

SUPPORTING BIOMASS USAGE AND PRODUCTION TO DECARBONIZE AGRICULTURE INDUSTRY – THE AGROFOSSILFREE PROJECT

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ABSTRACT: The AgroFossilFree project aims to support the implementation of Fossil-Energy-Free Technologies and Strategies (FEFTS) in the agricultural sector. Its primary focus is on integrating renewable energy sources, including biomass, into key agricultural industries. The project acts as a coordinator, bringing together stakeholders and offering valuable information on FEFTS in agriculture. One of the project goals is to establish an online platform that serves as a knowledge hub for farmers, advisors, researchers, and industrial partners seeking information on FEFTS. Aligned with the EU Green Deal and the Farm to Fork strategy, the AgroFossilFree project aims to decrease the reliance on fossil energy use in farm operations. It endeavours to bridge the gap between existing FEFTS and current agricultural practices in the EU by facilitating the exchange of innovative ideas and information among stakeholders. By narrowing this gap, the project aims to promote a more sustainable European agriculture by reducing energy consumption, environmental impact, and socioeconomic implications. Through the collection, categorization, and dissemination of knowledge, the AgroFossilFree project encourages the adoption of FEFTS by stakeholders. It also emphasizes compliance with policies and legal frameworks aimed at reducing fossil energy use, while promoting sustainable practices in food production. This paper provides an overview of the AgroFossilFree project, which is funded by the European Commission's Horizon 2020 program.

Keywords: Biomass, RES integration, Agriculture, Strategy, Policies implementation, AgEnergy Platform, Sustainability, Defossilisation

1 INTRODUCTION

Agricultural emissions play a significant role in driving climate change compared to other sectors. In 2015, the agricultural sector accounted for approximately 10% of the EU's total greenhouse gas (GHG) emissions, excluding land use, land use change, and net forestry removals [1]. These emissions primarily stem from livestock production (enteric fermentation and manure management) and the use of fertilizers on agricultural soils. A recent study [2] indicates that energy-related emissions in agriculture, except for horticultural crop types, are relatively minor compared to other sources.

However, despite their relative insignificance, the absolute energy consumption in agriculture remains substantial. Fossil energy is extensively used for activities such as fertilizer and pesticide production, as well as for heating, cooling, transportation, and electricity. The AgroFossilFree project [3] aims to support the adoption of Fossil-Energy-Free Technologies and Strategies (FEFTS) as a means to reduce fossil fuel usage and promote the implementation of renewable energy sources.

FEFTS encompass various tools and approaches that enable cleaner and more efficient energy production and utilization in agriculture. These strategies are categorized based on their specific applications in dedicated agricultural technologies. The main categories include Clean Energy Production and Energy Efficiency

Improvement, with an additional category dedicated to Carbon Sequestration.

2 THE AGROFOSSILFREE PROJECT

The AgroFossilFree initiative (Figure 1) aims to facilitate the incorporation of Fossil Energy Free Technologies and Systems (FEFTS) in the agricultural sector by coordinating efforts among various stakeholders and disseminating information on FEFTS in agriculture.

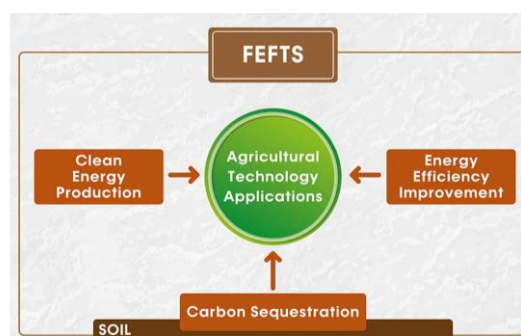


Figure 1: Overview on Fossil-Energy-Free Technologies and Strategies (FEFTS)

The project particularly emphasises applications that encourage Renewable Energy Sources (RES) integration in key agricultural sectors, with a special focus on biomass, such as solid biomass conversion, biomass burners, and boilers. Our research indicates a strong focus on biomass and solar energy applications in both research and industry.

The first goal of this project is to establish an online platform (AgEnergy Platform) where farmers, advisors, researchers, industrial partners, and other stakeholders can access valuable information on FEFTS targeting agriculture. The ultimate goal would be to promote and facilitate the adoption of FEFTS, to this end, a FEFTS research roadmap and policy guidelines to de-fossilise EU agriculture will be published. The AgroFossilFree project aligns with high-level EU strategies, such as the EU Green Deal and the Farm to Fork strategy, by aiming to reduce fossil energy usage in farm operations. The project also seeks to bridge the gap between existing FEFTS and daily EU agricultural practices by promoting the effective exchange of innovative ideas and information among research, industry, extension services, and the farming community. Closing this gap will allow European agriculture to become more sustainable, reducing energy, environmental, and socioeconomic impacts. With all the knowledge gathered, organised, and presented on the platform, the European agricultural sector can support and adhere to fossil energy reduction policies, related legal and regulatory frameworks, and sustainable food production practices.

The expected results of the project are:

- Analysis and assessment of the current energy usage in EU agriculture and the necessary steps to achieve a European fossil-energy-free and independent agricultural sector.
- Identification and presentation of directly existing applicable FEFTS, ranging from applied research findings to market solutions, and evaluation of existing financial tools for de-fossilising activities.
- Collaboration with all pertinent stakeholders in thematic workshops (open-field agriculture, greenhouse and livestock), utilizing interactive physical and online methods to generate community-based ideas for integrating FEFTS into agricultural systems at regional and EU levels.
- Development of an online platform featuring all identified available FEFTS for stakeholders, along with a Decision Support Toolkit offering suggested interventions and financial tools based on user interaction.
- Formulation of policy guidelines at EU, national and regional levels to be communicated and to promote the adoption of FEFTS in agricultural activities in the near future.

The AgroFossilFree project, funded by the Horizon 2020 Programme of the European Commission (Grant Agreement Number 101000496), commenced in October 2020 and has a duration of 3 years. An overview on the status of the project is presented in the following chapters.

3 RESULTS

3.1 Current energy use status in EU agriculture

The current energy status in EU agriculture has been

evaluated and the main findings indicate that energy use in agriculture throughout EU is significant and very much fossil fuel dependent. Among the findings of the AgroFossilFree Project, 3 Scientific Papers were produced and published in prestigious Scientific Journals. The 1st paper called “Energy use in open-field agriculture in the EU: A critical review recommending energy efficiency measures and renewable energy sources adoption” [4] is published in Renewable and Sustainable Energy Reviews. The second paper called “Energy Use in the EU Livestock Sector: A Review Recommending Energy Efficiency Measures and Renewable Energy Sources Adoption” [5] is published in Applied Sciences. Whereas, the third paper, which is about the Energy usage in the Greenhouse Sector and is called “Energy Use in Greenhouses in the EU: A Review Recommending Energy Efficiency Measures and Renewable Energy Sources Adoption” [6] is published in MDPI’s Applied Sciences. These papers are categorized based on the agricultural sector (Open-field, Livestock and Greenhouse) in which the search is being conducted. The most important findings of these papers are presented in the following section.

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, AgroFossilFree results suggest that if indirect energy use associated with the production and transport of fertilisers and pesticides was included, the proportion of energy use in the EU-27 would be 62% higher overall.

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

For open-field agriculture, the use of fertiliser is the largest energy consuming activity in EU agriculture, accounting for around 50% of all energy inputs. On-farm diesel use accounts for 31%, followed by seeds at 6%, the production and use of pesticides at 5%, while other non-classified energy uses stands at 8% and are mainly dedicated to irrigation, storage and drying [4]. In all livestock systems, except for beef production, animal feed is the main energy consumer 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 depending on the production system [5]. In high yielding and high-energy intensive greenhouses, energy demand is dominated by heating and cooling. Lower yielding and less energy-intensive systems, on the other hand, require little to no heating/cooling and instead mainly rely on fertilisers, diesel use for machinery, irrigation and other activities. At the same time, energy use in greenhouses is variable and generally dependent on fossil sources. High energy systems are generally heavily climate controlled and heating and cooling processes are dominant, while low energy systems spend energy in various uses [6].

The above illustrates that for the EU to achieve the goals outlined in the Green Deal and the Farm to Fork strategy, the adoption of innovative technologies,

improvements in energy efficiency, and the further development and deployment of non-fossil energy sources for agriculture are required. In addition to this, a transition to more sustainable agricultural practices and farming systems is needed. For instance, 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.

Providing an overview of energy use in EU agriculture was a challenging topic due to the plethora of available, yet in some cases inconsistent data. However, multiple areas could benefit from further research. The understanding and estimates of energy use in EU agriculture would benefit from additional studies on energy use in all three main production systems, especially for greenhouse agriculture. In addition, further research into the energy use of non-conventional systems and crops that are cultivated on a minor scale is required as well as analysis of the correlations between farm indicators (size, location, specialization) and energy use.

In addition to these findings, important preparatory work has been done so far in order to a) identify farmers' needs, innovative ideas and interests regarding FEFTS through a farmers' survey addressing both adopters and non-adopters of FEFTS as well as advisors' interviews and b) find and promote innovative case studies on FEFTS. The results of the case studies led to the creation of multimedia material showing innovative and market available FEFTS, thus underlining the shift towards both a greener and more sustainable EU agriculture.

3.2 User needs, innovative ideas and interests of best practices on FEFTS

The data gathered through the 470 end-users' questionnaire-based survey was analysed, pointing to multiple factors that influence farmers' awareness and decision to adopt (or not to adopt) FEFTS and energy saving technologies and practices.

20 Practice Abstracts (PAs) have been produced so far and they are available on the project's website, while another 30 are expected to be added until September 2023. These abstracts are a direct dissemination tool to share with agricultural stakeholders of all types some useful information derived from the project which are presented in a very intuitive and comprehensive way.

Furthermore, within the AgroFossilFree project innovation cases that comprise the whole innovation process, starting with the identified need and the origins of the innovative idea through its development and finally its diffusion, were identified and documented. The exploration of innovation cases was based on the Spiral of Innovations (developed during the AgriSpin H2020 project) which identifies seven stages in an innovation process, from the initial idea until the embedding stage of the innovation. In each stage of the Spiral, there are different key activities to be performed and thus actors to be involved. To explore the innovation processes involved in 9 such cases, relevant to each case stakeholders were interviewed and both (written) 'case histories' and videos were produced. The latter were uploaded to the [AgroFossilFree YouTube channel](#).

3.3 Inventories of FEFTS

A methodology for a data gathering inventory was developed to feed the AgEnergy Platform, which was released in early 2022. This methodology included a

number of categories that will facilitate the web platform's search function. Information about FEFTS fed into the web platform was provided by both project consortium and project stakeholders. Dedicated categories of FEFTS available on the AgEnergy Platform are:

- Scientific papers;
- Research projects;
- Commercial technologies;
- Training and advising material;
- Financial support mechanisms.

A database was created and in total almost 2000 FEFTS entries registered, 1500 of which were published on the platform as more intriguing and comprehensive content provision (see **Table I**). The remaining entries are enlisted in the AgEnergy Repository and will be made publicly available after a thorough review.

Table I. FEFTS in the AgEnergy Platform per category.

FEFTS Category	No. of FEFTS (4/2023)	No. of FEFTS (9/2023)
Scientific Paper	733	980
Research Project	155	180
Commercial Product	399	530
Training Material	95	130
Financing Mechanism	98	130

It is worth noting that a large number of the FEFTS submitted so far, more than 300 entries, present biomass solutions, implementation methodologies, policy suggestions, financing mechanisms and more. Thus, highlighting the shift towards biomass related sustainable solutions. External users can now register new entries on the AgEnergy online information portal, which has been made public. As a result, the number of FEFTS available on the platform continues to grow, and innovative technologies are being added on a daily basis.

3.4 AgEnergy Platform

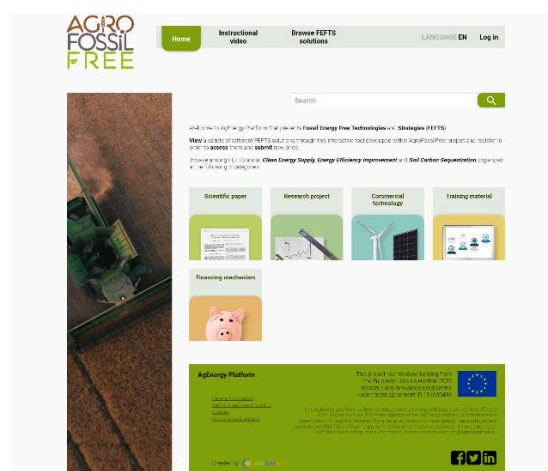


Figure 2: Homepage of the AgEnergy platform

As previously mentioned, AgroFossilFree created the AgEnergy Platform (<https://platform.agrofossilfree.eu/en>) in which all the available FEFTS are included in the form

of easily accessible and comprehensive material for end-users (Figure 2).

In January 2022, the official platform launch was conducted. All the submitted FEFTS can be found under 3 basic categories: Clean Energy Supply, Energy Efficiency Improvement and Soil Carbon Sequestration. The platform (Figure 3) and the FEFTS included in it, are currently being translated into the consortium's different spoken languages. These languages are English, Greek, Polish, Spanish, German, Dutch and Danish. This is done so that all interested stakeholders from different countries can access the available information in their native language.

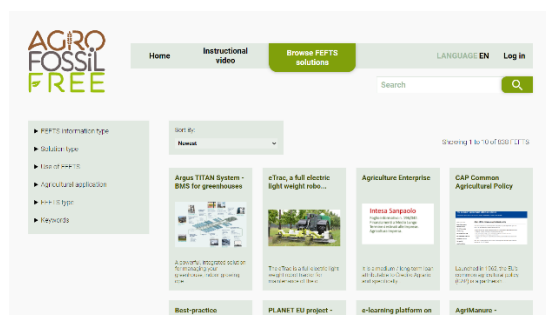


Figure 3: AgEnergy platform's FEFTS solutions

The platform provides detailed filters which allows end users to find any FEFTS targeting their needs by using a variety of methods, such as FEFTS information type, use of FEFTS, FEFTS type and related keywords.

Furthermore, all registered users can evaluate the available FEFTS solutions by answering a 10-question survey on general information of the FEFTS' degree of technology readiness as well as the environmental and socioeconomic impacts.

In addition, a decision support tool (DST) was developed and is available in <https://dst.agrofossilfree.eu/> [7]. Being a freely accessible online tool, it serves as an advisory mechanism to provide interested stakeholders with the most appropriate solution according to their needs. The tool aims to mimic the consultation process of a number of experts as if they were in the same room evaluating the input data provided by the end-user to propose the most interesting interventions for each farm. This DST based on Fuzzy Cognitive Maps, is integrated seamlessly within the AgroFossilFree platform and allows users to get a ranking of the technologies most suitable for their farm.

The DST succeeds in providing a first insight on which FEFTS would best suit the needs of any given farm by requesting minimum inputs from the user. More specifically, a short questionnaire of six questions enables the DST to understand the needs of the user. It cannot replace a detailed study needed to finally decide on an investment, but, still, it can be indicative and act as the first step in study process that would evaluate different options and provide the optimal investment for each farm. The pool of FEFTS within the AgEnergy Platform constitutes the feeding point of the DST, ensuring that an agile methodology is followed as the platform's content is continuously increasing.

3.5 Interactive and multi-actor regional workshops

Twenty-four multi-actor workshops were organized by AgroFossilFree partners in eight European countries (three per country) focused on (i) Open-field agriculture;

(ii) Greenhouses; and (iii) Livestock buildings. These workshops enabled the direct dissemination of innovative FEFTS solutions and the collection of grassroots innovations and requirements at the regional level by bringing together stakeholders representing research, extension services, industry, farmers and producers community. More particularly, from the regional workshops, useful information was acquired about the requirements and barriers for FEFTS adoption that the stakeholders are currently facing. At the same time, aiming to achieve a sustainable EU agriculture, it is also necessary to consider what additional policy recommendations, incentives, and new partnerships should be established and promoted.

Following the completion of the regional workshops, three transnational workshops were conducted. The first transitional workshop was held in Athens, Greece with Greenhouse agriculture theme, the second transitional workshop took place in Warsaw, Poland with an open-field crop production theme, and the last one held in Herning, Denmark with a livestock theme.

Key conclusions from the transnational workshops included: a) ways to adopt FEFTS are the continuous training (including e-platforms and online tools) and advising about new FEFTS, demonstration farms, funding FEFTS start-ups / spin-offs, and multi-actor research projects, b) the speed of transition to FEFTS is said to be dependent on the prices of fossil fuels, technological developments, and common efficiency improvement goals on EU partnership level. c) to some extent and in some countries, applicable and novel policies exist, but more effective policy support is desirable. A range of policies were suggested to help focus on supporting FEFTS adoption and improvements in energy efficiency, and it is recommended by multiple stakeholders that these policies focus on supporting returns on investments, d) key policy measures include subsidies, particularly for small and medium farms, e) the Agricultural Knowledge Information System (AKIS) between researchers, industry, advisors and farmers is insufficient in relation to FEFTS transition and requires EU support for national and European impact level optimisation.

The transnational workshops provided a good insight into the ideas of stakeholders from the eight innovation hubs. The three most energy intensive operations in open field agriculture, that should be addressed in terms of energy consumption, are fertilisation, tillage and transport. Precision application systems in fertiliser spreading and biofertilisers that are not derived from fossil fuels (especially nitrogen) should be further promoted. For saving both fossil fuel and inorganic fertilizers, cover crops and legumes, bio-fertilizers, and the adoption of conservation agriculture practices were suggested. The agricultural machinery used for agricultural practices and transportation of goods should be upgraded to become more energy efficient. Renewable electrification and alternative renewable fuels should be also taken into account. Livestock requires precision livestock techniques to reduce feed, building envelope insulation, installation of PVs on the rooftop and heat pumps for HVAC (Heating, Ventilation and Air Conditioning), prove the most complicated systems to integrate FEFTS effectively. As for greenhouses, energy consumption is greatly related to heating and irrigation application. It should be noted that precision agriculture and conservation agriculture gained interest from farmers, considering them as energy efficient

practices directly connected to their everyday practices. Another important finding is that in the current situation of increased energy costs, there is a window of opportunity for shifting to renewable energy and energy efficient systems providing a considerable cost reduction.

In addition, three online workshops engaging stakeholders across Europe—including farmers, industry representatives, advisors, technicians, researchers, innovation brokers, and policymakers—were held on February 25th and October 25th of 2022, and May 26th of 2023. These workshops presented the project's primary outcomes, such as the AgEnergy Platform and the DST, and summarized pivotal research findings related to farmers' needs, innovative ideas, and interests in agriculture defossilization technologies and strategies, derived from both regional and transnational workshops. Attendees also gained insights into successful implementations of FEFTS, as shared by various experts, with examples such as biogas and bio-methane tractors. Over 180 individuals participated across the three sessions, contributing their perspectives on potential FEFTS adoption in European agriculture. Recordings of the webinars are accessible on the [AgroFossilFree YouTube channel](#).

4 CONCLUSIONS

In conclusion, the AgroFossilFree project aims to promote the adoption of Fossil-Energy-Free Technologies and Strategies (FEFTS) in the agricultural sector. It focuses on integrating renewable energy sources, particularly biomass, into major agricultural sectors. The project's main objective is to assist agricultural stakeholders through the AgEnergy Platform and the DST, accessing valuable information on FEFTS that could help them reconsider and replace the conventional practices they follow in their agricultural activity with strategies that are oriented in EU's effort for green transition. Practice abstracts and comprehensive successful case study story videos are also available through the project's website in order to showcase some practical examples of how to implement defossilisation practices.

The project aligns with the EU Green Deal and the Farm to Fork strategy, aiming to reduce fossil energy usage in farming processes. By bridging the gap between existing FEFTS and current agricultural practices, the project promotes the exchange of innovative ideas and information among stakeholders. This contributes to a more sustainable European agriculture with reduced energy consumption and environmental impacts.

The project has made significant progress in assessing the current energy usage in EU agriculture and identifying areas for improvement. It has also collected user needs, innovative ideas, and best practices related to FEFTS all over across EU.

Multi-actor regional workshops have been organised to gather grassroots innovations and requirements, while transnational workshops have provided insights into policy measures and key areas of focus. Concrete policy recommendations and new research pathways are expected to be delivered on September 2023 (the official end of the project). In all the aforementioned outcomes, the importance of biomass technologies, precision agriculture, conservation agriculture, and the adoption of renewable energy and energy-efficient systems in various agricultural operations has been highlighted.

Through its research, communication, dissemination, and collaboration with stakeholders, the AgroFossilFree project drives the transition towards a more sustainable and fossil-energy-free agricultural sector.

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7 LOGO SPACE

