promote demonstration activities at the farm level aimed at showing the farmers in their own region/country how new smart technology or machinery perform. Demonstration farms are key examples of supporting strategies, facilitating the adoption and uptake of Innovative biogas production equipment.
- Promote tools that allow farmer experiences to be shared, as well as the exchange of information about training courses and, above all, to improve and harmonize the training courses provided.
- Enable small scale producers to group into clusters to connect to the electricity grid or gas supply chain.
- Promote and educate how farms can support CO_2 emissions reduction when becoming carbon negative.

Expected Impacts

- Developing carbon negative farms.
- Reduction of farming costs level therefore improving the margins, with a potential impact on the subsidies in the long run.
- Significantly reducing the purchase of chemical fertilizers poured into the fields. Immediate gain in soil health and especially in areas of livestock concentration.
- More sustainable and environmentally friendly slurry containment, leading to healthier environment and rivers with improvement for flora and fauna.
- Soil improvement due to use of organic fertilizers vs chemical ones.
- Transition to agricultural machines and transport vehicles running on biomethane produced from livestock manure within farms with an overall negative carbon footprint.
- Reduction of clean water consumption by developing more rainwater collection for farm use.
- Increase of logistic trucks or public transportation running on fugitive methane with negative carbon footprint.
- Livestock farms surrounding villages and communities could be more accepted by the local population and overall, more sustainable.

4.2.12. Energy upgrading/renovation of livestock buildings

What is the challenge?

Livestock housing requires adequate indoor thermal conditions to maximize production and animal welfare, especially to avoid heat stress. The importance of building envelope has not been addressed adequately in livestock productions regarding its significant impact on the competitiveness of the sector. This contribution is not only to farm economics but also to increase agricultural efficiency and productivity in a sustainable way to meet the challenges of higher demand in a (energy) resource-constrained and climate uncertain world. This policy brief is in line with the CAP objective 2 - Increase competitiveness.

Energy costs for heating and cooling livestock buildings are among the most significant production costs of livestock units, together with the animal feed (indirect energy carrier) costs, that have increased recently. When focusing separately on the livestock building design, the most important problem is related to the cost of heating and cooling during the whole year. Heating is the largest energy-consuming activity, accounting for around 90% of the total energy consumption, followed by ventilation and lighting[41]. On average, 17% of this energy consumption per kg of slaughter weight of pig meat was allotted to fossil fuel for heating, while for broiler production, fossil fuels for heating accounted up to 17% of the total energy use per kg of poultry meat[42].

In regions where the weather conditions are extremely variable and the buildings heating/cooling needs are high, the upgrading/renovating of livestock buildings is a rational choice for an energy efficiency improvement investment. In many countries, livestock production buildings are not insulated.

Building envelope insulation improvement through different measures (e.g., insulation on the walls and/or the roof, new windows with thermal break, etc.) does significantly reduce the energy needs of livestock facilities for all seasons while sustaining high thermal comfort of animals[43] .

Policy Recommendations

EU Level:

- Create database/categories of the many options for building envelope constructions and insulation materials and guide farmers how to select the most suitable solutions for different climatic conditions.
- Certification of animal products obtained through sustainable energy use practices and promoting animal welfare. This could ensure best wholesale prices and appreciation of environmental awareness from customers, which is in line with the CAP objective 1 - Improve the position of farmers in the food chain.

Member States Level:

- Develop the building code or guidance for farmers regarding the design of livestock building envelope.
- Establish a short- and long-term renovation scheme for upgrading the livestock building envelope, allowing farmers and industry to plan accordingly and enable a portfolio of options as wide as possible to suit farmers' needs.

[41] Costantino, A.; Fabrizio, E.; Biglia, A.; Cornale, P.; Battaglini, L. (2016) Energy Use for Climate Control of Animal Houses: The State of the Art in Europe. Energy Procedia 2016, 101, 184–191.
[42] Paris, B.; Vandorou, F.; Tyris, D.; Balafoutis, A.T.; Vaiopoulos, K.; Kyriakarakos, G.; Manolakos, D.; Papadakis, G. (2022) Energy Use in the EU Livestock Sector: A Review Recommending Energy Efficiency Measures and Renewable Energy Sources Adoption. Applied Sciences, 12, 2142.
[43] Masi, Rosa Francesca De; Ruggiero, Silvia; Tariello, Francesco; Vanoli, Giuseppe Peter (2021) Passive envelope solutions to aid design of sustainable livestock buildings in Mediterranean climate. Journal of Cleaner Production, 311, 127444.

- Implementation of an energy audit system (see Policy Brief “Farm Energy Audits”) that will be used by the member-states to reward the farmers investments in energy efficient livestock buildings either through direct funding or indirectly through tax exemptions.
- Setting specific privileges for farm owners who have upgraded their building infrastructure will also be a policy measure to attract the rest of livestock farmers to follow the pilot examples.
- Promote training activities for farmers and advisors at national and regional levels, demonstrating in situ the benefits of adopting the principles of building envelope insulation in terms of reduction of fossil energy consumption, increase in animal welfare (thermal comfort), and reduction of production costs.
- Facilitate farmers and agricultural service providers, through funding and subsidy programs, to acquire low energy livestock buildings while establishing new livestock production sites. Funding of upgrading/renovation programs for agricultural holdings (including livestock farming). Subsidies or low interest loans should be provided for a series of suggested interventions, such as insulation and window replacement.
- Demonstrations of pioneer technologies that advance these technologies to more mainstream accessible technologies for farmers. There is a need for policies to support pilot projects wherein the offset, storage, delivery, economically sound and safe use of building envelope insulation are tested and demonstrated to the agricultural sector and society.
- In Italy, renovations for livestock facilities are made possible thanks to investments like Heat Pumps and Parco Agrisolare (see Pol. Rec. #11 and #12). It is important to note that requirements and sanctions vary, on the Italian territory, also at the regional level. It is always advisable to refer to the national decrees and the specific local fields of application, via the sites of the Region to which they belong.

Research and development level:

- Develop sustainable structure and materials for livestock building envelope, which is suitable for the environment of livestock production and cost-effective.
- Design of livestock production buildings by investigating different scenarios to identify the best design strategy of livestock building envelope.
- Research in integrated design of building envelope, ventilation system, heating system and lighting system as well as considering the saving of labour hours and energy in terms of moving livestock.
- Applying energy and mass balance equations allows analysis of the thermal behaviour, but it is challenging to calculate these balances since the thermal behaviour of building envelopes can be impacted by many factors. Improving building design requires understanding the mass and energy balance of the system as a way to specify materials, dimensions, and (ventilation and climate control) equipment needed to maintain high animal welfare conditions.
- Only a few building codes are specifically designed for livestock building envelope, while the cutting-edge technology development in building envelopes is not adequately known by engineers in agricultural area.

Expected Impacts

- The sum of electrical and thermal energy consumption (primary energy consumption) can be reduced by at least 40% across EU climate zones by replacing old type envelope designs with modern ones.
- Improving the energy performance for climate control through the decrease of the overall consumption of thermal and electrical energy.

- Increased farm profitability, especially of poultry and pig farms, as energy costs are significantly reduced while maintaining the same income per production and favouring the sustaining of the rural population.
- The probability of heat stress occurring will be greatly reduced and therefore the production and animal welfare are ascertained.
- Contribute to improving the environmental as well as the overall sustainability of the livestock sector.
- Higher probability that farmers will stay in the business and thus reduce the number of citizens unemployed in rural area.
- More job positions can be opened for well-trained engineers who can work as consultants in design and upgrading of livestock building envelope.
- Promote training activities for farmers and advisors at national and regional levels.

4.2.13.The use of thermochemical fluids for energy saving and storage in agriculture

What is the challenge?

Increasing the **efficiency** of the thermochemical fluid systems is one of the major difficulties. Multiple processes are required to convert thermal energy to chemical energy and vice versa, and it is essential for overall efficiency to reduce energy losses at each stage.

Expanding the most common current technology, pumped hydroelectric storage, is **limited by geography**, and lithium-ion batteries are too **expensive for storing excess renewable** power over multiple days (around €140/kWh). The storage period defines how long the energy is stored (i.e., hours, days, weeks), and this is a challenge associated with implementing thermochemical energy storage.

Integration and compatibility: To ensure seamless integration, thermochemical fluid systems should be compatible with current energy systems and infrastructure. This covers considerations for energy storage, transportation, and consumption in various applications. The need to develop and operate coupled thermochemical energy storage systems makes thermochemical energy storage implementation difficult.

Stability and durability: Thermochemical fluids must be stable and durable over multiple cycles of energy conversion and storage. They should be able to tolerate high temperatures and other difficult operating conditions without significant degradation, ensuring an extended operational lifetime.

For broad adoption, the **cost-effectiveness** of thermochemical fluid systems must be competitive with other energy storage techniques. To make these systems economically viable, cost-effective materials and manufacturing processes must be developed.

Scalability: Developing thermochemical fluid systems that can be scaled up for practical uses is another challenge. Fluid systems must be designed to be easily implemented on a wider scale, allowing for widespread adoption and integration with existing energy infrastructure.

Environmental impact: The choice of fluids and associated materials should minimize negative environmental effects, including emissions and natural resource depletion.

Policy Recommendations

Strengthen and expand the EU's commitments to **combat climate change** with the goals of the Paris Agreement and ensure their effective implementation by member states by setting more ambitious emission reduction targets and **promoting the transition to a low carbon economy** and ensure their effective implementation by member states.

The **European Commission has recommended ten points for EU Member States to maximize energy storage** to its full potential. The Commission's suggested reforms for Europe's electricity design underline the fundamental role of flexibility that storage can provide to the electricity system. According to their recommendations, Member States should develop new market products, particularly for peak shaving, curtailment prevention, and congestion management, to secure predictable revenue streams for storage, both utility-scale and behind-the-meter. A lower carbon cap needs to be mandated in the capacity market.

On 14 March 2023, the Commission Recommendation Energy Storage – Underpinning a decarbonized and secure EU energy system was adopted. It addresses EU countries on the most important issues contributing to the broader deployment of energy storage. They should consider the double role of "consumer-producer" of storage by applying the EU electricity regulatory framework and by **removing barriers**, including **avoiding double taxation** and **facilitating permitting procedures.**

Joint EASE/EERA recommendations for a European Energy Storage Technology **include the need to develop and implement thermal energy storage** systems that are coupled to power-to-heat technologies, classify thermal storage systems based on the mass of the storage medium, the heat capacity of the storage medium, the temperature difference, and the melting or phase change enthalpy, and consider the storage period of thermal storage systems, which defines how long the energy is stored (i.e., hours, days, weeks).

Implement policies to **encourage renewable energy sources,** such as increasing support for research and development, **providing incentives** for renewable energy projects including solar, wind, and hydroelectric powers and removing barriers to their deployment.

Develop and implement regulations that **support energy efficiency** across sectors, including efficiency in buildings, transportation, and industrial sectors and the exploitation of the potential of energy storage in the design and operation of the networks.

Consider the specific characteristics of energy storage when designing network charges and tariff schemes and **facilitate permit granting** and encourage further exploitation of the potential of **energy storage in the design** and operation of the networks.

Encourage the **adoption of sustainable agriculture techniques**, such as organic farming, pesticide and fertilizer reduction, and the application of circular economy principles in the food production and distribution chain.

Boost **sustainable consumption** and production practices through **education, awareness** campaigns, and economic incentives.

Foster innovation and entrepreneurship in agricultural practices through **sponsoring R&D** activities, giving startup finance, and **fostering** favourable regulatory frameworks **for emerging technology.**

As part of the Policy and Valuation Track of the Energy Storage Grand Challenge Draft Roadmap, **provide tools, analyses, and recommendations** that **maximize the value of energy storage** to electric and thermal energy systems.

Expected Impacts

Thermochemical fluids + TES (Thermal Energy Storage) systems can help to **reduce greenhouse gas emissions from agricultural** energy use. Farmers can reduce their carbon footprint and environmental impact by improving energy efficiency and increasing the use of renewable energy sources. Supporting a more sustainable and environmentally friendly agricultural sector will help the EU to meet its climate goals.

Agricultural **heating and cooling systems,** such as greenhouse climate control, may take advantage of thermochemical fluids. These fluids can **efficiently transfer and distribute** heat, allowing crops to thrive in optimal conditions while minimizing energy consumption.

Thermochemical fluids can be used in **crop drying processes.** When compared to standard drying procedures, these fluids can efficiently **remove moisture** from harvested crops**, lowering drying time and energy requirements**. This improves crop post-harvest preservation.

Promoting renewable energy and energy efficiency can lead to a decrease in fossil fuel combustion and subsequently **improve air quality**, reducing the negative health impacts of pollution.

Thermochemical fluids can **improve crop nutrient absorption** by increasing nutrient solubility and availability in the soil. These fluids can aid in the breakdown of complex nutrients into more absorbable forms, resulting in enhanced nutrient uptake by plants.

Thermochemical fluids can **increase soil water retention**, lowering crop water stress. These fluids can aid in the **retention of moisture** in the root zone, resulting in a more regular water supply for plants, particularly in arid or drought-prone areas.

Thermochemical fluids can **aid in high-efficiency energy conversion processes**. It is now possible to convert low-grade waste heat into useful energy by using the reversible chemical interactions of these fluids, hence boosting **total energy efficiency.** This has the potential to have a large influence on industrial processes, power generation, and heating systems.

Diversification of the energy mix through the expansion of renewable energy sources can enhance the EU's energy security by **reducing dependence on imported fossil fuels**.

Thermochemical fluids can improve agricultural energy **efficiency** by **storing and releasing thermal** energy as needed. Excess energy created during **peak hours** (such as from renewable sources like solar or wind) can be stored for **later use** using TES (Thermal Energy Storage) devices, decreasing waste, and optimizing energy utilization.

Thermochemical fluids + TES (Thermal Energy Storage) systems can aid in the **management** of agricultural **energy demand.** Farmers can lessen their dependency on the electrical grid during expensive or stressful seasons by storing thermal energy during low-demand periods and releasing it at peak demand, reducing strain on the overall energy system.

Waste heat recovery systems can make use of thermochemical fluids. They can convert waste heat from industrial operations, electricity generation, and other sources **into usable energy.** This decreases energy waste while also **improving overall system efficiency**.

Adoption of thermochemical fluid-based energy-saving technology can result in **financial gains**. Improved energy efficiency **saves money** for companies, businesses, and consumers. Furthermore, the development and implementation of these technologies create new prospects for energy sector innovation, job creation, and economic growth.

4.3. GENERIC POLICY RECOMMENDATIONS

4.3.1. Financial Support to Fossil Energy Free Technologies and Strategies

What is the challenge?

- Lack of well-structured and coherent financial incentives specifically for FEFTS.
- There is an insufficient framework supporting pioneering entrepreneurs focusing on FEFTS development for agricultural use.
- The financing needs of smaller farms to integrate FEFTS in their production system are usually not addressed by horizontal tools.
- Many different subsidy policies by different government bodies, which in some cases can either be conflicting or not compatible. Specific economic incentives for FEFTS are not clearly provided.
- High uncertainty hindering investments in FEFTS, as the result of multiple factors like perceived uncertainties of technological maturity of specific FEFTS, of the economic viability of the investments as well as limited financing options for such investments.
- Farmers primarily sell agricultural products. Selling other products that are energy or carbon related is frequently not "on their radar", even if they could diversify their income streams, decrease food production cost, and improve their income.
- While all EU countries have a framework for Energy Communities, sometimes specific provisions for agricultural focus are missing.

Policy Recommendations

- Defossilising agriculture is a multi-sectoral endeavour that is based on multiple pillars: The Farm to Fork Strategy and the Common Agricultural Policy, the revised Renewable Energy and Energy Efficiency Directives along with the REPowerEU Plan. **Optimal harmonization among the different policies and directives should be ensured**. This challenge is more evident at the National level. There are cases where the administrative requirements for accessing funds or incentives under the renewable energy policies and the CAP differ and accessing tools stemming from one policy might not allow to access tools stemming from the other. For example, a farmer who wants to install a small wind turbine might need to navigate both agricultural and energy regulations, each with their own set of complex application procedures, eligibility criteria, and reporting requirements. Another example is that the CAP supports biofuels, some of the Member States do not allow farmers to produce their own biofuels on-site in their farms.
- **Well-structured financial incentives**: While the energy policy of the EU includes a variety of financial incentives to support the deployment of renewable energy technologies, these incentives need to be aligned with the realities of agriculture under specific measures. At the same time, the eco-schemes of the current CAP (25% of the direct payments), which are voluntary programs that incentivize farmers to adopt sustainable and climate-friendly practices, **should be designed in a way that effectively supports the adoption of FEFTS**. The new CAP has higher green ambitions, adopts the eco-schemes instrument with at least 25% of the direct payments to be dedicated to them and foresees green architecture tools. At the same time, there is high flexibility in many aspects concerning how the Member States will implement the CAP. In the future, CAP can foresee more compulsory measures facilitating the defossilization of EU agriculture. Concrete targets like the ones present in the RED II directive can provide better direction to the Member States. While the set of Agri-environmental indicators (AEIs) track the integration of environmental concerns into the CAP at EU, national and regional levels, these are not high-level political targets that can be communicated with ease.

- Even though the need for financial incentives is horizontal across the EU, the Member States need to employ measures to support FEFTS that are in **alignment with their geographical and socioeconomic conditions, the rest of their policies and then implemented instruments**.
- **Framework for supporting pioneering entrepreneurs:** The EU has several horizontal policies and measures including incubation programs, mentorship, and access to capital. At the same time, the CAP includes support for young farmers and new entrants, providing them with access to land, capital, and training. This can help facilitate the entry of new entrepreneurs in the agricultural sector who are interested in adopting FEFTS. Intuitive tools are needed so that farmers are aware of the different schemes and mechanisms and are supported for effectively combining them. One great example is the European Commission's "De-risking Energy Efficiency Platform" (DEEP)[44]. This is an open-source database for monitoring and benchmarking energy efficiency investment performance. It aims to help users to better understand the real risk and benefits of energy efficiency investments based on market evidence and tangible track records. The DEEP 2.0 platform includes over 17 000 energy efficiency projects from 30 providers. Such a platform for defossilisation investments in agriculture can play a significant role in the way forward, either as a new platform or as an extend of the DEEP.
- **Financing needs of smaller farms:** small farms face specific challenges many times including limited collateral, less diversification in their operations, lack of credit history, high upfront costs which cannot be afforded without access to credit coupled often with limited financial literacy of small farmers. This reality creates the need for specific support for smaller farms. This can be realized either through dedicated instruments or with instruments providing the necessary versatility and adaptability with the small farm realities. Some of the characteristics these instruments could have include flexibility, accessibility, risk mitigation, longer term loans and micro-finance options.
- **Streamline subsidy policies** and ensure that they are compatible with each other to avoid conflicting rules that can make farmers ineligible for certain benefits.
- Provide long-term **certainty and stability** to investors and farmers **by setting clear targets** for emissions' reduction and sustainable agricultural practices. Governments ought to promote de-risking mechanisms, coupled with a mechanism to optimize investment plans before these are eligible for the new schemes can unlock high private capital for investments in FEFTS.
- Encourage farmers to **diversify their income streams** by promoting the **production and sale** of energy-related products, such as electricity, liquid biofuels, and biogas. Create new food/clean energy business models.
- Create **specific economic provisions within the Energy Communities** framework to support agricultural projects and initiatives put forward by Agricultural Cooperatives or other Agricultural Associations.
- Fund **training and knowledge transfer programs** that promote sustainable agriculture practices and clean technologies business models.

Expected Impacts

- **Reduced greenhouse gas emissions:** Funding sustainable agriculture practices and the deployment of renewable energy technologies and energy efficiency measures can reduce greenhouse gas emissions from the agriculture sector and help the EU achieve its climate targets.
- **Increased energy security:** Increased use of renewable energy in agriculture and adoption of energy efficiency practices can reduce the sector's dependence on fossil fuels, increasing energy security for

[44] https://commission.europa.eu/news/improved-platform-monitoring-energy-efficiency-financing-deep-20-2021-07-01_en

farmers and reducing the EU's overall energy import dependence.

- **Improved farm incomes:** Diversifying income streams through the production of renewable electricity and fuels, along with carbon farming and other non- food products can improve the financial sustainability of farms.
- **Enhanced biodiversity and soil health:** Sustainable agriculture practices can enhance biodiversity and soil health, contributing to the preservation of ecosystems and the promotion of agroecology.
- **Increased rural development:** Promotion of FEFTS can support rural development, creating new jobs and business opportunities in rural areas.
- **Improved air and water quality:** Adoption of sustainable agriculture practices can improve air and water quality by reducing the use of pesticides and fertilizers and promoting the conservation of natural resources.
- Defossilising agriculture is a multi-sectoral endeavour that is based on multiple pillars: The Farm2Fork Strategy and the Common Agricultural Policy, the Revised Renewable Energy and Energy Efficiency Directives along with the REPowerEU Plan. **Optimal harmonization among the different policies and directives should be ensured**.
- **Well-structured financial incentives**: While the Energy Policy of the EU includes a variety of financial incentives to support the deployment of renewable energy technologies, these incentives need to be aligned with the realities of agriculture under specific measures. At the same time, the eco-schemes of the current CAP (25% of the direct payments), which are voluntary programs that incentivize farmers to adopt sustainable and climate-friendly practices **should be designed in a way that effectively supports the adoption of FEFTS**.
- Even though the need for financial incentives is horizontal across the EU, the Member States need to employ measures to support FEFTS that are in **alignment with their geographical and socioeconomic conditions, the rest of their policies and then implemented instruments**.
- **Framework for supporting pioneering entrepreneurs:** The EU foresees several horizontal policies and measures including incubation programs, mentorship, and access to capital. At the same time, the CAP includes support for young farmers and new entrants, providing them with access to land, capital, and training. This can help facilitate the entry of new entrepreneurs in the agricultural sector who are interested in adopting FEFTS. Intuitive tools are needed so that farmers are aware of the different schemes and mechanisms and are supported for effectively combining them.
- **Financing needs of smaller farms:** This can be realized either through dedicated instruments or with instruments providing the necessary versatility and adaptability with the small farm realities.
- **Streamline subsidy policies** and ensure that they are compatible with each other to avoid conflicting rules that can make farmers ineligible for certain benefits.
- Provide long-term **certainty and stability** to investors and farmers **by setting clear targets** for emissions' reduction and sustainable agricultural practices. Governments ought to promote de-risking mechanisms, coupled with a mechanism to optimize investment plans before these are eligible for the new schemes can unlock high private capital for investments in FEFTS.
- Encourage farmers to **diversify their income streams** by promoting the **production and sale** of energy-related products, such as electricity, liquid biofuels and biogas. Create new food/clean energy business models.
- Create **specific economic provisions within the Energy Communities** framework to support agricultural projects and initiatives put forward by Agricultural Cooperatives or other Associations.
- Fund **training and knowledge transfer programs** that promote sustainable agriculture practices and clean technologies business models.

4.3.2. Regulatory support to Fossil Energy Free Technologies and Strategies

What is the challenge?

- **High bureaucracy and multi-step procedures:** This often requires significant time and effort by farmers, discouraging the employment of FEFTS. For example, the installation of a small wind turbine in Greece (less than 60 kW) includes multiple steps that a farmer would have to hire a consultant to undertake with considerable cost. In addition to the above, you would need positive opinions from the competent services, such as the Archaeological Services, the Forestry Department, the Directorate of Agricultural Development, the Civil Aviation Authority, the Hellenic Army General Staff, and the Urban Planning Department. Similar conditions occur in several EU countries.
- **Lack of trust and clear alignment:** The ever-changing policies and overall lack of trust impede the alignment of EU targets with National Policies, often leading to confusion. The EU policies often undergo frequent changes to respond to emerging environmental and energy concerns. However, these continuous shifts can lead to a complex policy landscape that is difficult for individual farmers to navigate. This complexity can create confusion about which policies apply to them and what they need to do to comply. Farmers may become sceptical of the promises made by the policies if they see frequent shifts in priorities or support mechanisms at the National Level. For example, in Greece, the guarantied prices for farm photovoltaics were reduced by 12% in 2014 horizontally for all farmers irrespective of crucial parameters like the time the PV parks were initially connected to the grid and the corresponding installation cost at that time. While this happened almost a decade ago, it is still causing mistrust issues among farmers in relation to governmental policies for farm based renewable energy investments.
- **Gap between Renewable Energy and Energy Efficiency policies and the agricultural sector:** Both at EU and National Level the progress realized in relation to Renewable Energy and Energy Efficiency regarding the deployment of renewables, energy labelling, minimum energy performance standards and eco-design, buildings sector and industry is immense, and the EU is leading the way globally. The agricultural sector on the other hand has not seen comparable activities being implemented. For example, very few appliances/devices used in agriculture are covered by eco-design.
- **CAP issues:** While the new CAP has higher green ambitions, adopts the eco-schemes instrument with at least 25% of the direct payments to be dedicated to them and foresees green architecture tools, there are no concrete provisions of compulsory character for the Member States for facilitating the adoption of FEFTS.
- **Unclear biofuel policies:** The policies and regulations concerning biofuels and renewable fuels of non-biological origin are not easily specified/adapted for farmers' own on-site fuel production.
- **Inadequate food labelling:** There is a need for food labels that highlight the energy (direct and indirect) sustainability of agricultural produce.
- **Marginal consideration of agriculture in energy planning:** In some member states, agriculture is barely considered when energy planning takes place.
- **Lack of integrated biomass use planning:** While this has the potential to promote circular economy and security of supply in agricultural areas it is usually missing.
- **Unaligned electricity flexibility schemes:** Time-varying tariffs are not aligned with the needs and potential for self-production of agriculture.
- **Absence of certification schemes:** These are necessary to facilitate the deployment of financing mechanisms.

- **Insufficient acknowledgement of small farms:** The specific needs of small farms are often overlooked in policy and regulatory frameworks.
- **Underutilized energy audits:** This tool is not well-deployed in the sector.

Policy Recommendations

- **Streamline and digitize procedures:** Implement "one-stop-shop" schemes to minimize both effort and time for implementing FEFTS investments.
- **Harmonize policies:** Ensure that policies promoted by different ministries are fully harmonized and clearly aligned with EU policy targets.
- **Specify food/energy policies:** Detailing of general energy policies for the specifics of the agriculture sector is crucial, considering combined food and energy production.
- **Allow farmers to produce and use directly renewable fuels:** Both EU and National policies should facilitate this.
- **Promote sustainable food labelling:** Food labelling schemes ensuring energy use sustainability and carbon neutrality need to be promoted at the EU level.
- **Integrate agriculture in energy planning:** Governments need to actively include agriculture in energy planning exercises including spatial analysis of rural areas.
- **Implement circular economy policies:** Integrated planning needs to ensure synergies between agriculture and industry in a circular and symbiotic process.
- **Develop agriculture-focused electricity flexibility schemes**: Policies should earmark the investigation of such schemes.
- **Promote FEFTS related certification schemes:** These need to be promoted through the policy/regulatory framework.
- **Address the needs of small farms:** Policy and regulatory framework development must clearly and coherently address their needs.
- **Promote energy audits:** A comparable framework for energy audits in farms needs to be developed and promoted.
- **Improve policy communication:** Enhance communication activities to reduce misconceptions and ensure that farmers understand the goals and benefits of policies.

Expected Impacts

- **Increased adoption of FEFTS:** Streamlined processes and clear policies would increase the adoption of these technologies and strategies, leading to reduced greenhouse gas emissions.
- **Improved farmer understanding and participation:** Clearer communication and harmonization of policies would improve farmer understanding and participation in defossilising efforts.
- **Enhanced energy efficiency:** Detailed energy policies for farmers to optimise their processes in terms of energy consumption and allowance of farmer-owned renewable fuel production could lead to greater energy efficiency in the agricultural sector.
- **Promotion of sustainable practices:** Sustainable food labelling and circular economy policies would promote sustainable practices across the supply chain.
- **Improved planning and integration:** Including agriculture in energy planning and flexibility schemes would ensure better resource allocation and integration of the sector in the energy economy.
- **Increased recognition of small farms:** Addressing the needs of small farms would ensure that all farmers, regardless of size, can contribute to and benefit from the transition to sustainable practices through FEFTS integration.

- **Improved resource management:** Regular energy audits could lead to better resource management and energy savings.

4.3.3. Technology, Knowledge Transfer, and Awareness Building provisions to support Fossil Energy Free Technologies and Strategies diffusion

What is the challenge?

- **Complexity of technology choice:** The diverse array of available FEFTS makes it difficult for farmers to select the most suitable ones.
- **Regional discrepancies:** Different regions have varying understandings and levels of acceptance of FEFTS.
- **Inadequate real-world proofs of concept:** A lack of extensive real-world FEFTS farm demonstrations for farmers hinders their acceptance and implementation.
- **Congested distribution grids in rural areas**: This poses a significant barrier to the effective deployment of FEFTS and particularly clean electric energy production systems.
- **Misconceptions about energy costs:** Many farmers overlook indirect energy inputs, such as fertilizers, focusing only on utility and fuel bills.
- **General lack of awareness about FEFTS:** This is evident across all levels, from farmers to policymakers.
- **Inadequate advisory/extension services:** empower advisory and extension services with knowledge about FEFTS and their availability by more training and education on national level.
- **Shortage of training programs:** Farmers need more educational opportunities to understand and implement FEFTS effectively.
- **Communication gaps:** at various levels and missing links in the communication chain.
- **Limited experience with energy communities:** Lack of understanding of how the framework of energy communities can support agriculture.

Policy Recommendations

- Enforce **Agricultural Knowledge and Innovation Systems (AKIS)** (Research, Extension, Industry, farmers) to participate in FEFTS promotion in farming.
- **Establish "FEFTS innovation brokers":** These expert structures can provide tailor-made technological solutions for farms in all countries.
- **Promote localized standardized technical solutions:** These should be well-tested, user-friendly, and suitable for local conditions.
- **Support FEFTS demonstration projects:** Promote projects that demonstrate individual FEFTS or combinations of them backed by randomized control trials to yield useful and undisputed conclusions.
- **Encourage flexibility schemes and energy storage:** This would promote self-consumption for farms and alleviate grid congestion.
- **Promote data sharing:** Encourage the sharing of standardized, anonymized data on farm energy balance for policy development and farmer training.
- **Implement "Train the trainers" programs**: Upskill advisors and extension services on FEFTS.
- **Organize targeted workshops for farmers:** Provide practical training and awareness-building opportunities.
- Create **transfer centres** in rural areas to provide advisory for FEFTS diffusion.

- Include **more engineering disciplines** in advisory/extension services to support Agronomists in technical issues.
- **"Train the Farmer" programs:** lifelong learning processes in existing and future FEFTS for different types of farms.
- **Utilize digital tools:** AI/social media for knowledge transfer/communication.
- **Highlight success stories** of energy communities adopting FEFTS.

Expected Impacts

- **Easier adoption of suitable technologies:** Farmers will be better equipped to select and implement appropriate FEFTS.
- **Improved understanding and acceptance of FEFTS:** Standardized solutions, demonstration projects, and enhanced advisory services will improve comprehension and acceptance.
- **Enhanced grid management:** Flexibility schemes and energy storage can alleviate grid congestion and improve energy management.
- **Increased awareness:** Comprehensive training programs, workshops, and digital tools will increase awareness and insight of FEFTS across all levels.
- **Strengthened rural communities:** Promotion of successful energy communities will provide a model for alliance among farmers and further adoption of FEFTS.
- **Boost to Innovation**: The presence of "innovation brokers" and the promotion of demonstration projects can lead to a surge in technological innovation in the agricultural sector. This can result in more efficient and sustainable farming practices, potentially extending beyond FEFTS.
- **Increased farm energy Independence**: By enhancing the understanding and use of FEFTS, farms can increase their energy self-sufficiency. This can lead to significant cost savings and reduced dependence on external energy supplies.
- **Economic development opportunities**: The increased adoption of FEFTS can lead to the creation of new jobs and business opportunities, stimulating rural economies and potentially leading to increased income for farmers.
- **Resilient Communities**: Knowledge transfer initiatives and the successful implementation of energy communities can foster stronger, more resilient communities. Shared knowledge and resources can help these communities better handle future challenges.
- **Environmental Benefits**: Wider adoption of FEFTS can lead to substantial environmental benefits. These include a reduction in greenhouse gas emissions, improved soil health and biodiversity, and more efficient use of resources, all of which contribute to climate change mitigation.
- **Improved Policy Alignment and better-informed policymaking**: With shared data and increased awareness of FEFTS, policies at different levels of governance (local, national, EU) can be better aligned and result in more coherent and effective policy defossilisation strategies.
- **Cultural Change**: By fostering awareness and understanding of FEFTS, a cultural shift can occur within the farming community. This can lead to a widespread embrace of sustainable farming practices, with long-term benefits for the environment, public health, and food security.
- **Enhanced Public Trust**: The successful implementation of FEFTS and the demonstration of their benefits in farming can enhance public trust in the agriculture sector. This can lead to increased public support for sustainable farming practices and policies.
- **Global Leadership**: The EU can position itself as global leader in sustainable agriculture and inspire others to assist in combating climate change globally.

5. CONCLUSIONS

In conclusion, this document is one of the main outputs of the H2020 project AgroFossilFree and contains a summary of the identified policy gaps in the adoption and use of FEFTS and policy guidelines to accelerate the adoption of FEFTS in the EU agricultural sector with the goal of defossilising agriculture in the long run and contributing to making Europe a carbon neutral continent by 2050.

Both the policy gaps identified and policy recommendations are particularly relevant for EU and national policymakers as they are based around the ideas and needs of European farmers themselves over a three year period (through surveys, national workshops, transnational workshops) and cover all the main sectors (open-field, greenhouses, livestock) of EU agriculture while are further enhanced by experts in each field.

Based on these inputs, which were analysed in detail, 19 key policy recommendations have been synthesized and are presented in this report. These cover horizontal policy recommendations that can be applied to any type of farm and FEFTS, specific agricultural production system policy recommendations that can assist specific FEFTS to be applied in farms of certain production systems, and generic policy recommendations that our consortium considers necessary to support a green transition in EU agricultural. The developed policy guidelines on regional and EU level are proposed to be addressed by the future Common Agricultural Policy, Renewable Energy Directive, Green Deal and Farm-to-Fork strategy and upcoming legal initiatives (national and EU level).

It is clear that weaning EU agriculture from its dependence on fossil fuels will require decades. Our results from the project show that farmers are generally willing to undertake sustainable transitions and that key FEFTS are now becoming available and more affordable but that a number of crucial barriers continue to exist. In our view, it is crucial that the policies outlined in this report are effectively implemented with a long-term view and will provide farmers with the guidance, technical and financial support and assurance to make sustainable transitions on their farms leading to a more sustainable and resilient EU agricultural sector.

6. ANNEXES

PRACTICE ABSTRACT NO. 1

Enabling the creation and growth of energy communities in rural areas

Main results / outcomes

With a well-designed enabling framework, the community energy sector can grow substantially as the examples of Scotland with its CARES scheme and the Netherlands with the Post Code Rose mechanism illustrate. In the Netherlands the number of citizen-led initiatives grew from about 70 to 700 in 7 years. Ownership of wind and solar farms boosts the local economy and social acceptance . It gives young people opportunities to stay in their rural area.

Practical recommendations

Each Member State should do an assessment of barriers and potential for the development of energy communities at the national level and the findings of such an assessment should be used for the design of a complete enabling framework for them to be able to participate in the market without discrimination compared to other market actors. An ambitious community energy sub-target within the renewable energy target (like in Scotland, the Netherlands and Wallonia) should be set by all Member States. Tailored community building support, legal, financial, and technical advice for energy communities make up an essential element of the enabling framework. There should be a holistic strategy to provide financing and advice across different levels of project development. Specific allocation and targeting of development programs and EU public funds (Recovery and Resilience Funds, Cohesion & Regional Development Funds, Modernisation Fund) for energy communities in a national, regional, and local level is required.

Ecopower coop members visit building site wind turbine (Schelle, BE, 2023)

Glasgow, Tuesday 19 September 2023

Further information

- Report on enabling frameworks: https://www.rescoop.eu/toolbox/enabling-frameworks-for-renewable-energy-communities-report-on-good-practices
- YouGov study: European citizens want ownership of wind and solar projects in their neighborhood - REScoop

About this abstract

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AgroFossilFree is a H2020 multi-actor project that will evaluate the current status in EU agriculture regarding energy use and assess existing needs, allowing farmers to optimize agricultural production through more efficient energy use and reduced GHG emissions, resulting in economic, agronomic and environmental benefits. AgroFossilFree will create a framework under which critical stakeholders will cooperate to evaluate and promote the currently available Fossil-Energy-Free Technologies and Strategies (FEFTS) in EU agriculture. The project is running from October 2020 to September 2023.

Website: www.agrofossilfree.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement ID 101000496

PRACTICE ABSTRACT NO. 2

Farm Energy Audits

Main results / outcomes

The majority of EU farms do not conduct energy audits as farmers are not familiar with the procedure and the profits gained from it. Whereas, energy audits are mandatory for residential and commercial buildings so as to determine their energy efficiency. The advantages of doing Farm Energy Audits are:

- **Reduction of energy consumption and related emissions in agriculture** through changes to be applied by farmers for the energy optimization of their farms
- Increased farm profitability, as **costs related to energy use will be significantly reduced** while maintaining the same incomes per production, favouring rural population maintenance or increase.
- **Possibility for the conduction of targeted research** in areas required since the results of all farm energy audits will be gathered to create a unified database.
- Acquisition of the knowledge regarding the EU farms energy status through **a registry that will provide to policy makes the information to focus their policies** for energy consumption reduction.

Practical recommendations

__EU Level:__

- **Promote the advantages of conducting farm energy audits** on national level towards minimization of energy consumption combined with farm operational cost reductions.
- **Create a uniform methodology** to be followed for conducting energy audits across EU.

__Member States Level:__

- Create a platform where the energy audits could be done effortlessly. Ensure that the existing energy audit processes are adapted and followed for farms of all types.
- **Keep the audit procedure optional and then move to mandatory certificate of completion**.
- Farmers who have done an energy audit could be **eligible for financing aid programs** for upgrading their equipment and their **products could be promoted as eco-friendly and greener** while increasing the price.

Further information

AgroFossilFree D3.7: Report on identified policy gaps and policy guidelines (https://www.agrofossilfree.eu/deliverables/#1606215127215-a809e42c-7525)

About this abstract

Authors: Foteini Vandorou (IBO - CERTH)
Date: July 2023

AgroFossilFree is a H2020 multi-actor project that will evaluate the current status in EU agriculture regarding energy use and assess existing needs, allowing farmers to optimize agricultural production through more efficient energy use and reduced GHG emissions, resulting in economic, agronomic and environmental benefits. AgroFossilFree will create a framework under which critical stakeholders will cooperate to evaluate and promote the currently available Fossil-Energy-Free Technologies and Strategies (FEFTS) in EU agriculture. The project is running from October 2020 to September 2023.
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PRACTICE ABSTRACT NO. 3

AGRO FOSSIL FREE

CERTH CENTRE FOR RESEARCH & TECHNOLOGY HELLAS

iBO Institute for Bio-economy & Agri-technology

European Low Energy / Carbon Label of Agricultural Products

Main results / outcomes

- The idea of labelling agricultural products for the benefit of the final consumer (e.g., organic logo) has produced distinctive labels that make it easier for consumers to identify them and help farmers to market them with potential better prices and economic aid.
- Such labelling can only be used on products that have been certified by an authorised control body, using a certain methodology to check the fulfilment of strict conditions in the production system.
- An EU defossilisation labelling system for agricultural products could act as an official certification scheme for foodstuffs produced with sustainable direct and indirect energy use practices that end up to GHG reductions.

Practical recommendations

- **Clear and transparent official certification scheme** for direct and indirect energy use reduction by introducing a framework for monitoring, reporting and verification of the energy use reduction level and the GHG emissions reductions **approved by an official authority of the EU** and **registered in an official registry** to prevent double-counting and avoid green-washing.
- The certification framework should be initially set from the EU's responsible authority (top-down) but should also **allow externals to propose certification** of specific products (bottom-up) that after reviewing by a specialised committee could be a part of the official certification scheme.
- Labelling low or zero fossil energy agricultural products should be of **low cost for farmers** and the products should receive **higher market prices** and **CAP support** to attract farmers into sustainable energy use and efficiency.
- Extension services, private advisors and innovation brokers should inform farmers about such schemes and provide **services to receive this label** and promote these products to consumers.

Further information

AgroFossilFree D3.7: Report on identified policy gaps and policy guidelines (https://www.agrofossilfree.eu/deliverables/#1606215127215-a809e42c-7525)

About this abstract

Authors: Thanos Balafoutis (IBO - CERTH)
Date: July 2023
AgroFossilFree is a H2020 multi-actor project that will evaluate the current status in EU agriculture regarding energy use and assess existing needs, allowing farmers to optimize agricultural production through more efficient energy use and reduced GHG emissions, resulting in economic, agronomic and environmental benefits. AgroFossilFree will create a framework under which critical stakeholders will cooperate to evaluate and promote the currently available Fossil-Energy-Free Technologies and Strategies (FEFTS) in EU agriculture. The project is running from October 2020 to September 2023.
Website: www.agrofossilfree.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement ID 101000496

PRACTICE ABSTRACT NO. 4

Agrivoltaics for open-field agriculture

Main results / outcomes

Agrivoltaics (APV), the integration of agriculture with solar PVs, emerges as a potential remedy, allowing dual land utilization by combining solar energy generation with crop cultivation. This promises a more sustainable approach to land use, ensuring food production is not compromised for energy needs. Based on research from the HyPErFarm H2020 project, the total EU's potential capacity for APV systems is estimated at 51 TW, potentially producing around 71,500 TWh of electricity each year.

Practical recommendations

Setting standards for what counts as an APV system is essential. Europe doesn't have a single definition for Agri-PV, so using ideas from German, French, and Italian rules could help set clear standards. For real APV systems, they need financial help for a while, similar to past support for new green technologies. APV requires a different setup, which means higher starting costs; so it's really important for public groups to help out. The rules need to be made faster, so we don't slow down APV projects, maybe by giving out ready-to-use designs and fixing issues with connecting to the electricity grid. Since APV works in a spread-out way, we need other options for expanding the grid and backing groups of users. Boosting APV work at the EU level, from research money to making things locally, is a must. Even though the Horizon Europe program doesn't focus much on APV, money for testing new setups is key for making rules and learning more. Getting the word out, from farmers to stores and customers, helps connect tech with what people want to buy. Stores can use ads to push APV items, teaching shoppers to look for green APV goods.

Figure 1: HyPErFarm Agrivoltaics Installations. Left) Krinner, Germany; center) Transfarm KUL, Belgium; right) Aarhus University, Denmark.

Further information

HyPErFarm Scientific publications;
HyPErFarm Practice Abstracts
AgriPV Tool

About this abstract

Authors: Alan Gonzalez Morales (PNO Innovation BE – Clustering activities leaders)
Date: August 2023
AgroFossilFree is a H2020 multi-actor project that will evaluate the current status in EU agriculture regarding energy use and assess existing needs, allowing farmers to optimize agricultural production through more efficient energy use and reduced GHG emissions, resulting in economic, agronomic and environmental benefits. AgroFossilFree will create a framework under which critical stakeholders will cooperate to evaluate and promote the currently available Fossil-Energy-Free Technologies and Strategies (FEFTS) in EU agriculture. The project is running from October 2020 to September 2023.
Website: www.agrofossilfree.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement ID 101000496

PRACTICE ABSTRACT NO. 5

Alternative Fuels for Agricultural Machinery

Main results / outcomes

Electrification with batteries and fuel cells seems as a logical step forward for AG machinery, however issues of weight, energy density, and fast refueling of energy storage on-board for a effective and efficient operating range must be considered. Therefore, full electrification seems feasible for small-sized agricultural machines, while for mid- and large-sized and for high power applications there is no alternative to internal combustion engine.

Practical recommendations

Renewable and low-carbon fuels (biomass fuels, hydrogen and e-fuels) will grow in importance as combustion engines remain a necessary key energy converter for agricultural machinery in the short, mid and long-term due to its specific type of use. Agriculture must be recognized as key sector for use of e-fuels and Hydrotreated Vegetable Oil (HVO i.e. renewable diesel) as drop-in replacement fuels. Biomass fuels may have co-benefits as organic fertilizer and alternative protein source, and in the case of biomethane it contributes to a circular economy model for livestock sector and solves the ammonia/methane emission problem.

1. Methane combustion engine

2. Tractor fueling from Livestock Fugitive Methane

Further information

GHG emissions from burning fossil fuel in AG machinery counts for 10% of total AG emissions or ca. 1% of total EU-27 GHG emissions (https://di.unfccc.int/detailed_data_by_party).

About this abstract

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Date: July 2023
AgroFossilFree is a H2020 multi-actor project that will evaluate the current status in EU agriculture regarding energy use and assess existing needs, allowing farmers to optimize agricultural production through more efficient energy use and reduced GHG emissions, resulting in economic, agronomic and environmental benefits. AgroFossilFree will create a framework under which critical stakeholders will cooperate to evaluate and promote the currently available Fossil-Energy-Free Technologies and Strategies (FEFTS) in EU agriculture. The project is running from October 2020 to September 2023.
Website: www.agrofossilfree.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement ID 101000496

PRACTICE ABSTRACT NO. 6

Precision Agriculture as energy consumption reduction strategy

Main results / outcomes

Adopting Precision Agriculture (PA) technologies can have a positive impact on farm productivity and economics, providing higher or equal yields with lower production cost than conventional practices. The farming community can save a lot of cost and prevent further GHG emissions by applying PA techniques (i.e., guidance, recording, decision-making and reacting) that suggest optimal routes for less fuel consumption by agricultural vehicles (path planning) and reduction of agricultural inputs through site-specific application (target inputs to spatial and temporal needs of the field). PA can be applied to almost every category of greenhouse and open-field crop production (i.e., arable, orchards, vineyards, vegetables). Certain high-tech equipment most times is necessary.

Practical recommendations

In order for PA to be promoted as an energy consumption reduction strategy, subsidies and incentives should be given to farmers to acquire technologies that allow precision input application. In case of expensive equipment, the concept of joint ownership/purchase by a group of farmers or associations should be promoted and simplified. Alongside, activities to raise agricultural communities' awareness on PA are needed, supporting farmers on gaining knowledge on how to implement certain methods and what are the outcomes they should expect and participating in training programmes (under common EU standards). In addition, farmers could record their inputs (annually) in order to facilitate any EU state to either provide multiple rewards (for the successful cases) or recommendations from advisory services for further improvement. Extension services should be trained adequately to provide recommendations and technical support to farmers applying PA practices.

Figure 1: Variable rate input application

Further information

The new Common Agricultural Policy (CAP) of the European Union (EU) has put PA on the list of eco-schemes practices eligible for funding and a total of 270 billion euros will be spent on EU farms until 2027 (https://www.arc2020.eu/cap-beyond-the-eu-precision-agriculture/)

About this abstract

Authors: Konstantinos Vaiopoulos, Centre for Research and Technology Hellas (CERTH)

Date: July 2023

AgroFossilFree is a H2020 multi-actor project that will evaluate the current status in EU agriculture regarding energy use and assess existing needs, allowing farmers to optimize agricultural production through more efficient energy use and reduced GHG emissions, resulting in economic, agronomic and environmental benefits. AgroFossilFree will create a framework under which critical stakeholders will cooperate to evaluate and promote the currently available Fossil-Energy-Free Technologies and Strategies (FEFTS) in EU agriculture. The project is running from October 2020 to September 2023.

Website: www.agrofossilfree.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement ID 101000496

PRACTICE ABSTRACT NO. 7

AGRO FOSSIL FREE

ΓΕΩΠΟΝΙΚΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΑΘΗΝΩΝ
AGRICULTURAL UNIVERSITY OF ATHENS

Policy Brief: Carbon Farming for Carbon Removals

Main results / outcomes

Carbon farming aims to optimise carbon capture from the atmosphere to plant material and soil. Many farming techniques that support carbon farming (such as conservation agriculture) exist but are not practiced on a large scale. It is necessary to create incentives for the adoption of climate-friendly practices through carbon farming, as currently, there is not yet a targeted policy tool (under development) to significantly incentivise the increase and protection of carbon sinks.

Practical Recommendations

- Accelerate the development of certification methodologies based on the QU.A.L.ITY criteria set out in Carbon Removal Certification Framework, CRCF)
- Support the work of the Carbon Removal Expert Group on the voluntary certification of carbon removals and request an assessment of whether a functional EU carbon farming tool can be developed
- Continue to develop the standardisation of monitoring, reporting and verification methodologies to provide a framework for carbon farming
- Continue to promote carbon farming practices through the CAP
- Depending on the recommendations of Carbon Removal Expert Group on the voluntary certification of carbon removals support the development of an EU-wide carbon farming system
- Develop a range of incentives that support the adoption of carbon farming practices
- Support R&D processes that attempt to measure the impacts and life cycle of carbon sequestration techniques
- Develop education and extension processes on the environmental and economic benefits of carbon farming techniques

Figure 1. Image that shows carbon farming. Copyright: FREEPIK

Expected Impacts

The expected impacts of the policy recommendations include improved farm incomes, enhanced resilience to climate change, increased carbon sequestration, enhanced biodiversity and soil health, positive environmental externalities

About this abstract

Authors: Bas Paris, Agricultural University of Athens

Date: July 2023

AgroFossilFree is a H2020 multi-actor project that will evaluate the current status in EU agriculture regarding energy use and assess existing needs, allowing farmers to optimize agricultural production through more efficient energy use and reduced GHG emissions, resulting in economic, agronomic and environmental benefits. AgroFossilFree will create a framework under which critical stakeholders will cooperate to evaluate and promote the currently available Fossil-Energy-Free Technologies and Strategies (FEFTS) in EU agriculture. The project is running from October 2020 to September 2023.

Website: www.agrofossilfree.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement ID 101000496

Adoption of Conservation Agriculture to enhance soil carbon stock and reduce GHG emissions in European Agriculture

Main results / outcomes

Creating policies that facilitate making a transition in European agriculture towards more sustainable land-use production systems based on the three principles of Conservation Agriculture (Minimum Mechanical Soil Disturbance; Permanent soil organic cover; Species diversification) will increase the carbon stock in the soil, reduce dependence on fossil fuels in agriculture and contribute to the adaptation and mitigation of climate change.

Practical recommendations

Conservation Agriculture adoption is proven as one of the most suitable agricultural systems to achieve the European climate targets. However, to reach these goals some policy recommendations are needed at the European and National level.

EU Level

- Promote carbon farming practices based on the principles of Conservation Agriculture (No-tillage and/or strip-till in arable crops and groundcover in woody crops) through the CAP and other EU policies and facilitate access to the information to make the transition from conventional to Conservation Agriculture.
- Creation of a harmonized European Label that certifies the farm contributes to mitigating Climate change by soil carbon sequestration and minimising emissions.
- Promote direct payments to farmers who store carbon and reduce their carbon footprint by reducing direct and indirect fossil energy consumption.

National Level

- Facilitate farmers and agricultural service providers, through subsidy programmes, to acquire direct seeders, which is needed to establish No-till in the farmland and encourage cooperation between farmers.
- Promote training activities for farmers and advisors at national and regional levels.

Figure 1: Conservation Agriculture contributions to the European environmental policies.

Further information

[Project website]
[Conservation Agriculture Climate Change Report]
[Conservation Agriculture for boosting Green Deal in Europe]

About this abstract

Authors: Julio Román-Vázquez (European Conservation Agriculture Federation)

Date: July 2023

AgroFossilFree is a H2020 multi-actor project that will evaluate the current status in EU agriculture regarding energy use and assess existing needs, allowing farmers to optimize agricultural production through more efficient energy use and reduced GHG emissions, resulting in economic, agronomic and environmental benefits. AgroFossilFree will create a framework under which critical stakeholders will cooperate to evaluate and promote the currently available Fossil-Energy-Free Technologies and Strategies (FEFTS) in EU agriculture. The project is running from October 2020 to September 2023.

Website: www.agrofossilfree.eu

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ΓΕΩΠΟΝΙΚΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΑΘΗΝΩΝ
AGRICULTURAL UNIVERSITY OF ATHENS

Policy Brief Alternative crop nutrient providers (Green Fertilisers / Biofertilisers, biostimulants / Biochar)

Main results / outcomes

Around 50% of all energy used in EU agriculture is associated with the production and consumption of chemical fertilisers. The production of these fertilisers is based on fossil fuels, often natural gas. For the EU agricultural sector to move towards sustainable production systems a significant transformation is required in the production of fertilisers. Such products are green fertilisers, biofertilisers/biostimulants and biochar.

Practical recommendations

- Promote R&D processes that support the replacement of fossil fuels
- Support industries that produce and/or shift their production processes to green fertilisers
- Promote the use of biomethane and green hydrogen as a substitute of natural gas
- Through market incentives, ensure price competitiveness of green fertilisers
- Develop education and extension processes on the benefits of alternative crop nutrient providers
- Support the development of products that improve the quality of soils and support carbon sequestration
- Promote further the use of alternative crop nutrient providers through the Common Agricultural Policy
- Support local networks that prioritize the production of local biofertilizers
- Promote R&D processes on the long-term potential of biochar to improve soil fertility
- Promote demonstration projects and pilots that showcase alternative crop nutrient providers
- Provide a financial incentive to industry that uses pyrolysis and gasification technologies of agricultural biomass to produce biofuels or electricity and biochar as a by-product.

Fig 1: Image showing biofertilisers. Copyright: FREEPIK

Expected Impacts

The expected impacts of the policy recommendations include reduced greenhouse gas emissions, enhanced biodiversity and soil health, positive environmental externalities, improved public health, increased rural

About this abstract

Authors: Bas Paris, Agricultural University of Athens
Date: July 2023
AgroFossilFree is a H2020 multi-actor project that will evaluate the current status in EU agriculture regarding energy use and assess existing needs, allowing farmers to optimize agricultural production through more efficient energy use and reduced GHG emissions, resulting in economic, agronomic and environmental benefits. AgroFossilFree will create a framework under which critical stakeholders will cooperate to evaluate and promote the currently available Fossil-Energy-Free Technologies and Strategies (FEFTS) in EU agriculture. The project is running from October 2020 to September 2023.
Website: www.agrofossilfree.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement ID 101000496

Building Management Systems (BMS) for Agricultural Constructions

Main results / outcomes

Agricultural facilities encounter significant challenges, such as inefficient energy usage, suboptimal environmental conditions, and inadequate waste management. Smart Agriculture/ Agriculture 4.0 integrates inexpensive sensors and actuators with cloud computing and artificial intelligence (AI) to attain its objectives, enhancing farmers' decision-making capabilities and simultaneously diminishing their ecological impact

Practical recommendations

To promote BMS implementation, financial incentives in the form of grants, subsidies, and tax benefits can assist agricultural facility owners in overcoming initial investment barriers. Raising awareness through training programs and campaigns can educate about energy savings, improved animal welfare and productivity, and reduced environmental impact associated with BMS adoption. Regulations mandating BMS implementation in new constructions or major renovations can be enforced, establishing energy efficiency and environmental performance standards. Allocating funding for R&D initiatives focused on BMS technologies will facilitate innovation and address technical challenges. Providing free governmental technical assistance and expert advice can support agricultural facility owners in planning, installing, and operating BMS. Fostered partnerships between government agencies, industry associations, technology providers, and financial institutions can create a supportive ecosystem, allowing the sharing of best practices and success stories to encourage BMS adoption. The anticipated impacts of BMS adoption are substantial towards optimization of energy consumption and resource allocation, improved livestock and crop productivity and sustainability, reduced mortality rates, minimization of greenhouse gas emissions, through data-driven decision-making.

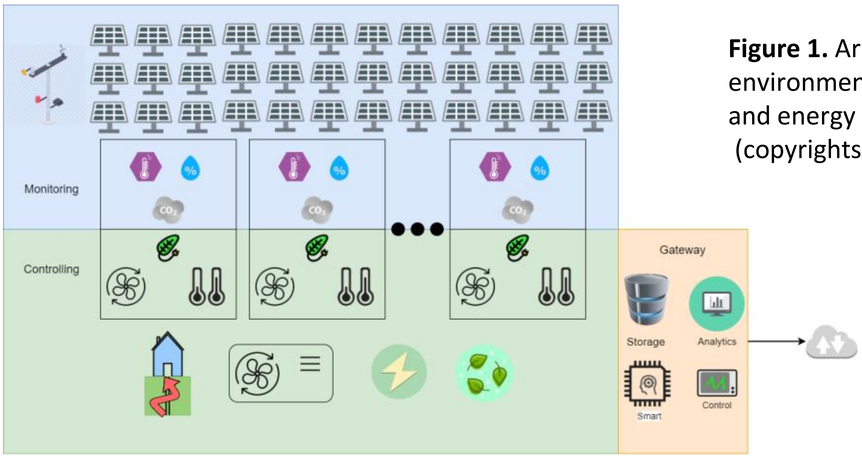

Figure 1. Arrangement for precise indoor environmental control of agricultural buildings and energy smart control. (copyrights Plegma Labs).

Further information

For further information visit www.res4live.eu, and the relevant Practice Abstract about "Precise indoor environmental control of agricultural buildings and energy smart control".

About this abstract

Authors: Stelios Kalogridis, Plegma Labs [RES4LIVE]
Date: July 2023
AgroFossilFree is a H2020 multi-actor project that will evaluate the current status in EU agriculture regarding energy use and assess existing needs, allowing farmers to optimize agricultural production through more efficient energy use and reduced GHG emissions, resulting in economic, agronomic and environmental benefits. AgroFossilFree will create a framework under which critical stakeholders will cooperate to evaluate and promote the currently available Fossil-Energy-Free Technologies and Strategies (FEFTS) in EU agriculture. The project is running from October 2020 to September 2023.
Website: www.agrofossilfree.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement ID 101000496

AGROFOSSILFREE
ΓΕΩΠΟΝΙΚΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΑΘΗΝΩΝ
AGRICULTURAL UNIVERSITY OF ATHENS
RES4LIVE
ENERGY SMART LIVESTOCK FARMING TOWARDS ZERO FOSSIL FUEL CONSUMPTION

Heat pumps for HVAC (Heating, Ventilation, and Air Conditioning) of agricultural constructions

Main results / outcomes

Agricultural construction requires precise control of air temperature and humidity for optimal welfare and productivity. Based on the experience gained by research activities funded by the EC, heat pumps are one of the few technologies that can ensure such conditions, since they are designed to provide heating, cooling, and dehumidifying in a space using electricity.

Practical recommendations

To maximize heat pump potential in agricultural facilities, we can conduct feasibility studies and pilot projects to evaluate efficiency and cost-effectiveness. By identifying applications where heat pumps yield energy savings, we can optimize systems for each location. Implementing monitoring and evaluation systems with smart technologies will enable real-time performance tracking and data analysis for energy-saving measures. Encouraging their integration with renewables, such as solar or geothermal power, reduces emissions and costs through hybrid, modular systems. Supporting R&D for agricultural-specific heat pump technologies includes funding research for harsh conditions and enhancing durability with innovative materials. Partnerships through forums and workshops can facilitate knowledge-sharing among manufacturers, stakeholders, and research institutions, as well as the development of guidelines and standards for design, installation, and operation, considering system sizing, noise levels, and environmental impact. Training programs for farmers and technicians, along with accessible educational material, will ensure successful implementation. Providing incentives and exploring financing models will offset costs and incentivize adoption of heat pump systems in agriculture.

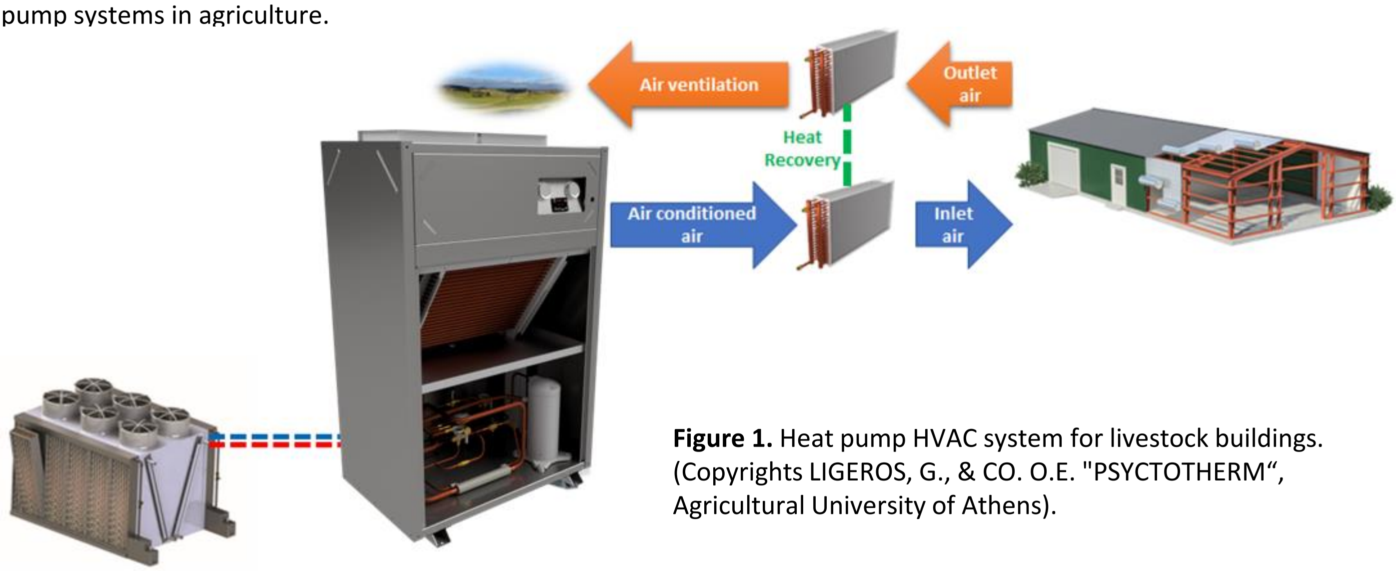

Figure 1. Heat pump HVAC system for livestock buildings. (Copyrights LIGEROS, G., & CO. O.E. "PSYCTOTHERM“, Agricultural University of Athens).

Further information

For further information visit www.res4live.eu, and the relevant Practice Abstract about "Heat pumps for climate control of livestock buildings“.

About this abstract

Authors: Dimitrios Tyris, Agricultural University of Athens [RES4LIVE].

Date: July 2023

AgroFossilFree is a H2020 multi-actor project that will evaluate the current status in EU agriculture regarding energy use and assess existing needs, allowing farmers to optimize agricultural production through more efficient energy use and reduced GHG emissions, resulting in economic, agronomic and environmental benefits. AgroFossilFree will create a framework under which critical stakeholders will cooperate to evaluate and promote the currently available Fossil-Energy-Free Technologies and Strategies (FEFTS) in EU agriculture. The project is running from October 2020 to September 2023.

Website: www.agrofossilfree.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement ID 101000496

PRACTICE ABSTRACT NO. 12

Photovoltaics (PV) and Photovoltaic Thermal (PVT) Collectors and Systems for agricultural constructions rooftops

Main results / outcomes

From numerous scientific studies, it can be appreciated that agriculture has high energy demands for heat and electricity. Globally, heat consists of 50% of the total energy consumption, while electricity, 20%. The costs of the energy consumption in greenhouses are up to 50% of the production costs and account for the second largest operating cost. Solar thermal technology can easily cover at least 60% of the hot water energy demand of agriculture. There is little renewable energy penetration in agriculture, and as fossil fuel costs are likely to rise in the future and as complete electrification would overwhelm the grid, a renewable heating solution like solar thermal or PVT technology is a must in the renewable energy mix future.

Practical recommendations

Solar thermal must be better recognised as a viable and cost-effective renewable heating solution. Although PV technology is on the rise and costs are lowering due to policy incentives, there is very few incentives on solar thermal and none for PVT. Support and subsidies for PVT technology and solar thermal must be facilitated just like PV technology, along with favourable investment plans for those that wish to invest in a new system. Imposing stricter carbon tax to fossil fuel usage will disincentivise its use. Building capacity within the agricultural industry around the opportunities of solar thermal and PVTs and share such research and innovation findings with key actors in the industry will support technology uptake. Local businesses developing and manufacturing PV and PVT products should be supported to ensure the supply chain is kept within the EU at a maximum.

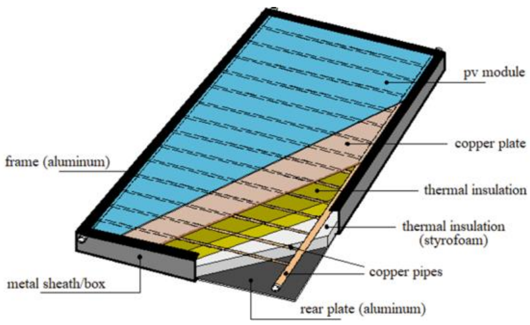

Figure 1. Description of PVT Collector

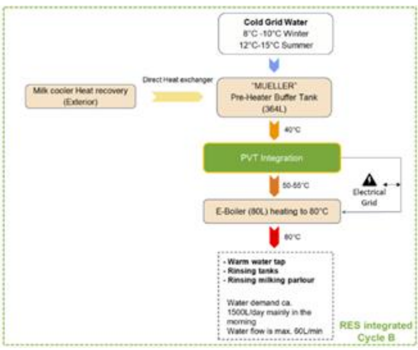

Figure 2. Possible integration of PVTs with a heat recovery system in a dairy farm

Copyrights MG Sustainable, RES4LIVE H2020 project.

Further information

For further information visit www.res4live.eu, and the relevant Practice Abstract about "Photovoltaic – Thermal collectors for electrical and thermal demands in livestock farms".

About this abstract

Authors: Alexander Loris, MG Sustainable [RES4LIVE]

Date: July 2023

AgroFossilFree is a H2020 multi-actor project that will evaluate the current status in EU agriculture regarding energy use and assess existing needs, allowing farmers to optimize agricultural production through more efficient energy use and reduced GHG emissions, resulting in economic, agronomic and environmental benefits. AgroFossilFree will create a framework under which critical stakeholders will cooperate to evaluate and promote the currently available Fossil-Energy-Free Technologies and Strategies (FEFTS) in EU agriculture. The project is running from October 2020 to September 2023.

Website: www.agrofossilfree.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement ID 101000496

PRACTICE ABSTRACT NO. 13

Biogas production from agricultural waste and other innovative feedstock / Biomethane upgrading for local consumption or grid injection

Main results / outcomes

Biogas production from livestock waste is a common practice, but numerous livestock farms have not yet integrated such systems for technoeconomic and social reasons as farmers are sceptical towards new methodologies. However, by incorporating such methodologies the numerous outcomes can be expected, such as:

- **Climate change mitigation** through the use of greener/alternative methodologies to produce biogas and biomethane, which will substitute fossil natural gas.
- More **energy independence** at farm and national levels.
- **Increased farm profitability**, as the residues produced on farm are fully self utilized.
- Significant **maintenance cost reductions** of the multi-feeding mode anaerobic digesters and increased life-expectancy.
- **Creation of new synergies** among farmers and energy providers.
- **Local awareness of citizens** in renewable energy.
- **Accelerated market uptake of the technology** through subsidies, technical support, and financial schemes.

Practical recommendations

- Promote R&D policies to **research and adapt new feedstocks** for biogas production.
- Facilitate access for farmers/energy providers to make the **transition from conventional biogas production to multi-feeding mode**.
- Provide farmers **financing aid and incentives** for the installation of new biogas plants
- Encourage smallholders to **create energy communities** for **common biogas plants or for selling feedstock to a biogas facility**.
- Promote **training activities for farmers and advisors**, **demonstrating in situ** the benefits of adopting new feedstocks for biogas production.
- **Encourage farmers to shift to mixed farms** so that manure and crop residues are used for biogas production and self consumption

Further information

AgroFossilFree D3.7: Report on identified policy gaps and policy guidelines

About this abstract

Authors: Foteini Vandorou (IBO-CERTH)
Date: July 2023

AgroFossilFree is a H2020 multi-actor project that will evaluate the current status in EU agriculture regarding energy use and assess existing needs, allowing farmers to optimize agricultural production through more efficient energy use and reduced GHG emissions, resulting in economic, agronomic and environmental benefits. AgroFossilFree will create a framework under which critical stakeholders will cooperate to evaluate and promote the currently available Fossil-Energy-Free Technologies and Strategies (FEFTS) in EU agriculture. The project is running from October 2020 to September 2023.

Website: www.agrofossilfree.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement ID 101000496

PRACTICE ABSTRACT NO. 14

Facilitating the development of energy independent farming in Livestock

Main results / outcomes

Making Methane from ruminant animals become an energy asset.

Available solutions to capture methane from manure for small & medium livestock farms will support many farmers into producing and consuming their own energy on site and run agricultural machines and transport vehicles on biomethane produced from livestock manure. This would consequently lead to establish carbon negative farms and would significantly reduce the use of chemical fertilizers. Digested material is an excellent natural fertilizer to restore organic matter in the soil. Even small and medium farmers will lower and stabilize their operational costs. Livestock farms reducing chemical fertilizer and producing energy for surrounding communities will be more accepted by the population.

Practical recommendations

The challenge is to make most of the livestock farmers capture the fugitive methane and transform it into energy on site, cutting most logistics costs for material purchased and external energy consumption. Therefore, such solutions should be promoted through farmers associations and advisory services. Policy makers should enable farmers, through subsidy programs, to invest in biomethane capture solutions, and biomethane usage for machinery and energy production. Demonstration activities, knowledge sharing and peer to peer learning are necessary to facilitate the quick adoption of innovative biomethane equipment.

Figure 1. Methane capturing system on 100 dairy cow farm powering a New Holland T6 180 methane tractor (copyrights New Holland).

Further information

GHG emissions from burning fossil fuel in agricultural machinery during the normal course of operation is around 10% of the GHG emissions of agriculture in comparison, or ca. 1% of total EU-27 GHG emissions (https://di.unfccc.int/detailed_data_by_party).

About this abstract

Authors: Gilles Mayer, New Holland; Vanja Biševac, CEMA aisbl
Date: July 2023
AgroFossilFree is a H2020 multi-actor project that will evaluate the current status in EU agriculture regarding energy use and assess existing needs, allowing farmers to optimize agricultural production through more efficient energy use and reduced GHG emissions, resulting in economic, agronomic and environmental benefits. AgroFossilFree will create a framework under which critical stakeholders will cooperate to evaluate and promote the currently available Fossil-Energy-Free Technologies and Strategies (FEFTS) in EU agriculture. The project is running from October 2020 to September 2023.
Website: www.agrofossilfree.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement ID 101000496

PRACTICE ABSTRACT NO. 15

AGRO FOSSIL FREE

AARHUS UNIVERSITY

Livestock building energy upgrading/renovation

Main results / outcomes

Livestock production buildings should provide an indoor temperature range in which animals have to use a minimal amount of energy to keep their body temperature constant and to maximize production and animal welfare, especially to avoid heat and cold stress. When focusing separately on the building design, the most important problem is related to the cost of heating and cooling. Heating is the largest direct energy consuming activity for confined livestock buildings, accounting for around 90% of the total consumption, followed by ventilation and lighting. On average 17% of the energy consumption per kg of pig meat was allotted to fossil fuel for heating, which is proportionally equal to broiler production [1]. One of the most wasteful direct energy parameters is heating and/or cooling of livestock buildings, which is a fact derived from the interaction with more than 1000 stakeholders in 8 European countries during the AgroFossilFree project. The reason is related to obsolete conditions of ventilation systems, building envelopes, heating systems and lack of automatic climate control installations.

Practical recommendations

Heat stress is envisaged to occur more frequently and severely throughout Europe, leading to serious economic losses, hence there is a need to adapt livestock buildings to the climate change. Livestock stakeholders recommends for regions where the weather conditions are extremely variable and the buildings heating/cooling needs are demanding, that upgrading/renovating livestock buildings is a rational choice for an energy efficiency improvement investment. It is also crucial to start analysing the energy consumption in every supply chain and operation on livestock farms.

Figure 1: Ceiling insulation of old pig stable using polyisocyanurat (PIR) (source: Recticel Insulation)

Further information

[1] Paris, B.; Vandorou, F.; Tyris, D.; Balafoutis, A.T.; Vaiopoulos, K.; Kyriakarakos, G.; Manolakos, D.; Papadakis, G. (2022) Energy Use in the EU Livestock Sector: A Review Recommending Energy Efficiency Measures and Renewable Energy Sources Adoption. Applied Sciences, 12, 2142.

About this abstract

Authors: Michael Nørremark, Senior Researcher, Aarhus University
Date: July 2023

AgroFossilFree is a H2020 multi-actor project that will evaluate the current status in EU agriculture regarding energy use and assess existing needs, allowing farmers to optimize agricultural production through more efficient energy use and reduced GHG emissions, resulting in economic, agronomic and environmental benefits. AgroFossilFree will create a framework under which critical stakeholders will cooperate to evaluate and promote the currently available Fossil-Energy-Free Technologies and Strategies (FEFTS) in EU agriculture. The project is running from October 2020 to September 2023.

Website: www.agrofossilfree.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement ID 101000496

The use of thermochemical fluids

Main results / outcomes

TheGreefa project investigated the use of the salt solution, called thermochemical fluids (TCFs) in agriculture in energy transfer and storage. Multiple processes are required to convert thermal energy to chemical energy and vice versa, and it is essential to increase the efficiency of the TCF systems. The salt solutions have the potential to replace the most common current technologies, like thermal storage based on warm/hot water or phase change material which has high thermal losses and a lower energy density.

Practical recommendations

There is a need to strengthen and expand the EU's commitments to combat climate change and ensure their effective implementation by member states by setting more ambitious targets and promoting the transition to a low-carbon economy through the wide implementation of renewable energy sources. The new policies should support energy efficiency across sectors, also innovations, R&D activities and testing of new technologies. The development of new products, particularly for peak shaving, curtailment prevention, and congestion management, to secure predictable revenue streams for storage, both utility-scale and behind-the-meter should is required.

When planning the energy strategy, EU member states should facilitate and promote the implementation of new efficient solutions. The dual role of the 'consumer-producer' of storage should be considered by applying the EU regulatory framework for energy and removing barriers, including avoiding double taxation and facilitating permitting procedures.

In terms of the agricultural sector, it is needed to encourage the adoption of sustainable agriculture techniques, such as organic farming, pesticide and fertilizer reduction, to encourage to use energy from renewable sources including thermal storage and the application of circular economy principles in the food production and distribution chain.

Figure 1 and 2: Caption of TheGreefa promotional video

Further information

TheGreefa promotional video

About this abstract

Authors: Begoña Benito, Serena Danesi, Jakub Pluta

Date: July 2023

AgroFossilFree is a H2020 multi-actor project that will evaluate the current status in EU agriculture regarding energy use and assess existing needs, allowing farmers to optimize agricultural production through more efficient energy use and reduced GHG emissions, resulting in economic, agronomic and environmental benefits. AgroFossilFree will create a framework under which critical stakeholders will cooperate to evaluate and promote the currently available Fossil-Energy-Free Technologies and Strategies (FEFTS) in EU agriculture. The project is running from October 2020 to September 2023.

Website: www.agrofossilfree.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement ID 101000496

PRACTICE ABSTRACT NO. 17

Financial Support to Fossil Energy Free Technologies and Strategies

Main results / outcomes

There's a notable absence of clearly defined financial incentives for FEFTS, leading to hurdles for innovation-driven entrepreneurs working in the agricultural sector. Government subsidy policies vary widely, sometimes conflict, and rarely specify support for FEFTS. Investments in FEFTS are often deterred due to multifaceted uncertainties around technology maturity and economic feasibility..

Practical recommendations

- Optimal harmonization among the different policies and directives should be ensured, especially at the National level.
- Financial incentives should clearly support FEFTS and in the future, CAP can foresee more compulsory measures in this direction
- Concrete targets like the ones present in the RED II directive can provide better direction.
- Member States need to employ measures to support FEFTS that are in alignment with their geographical and socioeconomic conditions, the rest of their policies and their implemented instruments.
- A Framework for supporting pioneering entrepreneurs can increase the adoption of FEFTS.
- Intuitive tools like the EC's "De-risking Energy Efficiency Platform" (DEEP) need to be deployed.
- There is a need for specific support for smaller farms.
- Streamlining of the different subsidy policies is required.
- Encourage farmers to diversify their income streams by promoting the production and sale of energy-related products.
- Create specific provisions within the Energy Communities framework to support agricultural projects.

Fig 1: Image representing financial support.
Copyright: FREEPIK

Further information

Various innovative financing mechanisms are presented in the AgEnergy Platform of the AgroFossilFree project.

About this abstract

Authors: George Kyriakarakos, CERTH / Athanasios Balafoutis, CERTH
Date: July 2023
AgroFossilFree is a H2020 multi-actor project that will evaluate the current status in EU agriculture regarding energy use and assess existing needs, allowing farmers to optimize agricultural production through more efficient energy use and reduced GHG emissions, resulting in economic, agronomic and environmental benefits. AgroFossilFree will create a framework under which critical stakeholders will cooperate to evaluate and promote the currently available Fossil-Energy-Free Technologies and Strategies (FEFTS) in EU agriculture. The project is running from October 2020 to September 2023.
Website: www.agrofossilfree.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement ID 101000496

PRACTICE ABSTRACT NO. 18

Regulatory Amendments to Support Fossil Energy Free Technologies and Strategies

Main results / outcomes

Streamlining procedures and clarifying policies can boost FEFTS use, reducing emissions. Better communication engages farmers in defossilisation. Tailored policies can improve agricultural energy efficiency. Promoting sustainable food labels and circular policies advances supply chain sustainability. Including agriculture in energy planning optimizes resources. Addressing small farms' needs fosters their role. Regular energy audits enhance savings /resource management..

Practical recommendations

- **Streamline and digitize procedures:** Implement "one-stop-shop" schemes to minimize effort/ time for implementing FEFTS investments
- **Harmonize policies**
- **Specify food/energy policies:** Detailing of general energy policies for the specifics of the agriculture sector is crucial, considering combined food and energy production
- **Allow farmers to produce and use directly renewable fuels**
- **Promote sustainable food labelling**
- **Integrate agriculture in energy planning**
- **Implement circular economy policies**: develop synergies between agriculture and industry in a circular and symbiotic process
- **Develop agriculture-focused electricity flexibility schemes**
- **Promote FEFTS related certification schemes**
- **Address the needs of small farms**
- **Promote energy audits:** A comparable framework for energy audits in farms is needed
- **Improve policy communication:** Enhance communication activities to reduce misconceptions and ensure that farmers understand the goals and benefits of policies

Fig 1: Image representing a sustainable farm. Copyright: FREEPIK

Further information

The website of the AgroFossilFree project provides many resources concerning policy issues relevant to the defossilization of the European agriculture. www.agrofossilfree.eu

About this abstract

Authors: George Kyriakarakos, CERTH / Athanasios Balafoutis, CERTH
Date: July 2023
AgroFossilFree is a H2020 multi-actor project that will evaluate the current status in EU agriculture regarding energy use and assess existing needs, allowing farmers to optimize agricultural production through more efficient energy use and reduced GHG emissions, resulting in economic, agronomic and environmental benefits. AgroFossilFree will create a framework under which critical stakeholders will cooperate to evaluate and promote the currently available Fossil-Energy-Free Technologies and Strategies (FEFTS) in EU agriculture. The project is running from October 2020 to September 2023.
Website: www.agrofossilfree.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement ID 101000496

PRACTICE ABSTRACT NO. 19

Technology, Knowledge Transfer, and Awareness Building Provisions to support Fossil Energy Free Technologies and Strategies Diffusion

Main results / outcomes

The wide range of FEFTS presents a challenge for farmers in deciding the best fit. Regional discrepancies in the comprehension and acceptance of these technologies exist. Limited real-world demonstrations hinder adoption. Crowded rural electricity grids can obstruct clean energy production. Misunderstanding about energy costs, like overlooking indirect inputs like fertilizers, is common. Awareness about FEFTS is generally low, from farmers to policymakers. Extension services often lack FEFTS technical expertise. Communication gaps persist at different levels.

Practical recommendations

- Enforce **AKIS** players to participate in FEFTS promotion to the farming processes.
- **Establish "FEFTS innovation brokers"**
- **Promote localized standardized technical solutions**
- **Support FEFTS demonstration projects**
- **Encourage flexibility schemes and energy storage**
- **Promote data sharing:** Encourage the sharing of standardized, anonymized data on farm energy balance for policy development and farmer training.
- **Implement "Train the trainers" programs**
- **Organize targeted workshops for farmers**
- Create **transfer centres** in all rural areas to provide close advisory to increase FEFTS diffusion.
- Include **more engineering disciplines** in advisory/extension services to support Agronomists in technical issues.
- **"Train the Farmer" programs**
- **Utilize digital tools:** Use AI and social media for efficient knowledge transfer and communication.
- **Highlight success stories**

Fig 1: Image representing the advisor's support to the farmer.
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Further information

The website of the AgroFossilFree project provides many resources concerning technology, knowledge transfer, and awareness building issues relevant to the defossilization of the European agriculture.
www.agrofossilfree.eu

About this abstract

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