Report on industrial FEFTS Solutions – 2nd Update

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Abstract

Novel Fossil-Energy-Free Technologies and Strategies (FEFTS) that are related to more sustainable energy production and use, have been developed by industry and research entities. More specifically, they refer to the tools that are required to address cleaner and more efficient energy production and use in all kinds of agricultural activities. The main focus of this document is to provide a report about the commercial FEFTS solutions that are collected as part of the AFF repository. These kinds of FEFTS can (or could potentially) be used by a wide variety of agricultural stakeholders towards defossilization of EU agriculture. According to the methodology and standards provided by D2.1, an already existing commercial technology or strategy could be considered as FEFTS, after an initial identification, where its specific characteristics are effectively categorized in a series of fields of interest. The structure of the survey as well as the analysis of the FEFTS that are presented in Chapter 3, are based on the structure established on D2.1. The AgEnergy platform's submission form follows the same structure as the one provided via the online Google survey. By the end of July 2023, 2102 FEFTS were collected in total, of which 1959 FEFTS were published on the AgEnergy platform after the FEFTS quality check screening process. Among these, 542 commercial technologies were published. This is the second and final update for Del.2.8.

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1. Introduction

1.1 Background Information

Novel Fossil-Energy-Free Technologies and Strategies (FEFTS) that are related to more sustainable energy production and use, have been developed by industry and research entities. More specifically, they refer to the tools that are required to address cleaner and more efficient energy production and use in all kinds of agricultural activities. The main focus of this document, is to provide a report about the commercial FEFTS solutions that are collected as part of the AFF repository. These kinds of FEFTS can (or could potentially) be used by a wide variety of agricultural stakeholders towards defossilisation of EU agriculture.

According to the methodology and standards provided by D2.1, an already existing commercial technology or strategy could be considered as FEFTS, after an initial identification, where its specific characteristics are effectively categorized in a series of fields of interest:

a) the agricultural application field (for which purpose the energy is produced/used)
b) the way that they promote/contribute to defossilisation:

(i) Supply of Clean Energy (either for energy production or storage) to substitute fossil energy
(ii) Energy Efficiency Improvement in comparison to conventional technologies/practices
(iii) Soil Carbon Sequestration which is an auxiliary category that mainly plays a Greenhouse Gas (GHG) compensation role (rather than green energy production or fossil fuel reduction (or elimination) means).

In more detail, Clean Energy Supply is primarily subdivided to energy production and storage systems, then the Renewable Energy Source type, the type of used energy (electrical, kinetic, chemical, etc.) and finally the specific technology used. The Energy Efficiency Improvement category is subdivided to the specific kind of energy improvement (efficiency on buildings, vehicles, tools, precision agriculture or livestock farming, etc.) and the corresponding technologies used for the aforementioned purposes. Soil Carbon Sequestration is further analyzed in terms of methods such as soil organic matter, minimum/ no tillage, nutrient management, crop diversification, etc. The FEFTS categories and subcategories are presented in Table 1.

Table 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

Under FEFTS level 2 sub-category, practical methods are clarified (for details, see FEFTS level 3 sub-category from Deliverable 2.1, Table 4 to Table 10).

Main aim of this deliverable is to update the previous report (D2.9) and present all the industrial FEFTS solutions registered, by both the consortium and outside companies, according to FEFTS categories above and give an analysis based on current collection status.

1.2 Methodology

To create the user-friendly AgroFossilFree (AFF) database, WIP and other partners followed a three-phase methodology for registering commercial Fossil-Energy-Free Technologies and Strategies (FEFTS).

Phase 1 (Initial Identification) involved conducting internet searches to identify various commercial FEFTS, including complete solutions, hardware, software, methodologies, components, and procedures that contribute to defossilisation in EU agriculture. The searches were based on a 3-level categorization provided in Deliverable 2.1, targeting sources like FEFTS manufacturers, retailers, and stakeholders such as farmers, producers associations, energy generators, contractors, advisory services, companies, industry, and policymakers.

During Phase 2 (Survey), the consortium collected commercial technologies using an online survey document (Google Forms) for the first FEFTS collection process (1st batch). Later, for the second collection process (2nd batch), the consortium exclusively used the AgEnergy platform, which provided all necessary information used in Chapter 3 (Analysis). To encourage participation, means of

communication were prepared, including letters, emails, and a promotional video (Figure 1), with clear benefits for companies to join the platform. This resulted in an increased contribution of commercial products directly from manufacturers and companies.

Externals (companies/manufacturers) were encouraged to submit their technologies through Google Forms initially and then through the AgEnergy platform after its launch. Additionally, INI created a video to attract companies and stakeholders to register their FEFTS.

Figure 1 Promotional video

After achieving the milestone of 200 submitted commercial Fossil-Energy-Free Technologies and Strategies (FEFTS) in the inventory by the end of September 2021, the screening process was scheduled before the launch of the AgEnergy platform to ensure its content's high quality and relevance. Initial screening involved removing duplicate, malicious, and incomplete entries, with "incomplete entries" lacking comprehensive information. Partners were asked to provide additional details for such records, and if not available, those entries were deleted.

The Task Leaders of WP2 conducted the screening process for each FEFTS category, with WIP responsible for industrial products. To ensure consistency, a FEFTS Quality Committee was formed comprising the Task Leaders. This committee oversees the screening of all submitted FEFTS on the platform, ensuring accuracy and reliability aligned with the AgroFossilFree project's objectives. Although the database allows public entries, they remain unpublished until validated by the FEFTS Committee, guaranteeing the platform's relevance and reliability.

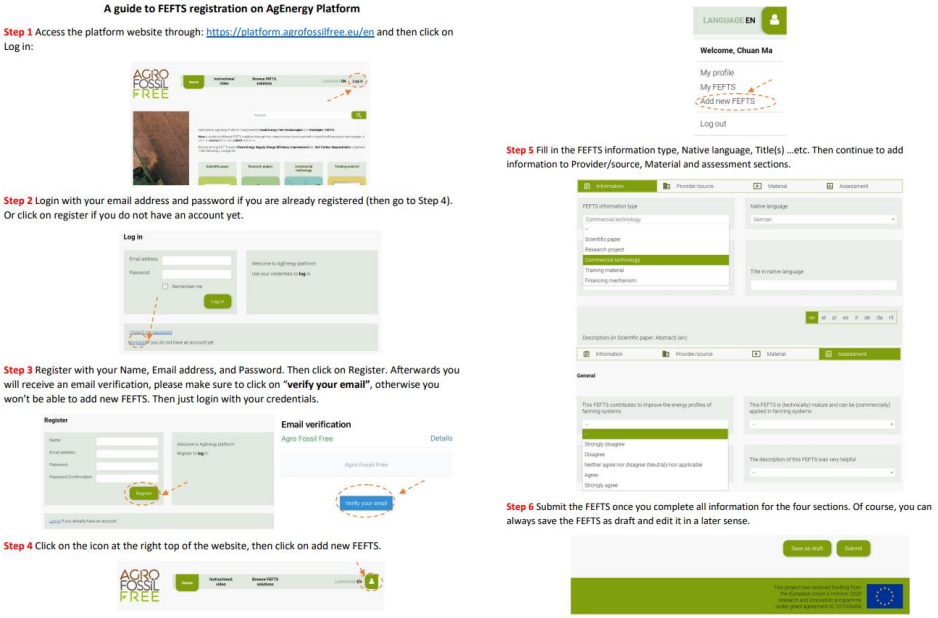


Figure 2 A guide to FEFTS registration on AgEnergy Platform

For the second and third batch of FEFTS collection, partners registered them directly on the AgEnergy platform, with a guidance document (Figure 2) created to assist in this process. The same screening procedure was applied to the second and third batch.

1.3 Survey

The survey structure, extensively defined in Deliverable 2.1, comprises four sets of questions (see Annex). The first section gathers general information about the identified commercial FEFTS, including its name, category, and the registering person's contact details and organization. The second section delves into more detailed information about the FEFTS and the manufacturer/company, such as the number of employees and headquarters' address. The third section covers FEFTS specifications and application fields. The fourth and most crucial section provides detailed information about the type of FEFTS being submitted, with three categories to choose from: Clean Energy Supply, Energy Efficiency Improvement, and Soil Carbon Sequestration, followed by specific sub-categories. The last section involves a general assessment of the FEFTS, requiring the user to answer questions based on available information regarding socioeconomic, environmental, and general aspects.

It is worth mentioning that both the survey structure and the subsequent analysis presented in Chapter 3 are based on the structure established in D2.1. Table 1 provides a basic schematic of this structure, which is replicated in the AgEnergy platform's submission form, mirroring the online Google survey's layout.

2. FEFTS collection outcomes

2.1 Data Collection – Partner's Role

By the end of August 2023, 2102 FEFTS were collected in total, of which 1959 FEFTS were published on the AgEnergy platform after the FEFTS quality check screening process. Among these, 542 commercial technologies were published. Table 2 shows the number of FEFTS collected and published per category for the three batches.

Table 2 Overview of FEFTS collection status

	Scientific Papers	Commercial Technologies	Training Material	Financing Mechanisms	Research project	Total
Target	1000	600			100	1700
Collected	1001	601	149	150	200	2102
Published	977	542	131	129	180	1959

2.2 Acceptance and exclusion criteria

For the case of commercial FEFTS, they were required to demonstrate clear potential for agricultural application and embody innovative technologies for energy saving or clean energy supply (production or storage). The most suitable commercial technologies or strategies were those with strong potential for practical implementation by farmers on their farms, such as energy-saving market-ready FEFTS solutions or sustainable energy production methods. Exclusion criteria included invalid records, which referred to entries lacking a clear alternative solution for fossil fuel use in agriculture.

2.3 Clarification of this report and its analysis

This report is the final update of D2.8 and differs from the previous reports (D2.8 and 1st update report - D2.9) in terms of the final number of FEFTS presented. The screening process for all FEFTS has been completed, and only qualified ones have been published on the website, allowing for a clearer overview. Besides the additional number of FEFTS that have been added, some FEFTS were rejected after the previous reports' completion, as they were found to have issues upon reevaluation (e.g., websites taken down, broken links, or incomplete entries), thus the difference between the numbers. The AgEnergy platform is continuously monitored to address incomplete entries or broken links, ensuring that only the best FEFTS are published and maintained on the platform.

3. FEFTS Analysis

3.1 General information about the published commercial FEFTS

In this section, general information about the companies of the published commercial FEFTS will be presented. The origin country of the companies is shown in Figure 3. Following this, in Figure 4 the sizes of the companies are presented.

As shown in Figure 3, for the third batch, most of the companies (manufacturer's origin or headquarters' basis in case of international companies) come from Denmark (27), followed by Germany (18). The majority of companies, 35 in total, are categorized under "Others," representing a diverse group not explicitly specified. China, America, and Switzerland each contribute 3 companies, while Ireland, England, Poland, and Italy have 3 to 14 companies featured. Greece does not have any companies in this batch. France and Spain are represented by 5 to 8 companies. The three batches showcase the global participation on the AgEnergy platform, with a diverse range of countries contributing their commercial products and innovations.

Figure 3 reveals that companies from Northern and Western European nations like Denmark, Germany, and Switzerland are most heavily represented in the published commercial FEFTS. This likely reflects the prominence of sustainability initiatives and investments in renewable energy in these countries. The agriculture sector's significance in national economies in countries like Denmark may also incentivize clean energy innovations. However, major agricultural producers in Southern and Eastern Europe like Spain, France, and Poland have fewer featured companies. Enhancing outreach to firms in these key farming regions could provide more solutions tailored to those markets.

Figure 4 illustrates the size distribution of companies in different batches. The data regarding company size is not publicly disclosed by the majority of companies, resulting in an unknown size for 247 (46%) of them. However, for the companies with known sizes, the distribution across various size ranges can be observed.

In the 1st batch, 15 companies fall within the 1 to 10 employees' category, 30 companies have 11 to 50 employees, 15 companies have 51 to 250 employees, and 31 companies have 251 or more employees. Moving on to the 2nd batch, the majority of companies' sizes remain unknown, accounting for 41% of the total. Among the known sizes, 13 companies have 1 to 10 employees, 44 companies have 11 to 50 employees, 14 companies have 51 to 250 employees, and 60 companies have 251 or more employees. Finally, in the 3rd batch, again, most companies' sizes remain unknown (78). However, among the companies with known sizes, 11 companies have 1 to 10 employees, 22 companies have 11 to 50 employees, 12 companies have 51 to 250 employees, and 28 companies have 251 or more employees.

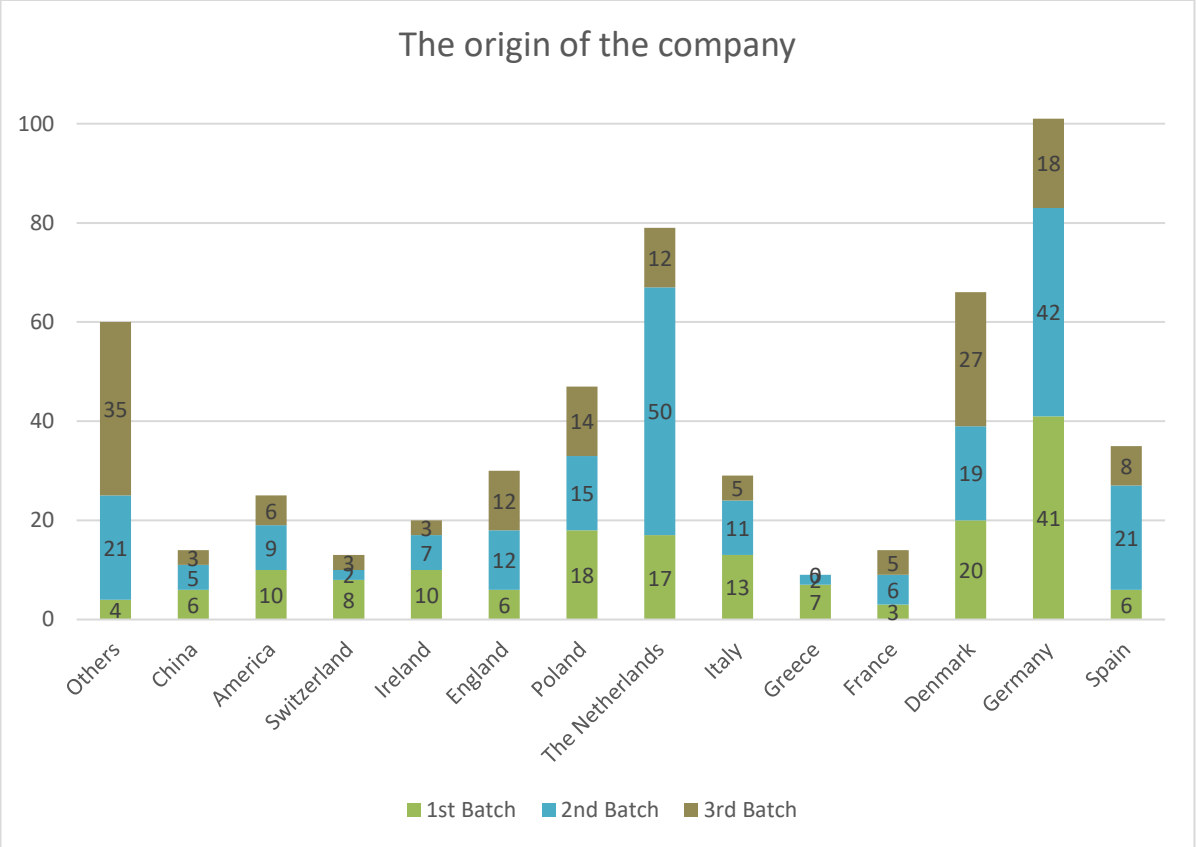


Figure 3 The published FEFTS companies' origin countries for all three collection processes

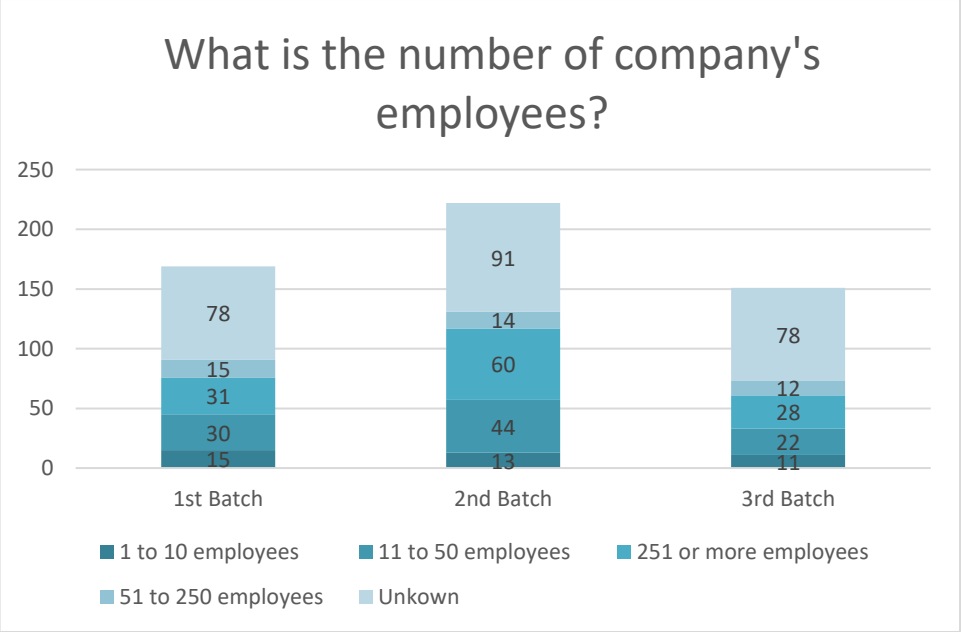


Figure 4 The number of companies' employees for all three collection processes

3.2 FEFTS specifications and applied sector

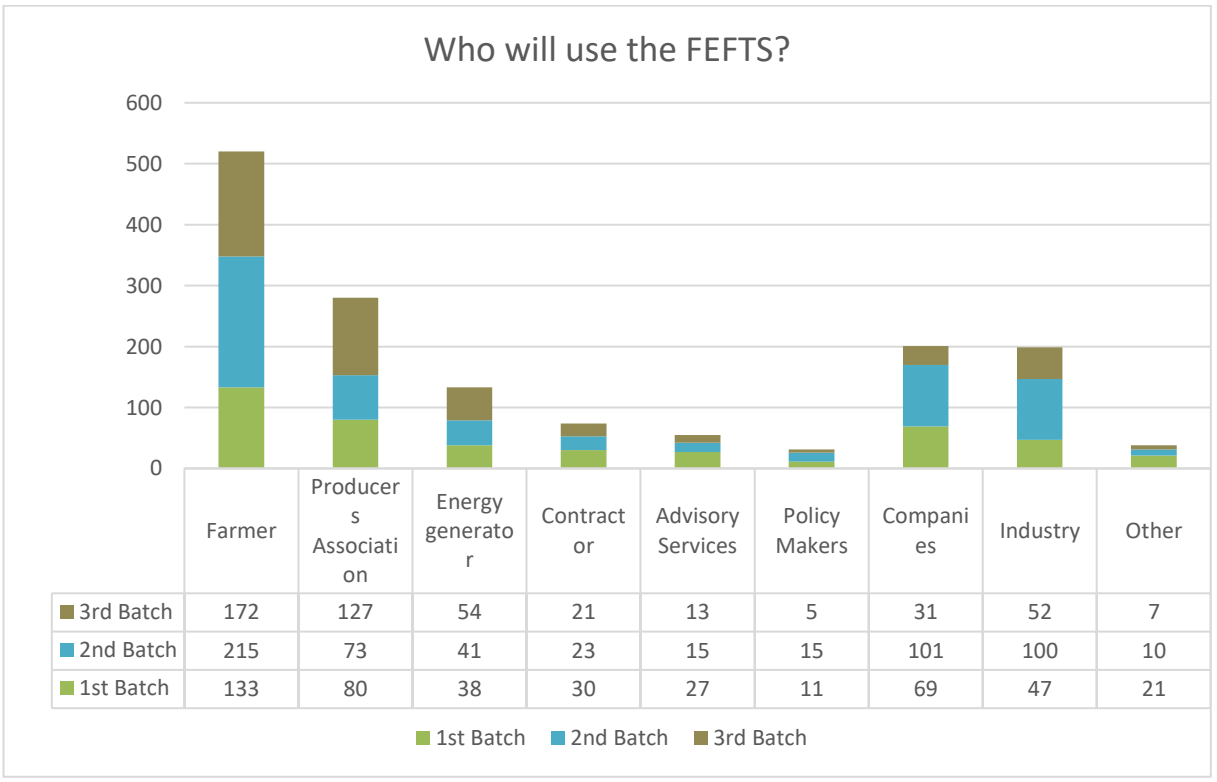
Figure 5 shows the intended users of collected commercial FEFTS technologies (for each FEFTS, multiple users' categories that fit to each use could be selected). For the first batch, farmers appear to be the ones that will be the most interested stakeholders for the collected FEFTS, as 133 different FEFTS are

targeted to their needs. Industry, producers' associations and companies are the second most interested types of stakeholders (47, 80, 69 FEFTS respectively). Energy generators are also important, as 38 technologies are intended for them. Contract and advisory services appear to be of less interest regarding these technologies with only 30 and 27 technologies for them respectively. Finally, 21 FEFTS could be considered as important ones for Policy makers.

For the second batch, most of the FEFTS collected (215) target farmers' needs, as it is always our focus. This is followed by companies and industry, of which 101 and 100 FEFTS serve their interest. Producers' associations are targeted by 73 FEFTS. Energy generators, contractors and advisory services have 41, 23 and 15 FEFTS targeting them. Finally, there are 15 FEFTS that could be of consideration for policy makers, and 10 for other audiences.

The data in the third batch indicates a focus on providing technologies for farmers and producers' associations, with 172 technologies specifically tailored for farmers and 127 for producers' associations. The distribution of commercial technologies for other user groups is as follows: 54 for energy generators, 21 for contractors, 13 for advisory services, 5 for policy makers, 31 for companies, 52 for the industry, and 7 for other user groups. There is an emphasis on catering to energy generators, contractors, advisory services, companies, and the industry. However, the number of technologies intended for policy makers and other user groups is relatively lower.

Farmers unsurprisingly emerge as the primary intended users for the collected commercial FEFTS in Figure 5, aligning with the project's focus on empowering farmers to reduce fossil fuel dependence. However, companies, industry players, and producers' associations also comprise major target audiences. This highlights the multiplier effect of equipping agribusinesses and collectives with clean technologies, rather than just individual farmers. Still, the relatively low number of solutions aimed at advisors and policymakers point to gaps in providing tools targeted at influencers who can encourage broader adoption.



	Farmer	Producers Association	Energy generator	Contractor	Advisory Services	Policy Makers	Companies	Industry	Other
3rd Batch	172	127	54	21	13	5	31	52	7
2nd Batch	215	73	41	23	15	15	101	100	10
1st Batch	133	80	38	30	27	11	69	47	21

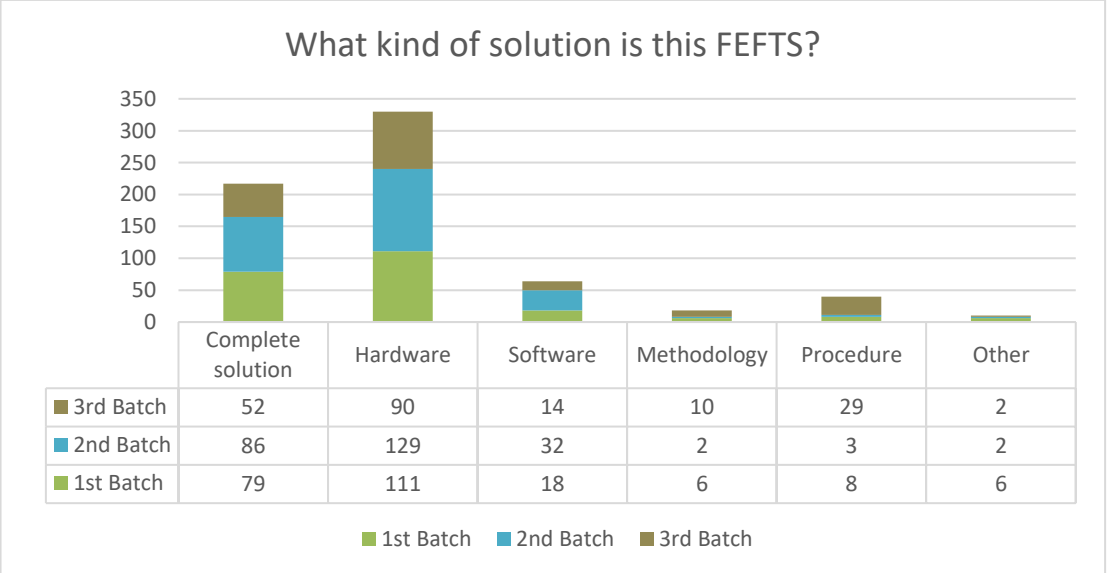
Figure 5 User groups for which the commercial technologies are intended for all three collection processes

Next, the FEFTS technology type is analyzed (Figure 6). The majority of the commercial FEFTS submitted for the 1st batch are complete solutions (79) and hardware (111). Whereas, 18 commercial technologies are software, while 6 are methodologies and 8 are procedures.

For the second batch, there are more hardware solutions (129) than complete solutions (86). More software solutions (32) appeared than the first batch. On the one hand, this might be due to our effort to enhance the platform the platform and incorporate more digitalized services and tools, but also due to the current growing trend of digital technologies use. The rest of commercial FEFTS are methodologies (2), procedures (3) and of other type (2).

Finally, in the 3rd batch, the distribution of FEFTS is as follows: 52 are categorized as complete solutions, 90 as hardware, 14 as software, 10 as methodology, 29 as procedure, and 2 fall into the other category. Across all three batches, hardware solutions consistently have the highest count, followed by complete solutions. Software solutions have a smaller presence in comparison. Methodology, procedure, and other categories have varying counts across the batches.

The predominance of hardware solutions shown in Figure 6 aligns with the expectation that commercial FEFTS will manifest as physical tools or systems that can be implemented on farms. However, the steady increase in software solutions across batches, points to the growing role of data-driven, digital technologies like analytics, sensors, and AI to optimize energy usage. Complete solutions integrating hardware and software could become more common to provide comprehensive capabilities versus stand-alone products. For example, an anaerobic digester unit coupled with intelligent remote monitoring and biogas optimization software. Methodologies and procedures also offer commercialization potential in the form of standardized processes and protocols around energy auditing, planning, maintenance etc. But few solutions are currently published in these segments. Overall, the distribution across technology types indicates opportunities to move beyond a hardware-centric view, towards more integrated system-based innovations combining physical and digital technologies along with robust supporting methods.



	Complete solution	Hardware	Software	Methodology	Procedure	Other
3rd Batch	52	90	14	10	29	2
2nd Batch	86	129	32	2	3	2
1st Batch	79	111	18	6	8	6

Figure 6 The type of published commercial FEFTS for all three collection processes

Regarding the agricultural domain of these FEFTS (open-field agriculture, livestock facilities and greenhouses), for the first batch, most of the commercial FEFTS are suitable and can be used in applications of open-field crop production (118). 96 of the collected technologies can be applied in livestock buildings and 85 are applicable in greenhouses. This shows that most of the technologies are

accessible in multiple agricultural domains (see Figure 7). For the second batch, most of the commercial FEFTS can be used directly in open field agriculture (127) and livestock buildings (126), while 113 for greenhouses. Most of the commercial technologies can be used in multiple domains and this is the reason the results do not sum up to the total number of Commercial FEFTS submitted.

In the 3rd batch, the distribution of FEFTS follows the trend of the 2 previous batches with last category being the greenhouses (70) followed by livestock operations (92) and open field agriculture (89). Overall, the FEFTS demonstrates its versatility by being used across various agricultural areas in each batch. It is employed in greenhouses, livestock operations, and open field agriculture, highlighting its adaptability and potential benefits in optimizing energy usage and technology implementation in diverse farming contexts.

Most technologies have cross-domain applicability, underscoring the common challenges faced regarding fossil energy use across domains. However, customized innovations tailored to domain-specific needs could provide further gains. Analysis of energy consumption patterns within each sub-sector could reveal where more domain-targeted solutions are needed.

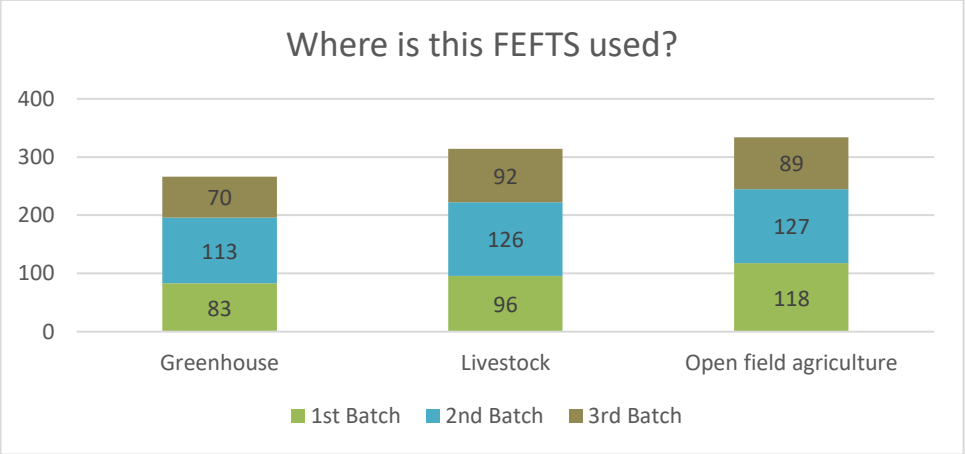


Figure 7 The agricultural domain of the published commercial FEFTS for all three collection processes

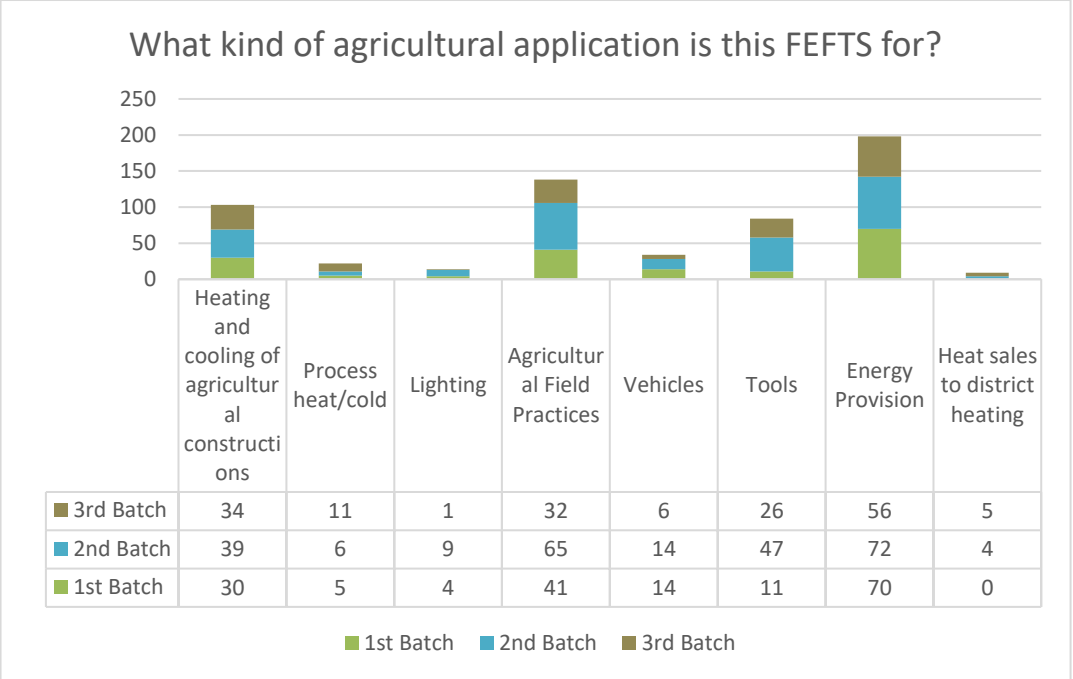
3.3 FEFTS application field

In the next diagram (Figure 8), the types of agricultural application of the collected commercial technologies are presented.

Most of the technologies in the first batch are agricultural field practices and heating and cooling for agricultural constructions and energy provision, with 41, 30 and 70 commercial products respectively. Vehicles have 13 technologies published. 11 technologies are registered under tools, 5 for process heat/cold and 4 for lighting. It should be mentioned that during the 1st screening procedure, all the FEFTS that were listed as multiple technology applications were categorized correctly as now the platform allows users to choose more than one category for a FEFTS. For the second batch, most of the technologies are agricultural field practices, energy provision and tools, with 65, 72 and 47 commercial products respectively. Heating and cooling of agricultural constructions get 39 technologies supported, while vehicles have 14 technologies registered. 9 technologies are registered under lighting, 6 for process heat/cold and 4 for heat sales to district heating.

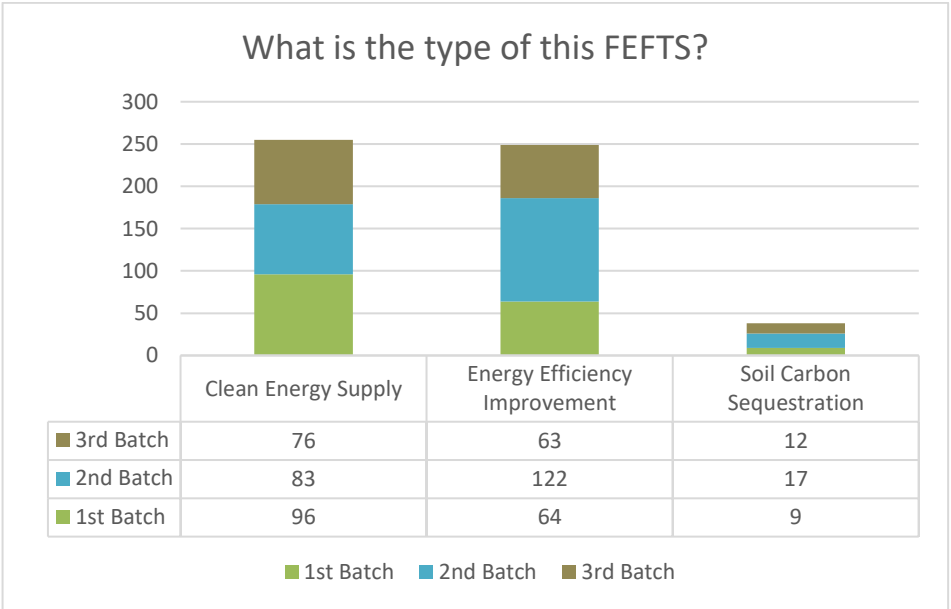
In the 3rd batch, the FEFTS are primarily employed in the heating and cooling of agricultural constructions, with a count of 34. They are also used for process heat/cold purposes, with 11 instances. Regarding lighting applications, there is only 1 instance of the FEFTS being utilized in the 3rd batch. In

terms of agricultural field practices, the FEFTS are deployed in 32 instances during the 3rd batch. When it comes to vehicles, the FEFTS are used in 6 instances during the 3rd batch. For tools related to agricultural activities, the FEFTS are employed in 26 instances. The FEFTS are also involved in energy provision, with 56 instances in the 3rd batch. Furthermore, in the 3rd batch, there are 5 instances each, of heat sales to district heating and energy sales to external consumers.



	Heating and cooling of agricultural constructions	Process heat/cold	Lighting	Agricultural Field Practices	Vehicles	Tools	Energy Provision	Heat sales to district heating
3rd Batch	34	11	1	32	6	26	56	5
2nd Batch	39	6	9	65	14	47	72	4
1st Batch	30	5	4	41	14	11	70	0

Figure 8 Types of agricultural application of published FEFTS commercial technologies for all three collection processes



	Clean Energy Supply	Energy Efficiency Improvement	Soil Carbon Sequestration
3rd Batch	76	63	12
2nd Batch	83	122	17
1st Batch	96	64	9

Figure 9 Type of the published commercial FEFTS technologies for all three collection processes

Regarding the types of the published commercial products, during the first batch, it can be seen in Figure 9 that most of them (57%) are under the Clean Energy Supply category, with 96 available

solutions, followed by 64 commercial products listed under Energy Efficiency Improvement, with the ratio of 38%. Soil Carbon Sequestration had the least registration, with 9 products which correspond to 5% of the total submissions. For the second batch, more than half of the commercial technologies (122) are for Energy Efficiency Improvement (the current geopolitical condition might have an impact on this change), with 76 FEFTS being on clean energy supply and only 17 for Soil Carbon Sequestration. For the third batch, half of the FEFTS are listed under clean energy supply (76), followed by energy efficiency (63), with only 12 carbon sequestration published.

It is clear that Soil Carbon Sequestration is a relatively smaller category compared to the other two. However, it must be taken into consideration that Carbon Sequestration in general is related more with applying specific practices and methodologies rather than purchasing and implementing commercial products that are available on the market.

3.3.1 Clean Energy supply

The figure below shows the energy type of the technologies under the Clean Energy Supply category. Energy Production System Technologies are mostly registered for the first batch (89, 92%), while Energy Storage Systems stand for 8% (7 products listed in total). For the second batch, the situation is similar to the first batch, with 76 commercial technologies registered under Energy Production Systems category, while 7 FEFTS under Energy Storage Systems. For the third batch, more FEFTS are published under energy storage with a number of 27 (36%). There are 49 energy production FEFTS published.

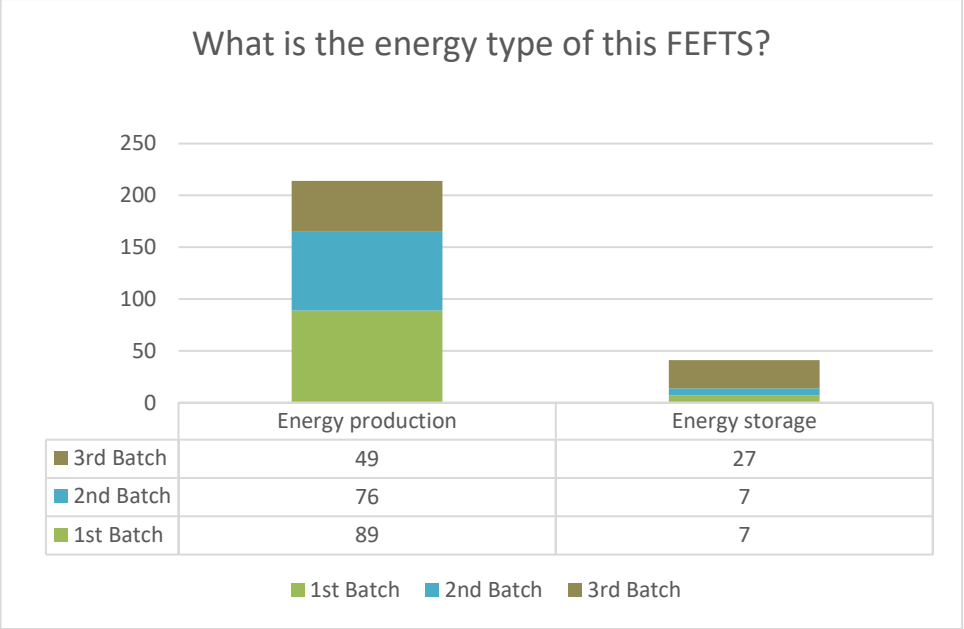


Figure 10 The Energy type of published FEFTS commercial technologies for all three collection processes

Despite growth in energy storage solutions in the latest batch as observed in Figure 10, energy production technologies still dominate the commercial FEFTS landscape. This highlights that substituting fossil power with renewable energy generation remains the primary focus currently. Making renewable energy storage more affordable and efficient could accelerate adoption by providing farmers steady clean energy even when generation fluctuates.

As Energy Production System is the predominant type of technology, it is important to analyze the next category which is the renewable energy source that is used for the energy production. Figure 11 shows that, for the first batch, the renewable energy source that most FEFTS used was solar energy (26 out of

89), followed by biomass and wind energy, with 22 and 18 products registered in each one of them. Sewage treatment plant and biogas category had 10 commercial products registered. For the second batch, the renewable energy source that most FEFTS use is still solar energy (30), followed by biomass (17), with 12 commercial technologies using wind energy and 9 of them using sewage treatment plant gas/biogases. Geothermal energy had 2 products registered, and aerothermal had 4. No commercial FEFTS used hydro and marine energy in the second batch.

For the third batch, biomass appeared to be the biggest renewable energy source (12 out of 49), followed by hydro (10) and solar (10). Both wind and sewage gas/biogases have 5 FEFTS listed, while 3 listed for marine energy and 2 for aerothermal. No commercial FEFTS published under geothermal in the third batch.

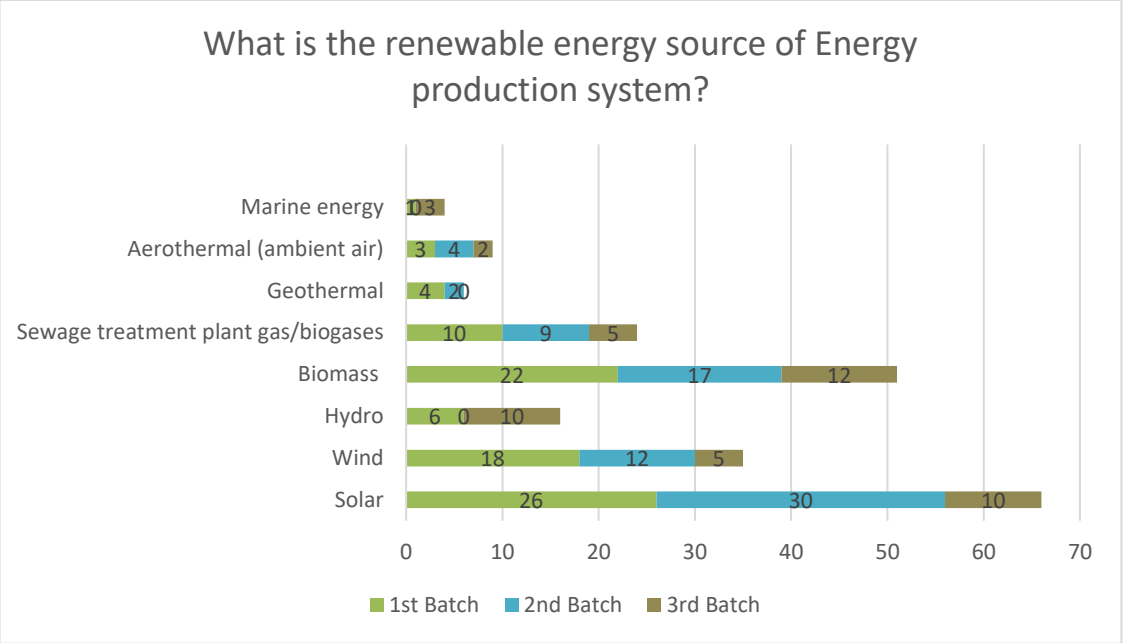


Figure 11 The renewable energy sources of Energy production system for all three collection processes

Figure 11 shows that solar, wind, and biomass (biogas) energy are the leading renewable sources leveraged so far, aligning with their maturity and cost-competitiveness. However, expanding into other sources like hydro, geothermal, and marine energy could further diversify the toolkit, especially for farms with suitable local resources. Needs and gaps will differ depending on the region, so mapping relevant renewables to location can guide development.

Regarding the specific technologies for Energy Production Systems, based on Figure 12, for the first batch, most of them are photovoltaics (25), wind turbines (18) and technologies based on solid biomass conversion (20). For the second batch, most of the energy production system used photovoltaics (30), solid biomass conversion technologies (13) and wind turbines (12). For the third batch, most of them are solid biomass conversion and hydropower (10), followed by solar thermal and photovoltaics (12). More solar thermal technologies were collected in the third batch to complete the website searching category.

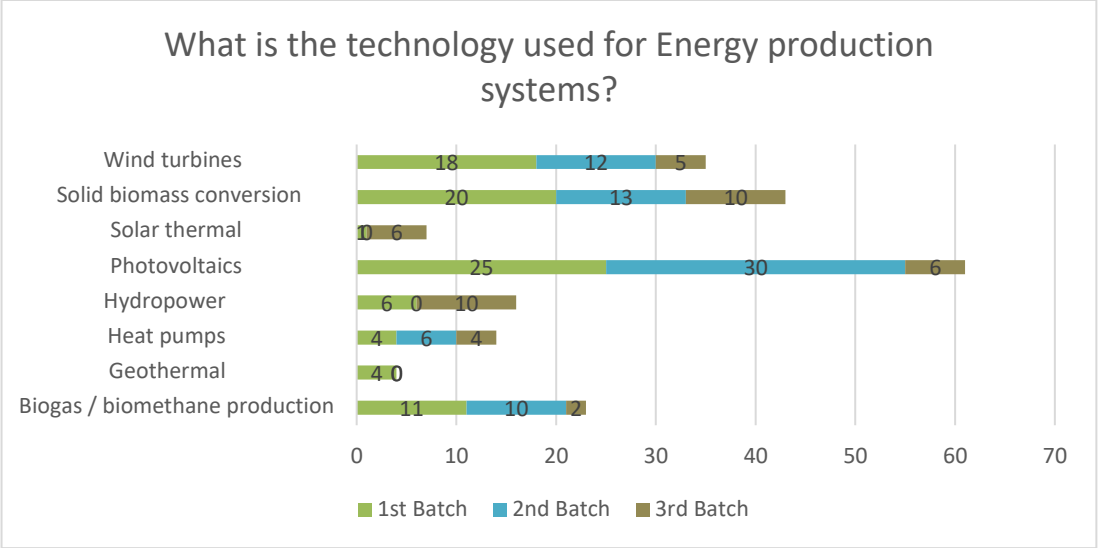
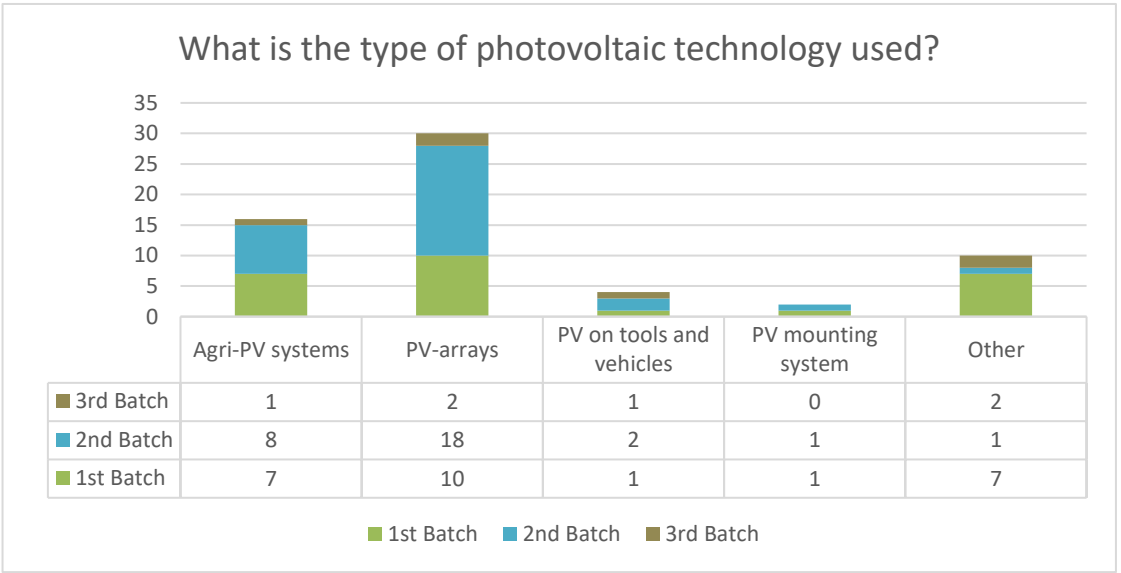


Figure 12 Specific technologies for Energy production systems for all three collection processes

Among Photovoltaics, for the first batch, 7 of them were about Agri-PV systems, 10 of them were about PV-arrays. Only 1 was PV on tools and vehicles (Figure 13). For the second batch, 18 of them are about PV-arrays, 8 of them are about Agri-PV systems. Only 2 are PV on tools and vehicles and PV mounting system. For the third batch, as the total number on photovoltaics is not very high, the technologies are spread among all the technologies.



	Agri-PV systems	PV-arrays	PV on tools and vehicles	PV mounting system	Other
3rd Batch	1	2	1	0	2
2nd Batch	8	18	2	1	1
1st Batch	7	10	1	1	7

Figure 13 The published commercial technologies of the photovoltaic technology type for all three collection processes

Figure 13 reveals a heavy skew towards PV arrays among collected photovoltaic technologies, with fewer innovations in integrated agricultural PV and solar vehicles/tools. This represents potential gaps in solutions tailored to farming contexts, rather than simply adopting general solar arrays.

As it was shown in Figure 12, solid biomass conversion was the second biggest category during the first batch when referring to specific technologies for Energy Production Systems. As a result, a further analysis of this category was done (Figure 14). During the first batch, technologies operating with

agricultural residues were registered the most, with 17 solutions dedicated. Technologies applicable for wood log, energy crops and pellets have 6, 10 and 9 technologies submitted. No FEFTS were registered under wood chips. For the second batch, there is 9 FEFTS using agricultural residues, 7 using wood chips and 4 for wood logs. 9 of the commercial technologies use Pellets. No commercial FEFTS were listed under energy crops.

During the third batch, a few new solutions in this category were listed. Among these FEFTS, 7 were under agricultural residues, 6 were under woodchips, 5 were under energy crops, and 4 were under pellets. Finally, there is 1 FEFTS under wood log.

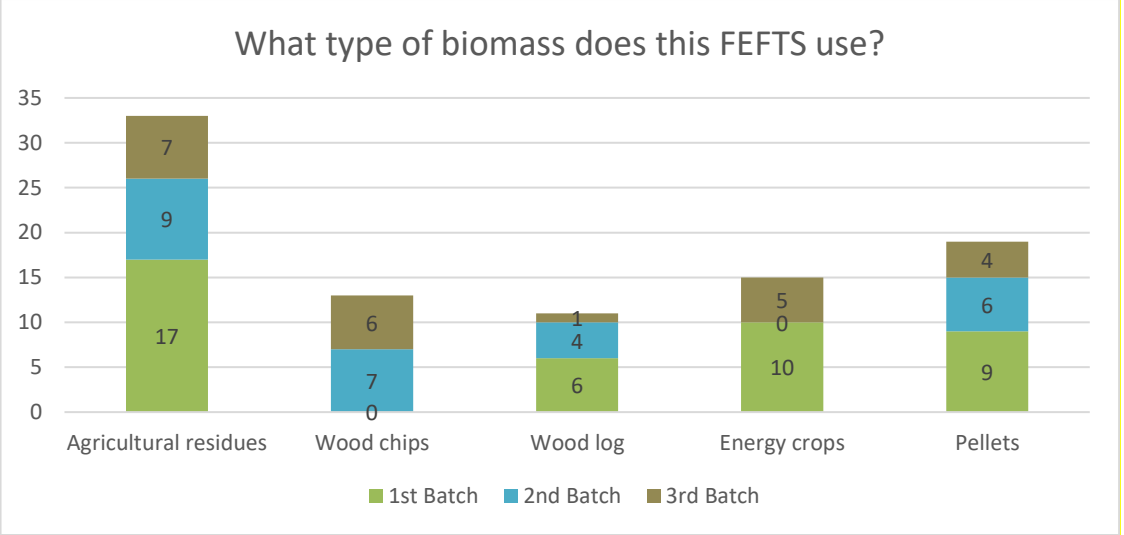


Figure 14 The published commercial technologies of the biomass technology for all three collection processes

The prominence of agricultural residue and pellets conversion systems shown in Figure 14 aligns with leveraging existing farm waste streams. However, untapped potential exists in expanding into dedicated energy crops to provide reliable biomass feedstock while enhancing the value of marginal croplands.

Figure 15 shows the energy range of the collected wind turbine technologies. During the first batch, 11 of them were small wind turbines ranging from 1-50 KW, 4 of them were medium wind turbines ranges from 50-999KW. This graph, in correlation with Figure 5, shows that mostly farmers tend to invest in small wind turbines for the farms to produce the energy required to cover their needs. Whereas bigger solutions tend to be used from companies and industries (where selling energy to the grid is of much more interest). The second batch of commercial FEFTS collected with equal amount of small and medium wind turbines (6 for each).

For the third batch, most of the wind turbines collected were small ones (6), with 2 mini turbines listed under Other. There are different types of wind turbine solutions because our objective was to fill all the categories that had not been addressed in the previous batches.

Small wind turbines dominate among published wind technologies in Figure 15, indicating they are seen as better fitting the scale of farm energy needs. Policy and financial support may be lacking for farmers to adopt larger wind systems. However, mid-scale community wind projects could provide a model to enhance viability.

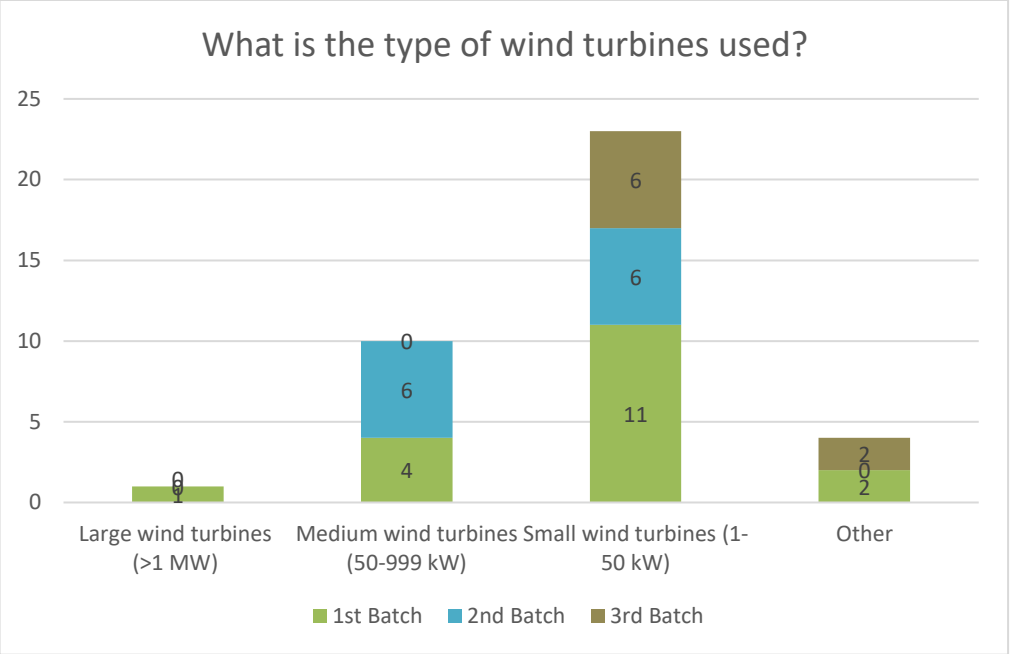


Figure 15 The published commercial technologies of the wind turbine type for all three collection processes

Figure 16 shows the specific technologies for Energy Storage Systems. During the first batch, 4 of them were on intermediate bioenergy carriers, other 3 were on electricity storage. For the second batch, the main energy storage systems are about electricity with 1 for intermediate bioenergy.

For the third batch, the category is further developed as we published more FEFTS with heat storage (7), which is not listed in previous batches. Storing biogas/biofuels as intermediate carriers also enables longer-term use as needed for transport or heating. Growth in on-farm storage can help overcome intermittent renewable generation. There are 14 commercial FEFTS listed under intermediate bioenergy and 6 for electricity.

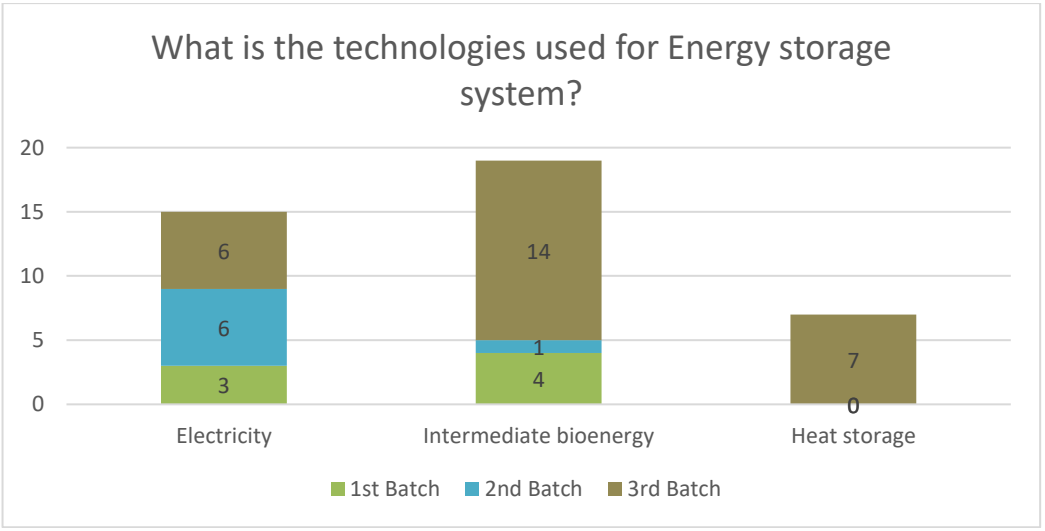


Figure 16 Specific technologies for Energy storage system for all three collection processes

3.3.2 Energy Efficiency Improvement

Despite Clean Energy Supply category, FEFTS related to Energy Efficiency Improvement are also

inventoried. It can be seen from Figure 9 that 46% of the registered commercial technologies are for energy improvement measures.

Analyzing the results from this category it can be seen that during the first batch most technologies were for precision agriculture and efficient vehicles (19 and 17). Efficient tools were also important with 15 technologies registered. Precision livestock farming and efficient buildings were submitted with 1 and 8 technologies separately. The detailed results are presented in Figure 17. For the second batch, it is clear that efficient tools (38) and precision agriculture (26) still take up a large percentage of the Energy Efficiency Improvement category. It is worth noting that 26 new technologies related to efficient buildings are also registered. FEFTS dedicated to efficient vehicles and precision livestock farming are also submitted with 15 and 11 technologies respectively.

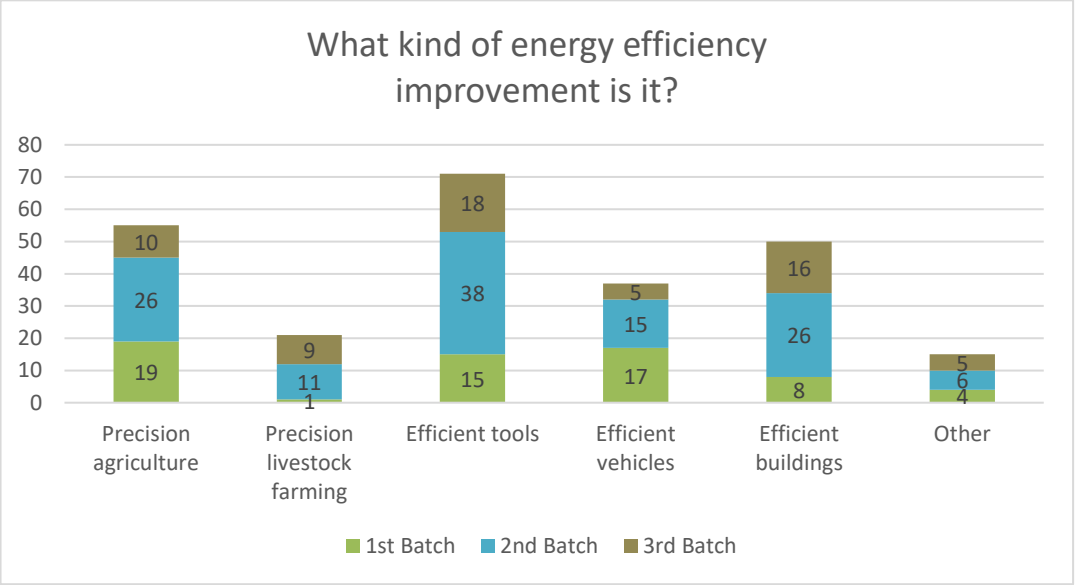


Figure 17 The published commercial technologies of the energy improvement type for all three collection processes

For the third batch, most of the improvement methods are still efficient tools (18 out of 63). Efficient building were listed for 16 FEFTS, while 10 were for precision agriculture and 9 for precision livestock farming. Last but not the least, the efficient vehicles were listed under 5 commercial FEFTS.

The predominance of tools, vehicles, and buildings related efficiency improvements seen in Figure 17 reflect the major direct energy uses on farms. Precision agriculture for input optimization also features prominently, underscoring its potential to curb indirect fossil fuel use. However, innovations in practices like precision livestock farming remain relatively scarce, highlighting a gap in energy-smart farming techniques.

3.3.3 Soil carbon sequestration

As shown in Figure 9, not many technologies are registered under Soil Carbon Sequestration category. Figure 18 illustrates that for the first batch, most of the technologies inventoried were referring to tillage (7, which accounted for 78% in total), other technologies such as soil organic matter and soil and water conservation techniques had only 1 registered solution by the consortium. For the second batch, there are more different types of soil carbon sequestration methods collected. The most technologies collected were referring to tillage, with a number of 10 in total. Other methods collected, such as nutrient management and soil and crop diversification, are collected 2 times both. There is also 1 commercial technology regarding soil organic matter and 2 for water conservation techniques.

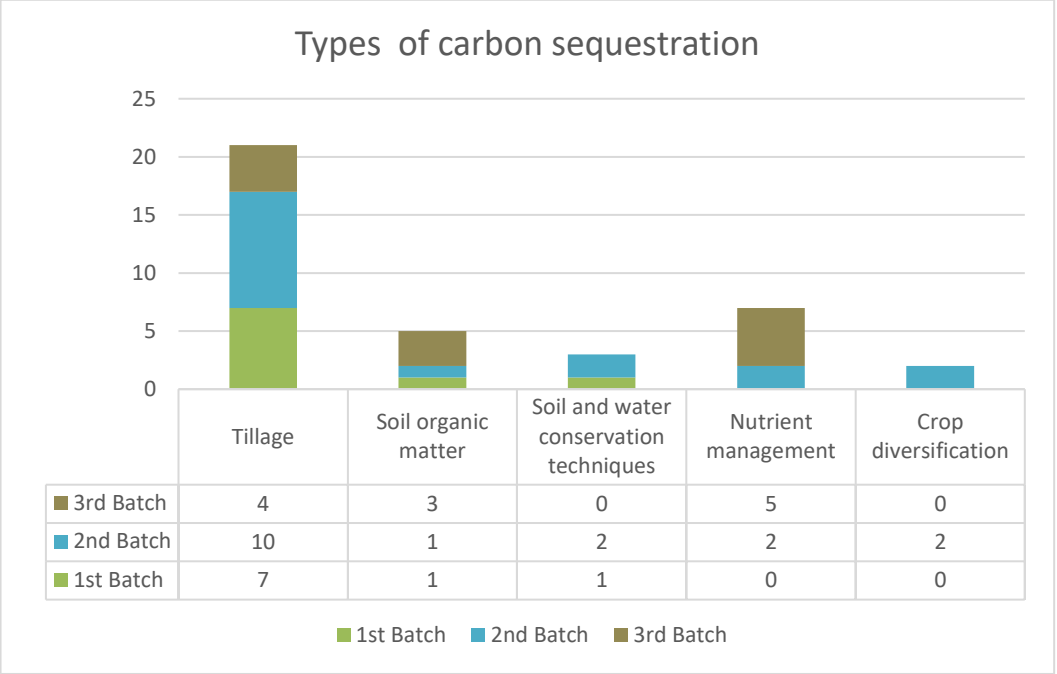


Figure 18 The technologies published referring to carbon sequestration methods for all three collection processes

For the third batch, the main type of carbon sequestration solution published was nutrient management (5 out of 12). Tillage is listed under 4 FEFTS, while soil organic matter is listed under 3 FEFTS. Overall, all kinds of carbon sequestration methods were listed through the three collection batches.

3.4 FEFTS Environmental Assessment Result

Overall, when combining the 3 aforementioned categories (Clean Energy Supply, Energy Efficiency Improvement and Soil Carbon Sequestration), fossil energy reduction is achieved either directly or indirectly.

Regarding the direct energy inputs, during the first batch, a great number of FEFTS could provide direct fossil energy use reduction through tools and equipment electricity consumption (78), followed by buildings' electric consumption (67), buildings' heat use (54), tractors and vehicles fuel consumption (47) and tools and equipment fuel consumption (37). From Figure 20, for the first batch most of the commercial products were dedicated to solutions about electricity consumption reduction on buildings and tools. For the second batch, many FEFTS reduce fossil-energy use directly through tools and equipment electricity consumption (105). Other FEFTS, reduce fossil-energy use mostly either reducing tractors' and vehicles' fuel consumption (48), or through buildings' electricity consumption reduction (66). Some of the collected FEFTS reduce fossil fuel usage through reducing tools and vehicles fuel consumption (57) and building's heat use (60).

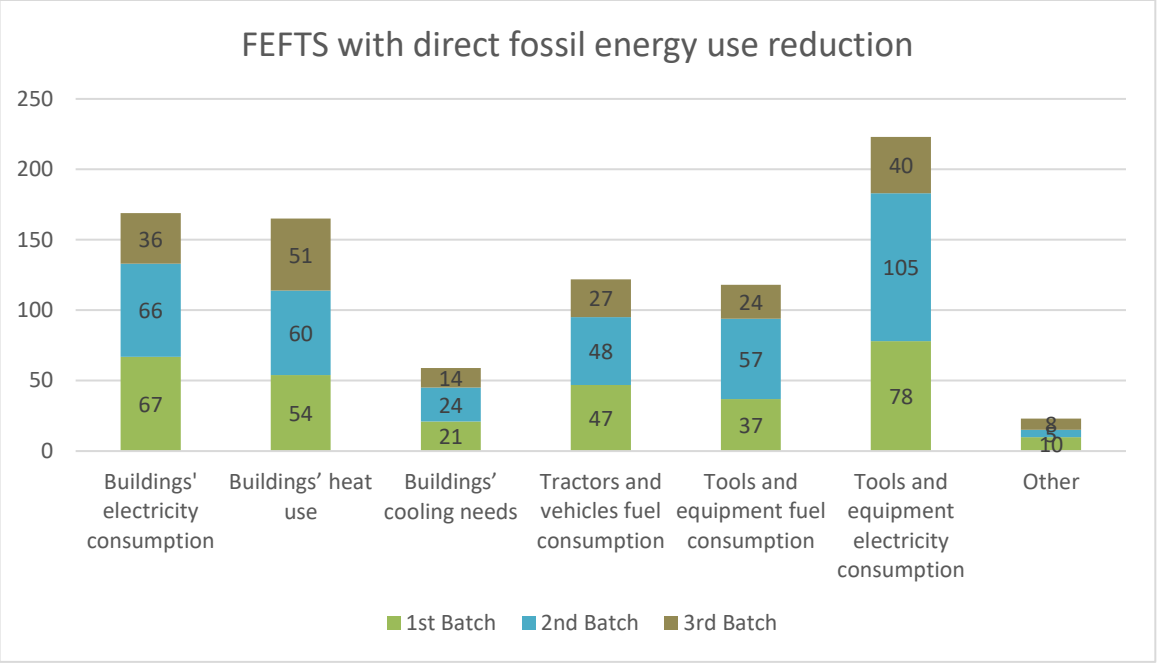


Figure 19 How published FEFTS reduce fossil energy use directly, results from all three collection processes

For the third batch, buildings' heat use appeared to be collected the most, with 51 FEFTS published, followed by tools and equipment electricity consumption reduction (40). Buildings' electricity consumption has been listed 36 times. While fuel consumption reduction on tools and equipment and tractors and vehicles were listed 24 and 27 times separately. Last but not least, buildings' cooling needs were also listed for 14 FEFTS.

The prevalence of solutions reducing building and equipment electricity usage seen in Figure 19 reflects substantial direct fossil energy consumption for these on-farm loads. Innovations reducing tractor fuel use are also well-represented, targeting a major operational cost and GHG source. This shows alignment with key energy hotspots identified in earlier project research.

Regarding the indirect energy inputs, for the first batch, it is evident from Figure 20 that, fossil energy use was reduced indirectly mostly through pesticide reduction and fertilizer reduction (23), tillage reduction (18), followed by animal manure reduction. By analyzing this figure, pesticide, fertilizer and tillage practices were the dominant indirect energy inputs. This corresponds with the results of AgroFossilFree's report D.1.1 on energy consumption in EU agriculture, thus showing the need for commercial products specifically dedicated to reducing these inputs. For the second batch, most of the technologies reduce fossil energy use indirectly through fertilizer, pesticide and feed reduction, with a number of 35, 29 and 17 respectively. Other reduction aspects, such medicine reduction (7), animal health care (34), manure reduction (10) and tillage reduction (8) also play a role in this regard. There are only 2 commercial technologies concerning indirect reduce of fossil usage through seed reduction.

For the third batch, fertilizer continues to be the biggest number for energy use reduction (20), followed by animal healthcare (14). The increasing of animal healthcare from the second batch on may be influenced by COVID as people paid more attention to health issues. Other reduction aspects such as pesticide reduction (9), manure reduction (6), tillage reduction (6), medicine and feed reduction (5 for each) and seed reduction (4) also play a role in this regard.

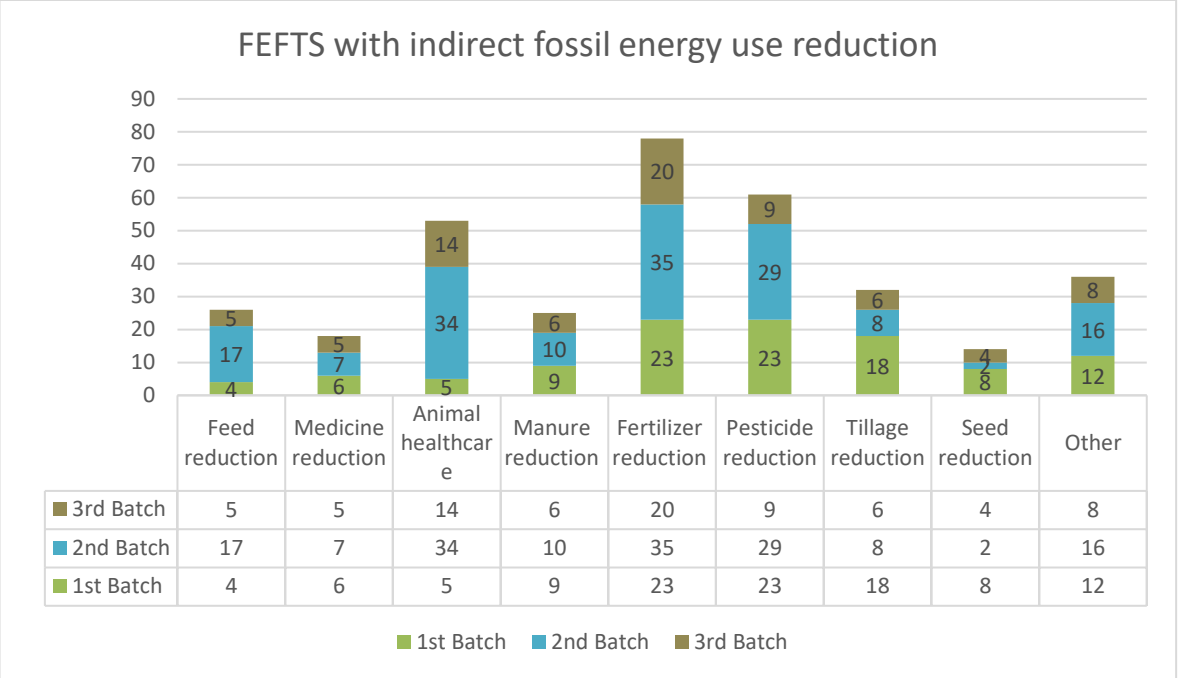


Figure 20 How published FEFTS reduce fossil energy use indirectly, results from all three collection processes

4. Conclusion and Reflection

In conclusion, this report offers a comprehensive overview and in-depth analysis of the commercial FEFTS collected as part of the AgroFossilFree project repository. The data clearly illustrates that the majority of solutions focus on clean energy supply and energy efficiency improvement, with fewer technologies related to soil carbon sequestration.

Regarding clean energy supply, the leading renewable sources leveraged across the collected commercial FEFTS include solar energy, biomass, and wind power. Among these, solar photovoltaics (PV arrays) are well-represented, while biomass predominantly relies on solid fuel conversion systems using agricultural residues and pellets. Small scale wind turbines, designed for on-farm usage, dominate the landscape over large scale alternatives.

These commercial FEFTS demonstrate remarkable versatility in their potential applications across diverse agricultural domains. While catering to farmers' needs, many products are also relevant for greenhouses, open field farming, and livestock operations. The solutions aim to promote fossil fuel reduction and sustainable energy usage by targeting direct energy inputs like electricity and fuel, as well as indirect inputs like fertilizers and pesticides.

Energy efficiency improvement technologies hold a significant share of the market, focusing on reducing equipment and tractor electricity and fuel usage. Another key area of focus is precision agriculture, optimizing input usage for enhanced efficiency.

While current soil carbon sequestration solutions are relatively scarce, techniques like conservation tillage, nutrient management, crop diversification etc. offer opportunities to sequester carbon and offset emissions.

In summary, the published commercial FEFTS span a wide range of technical applications, addressing all major facets of agricultural production. The consortium worked as a unified partnership with all beneficiaries contributing with their maximum effort. We achieved 542 registered and published

Commercial Products thanks to teamwork and the overall diverse contribution. Given the KPI of 1700 FEFTS (of any type) for our repository until the end of the project, both the initial goals that had been set and the vivid reaction of all partners, allowed for a successful completion of this task and exceeding the KPI by more than 250 FEFTS. By disseminating these commercial innovations, the AgroFossilFree project aims to catalyze the transition to fossil-free farming in Europe and globally.

Annexes

Annex A: Commercial Products retrieved from survey

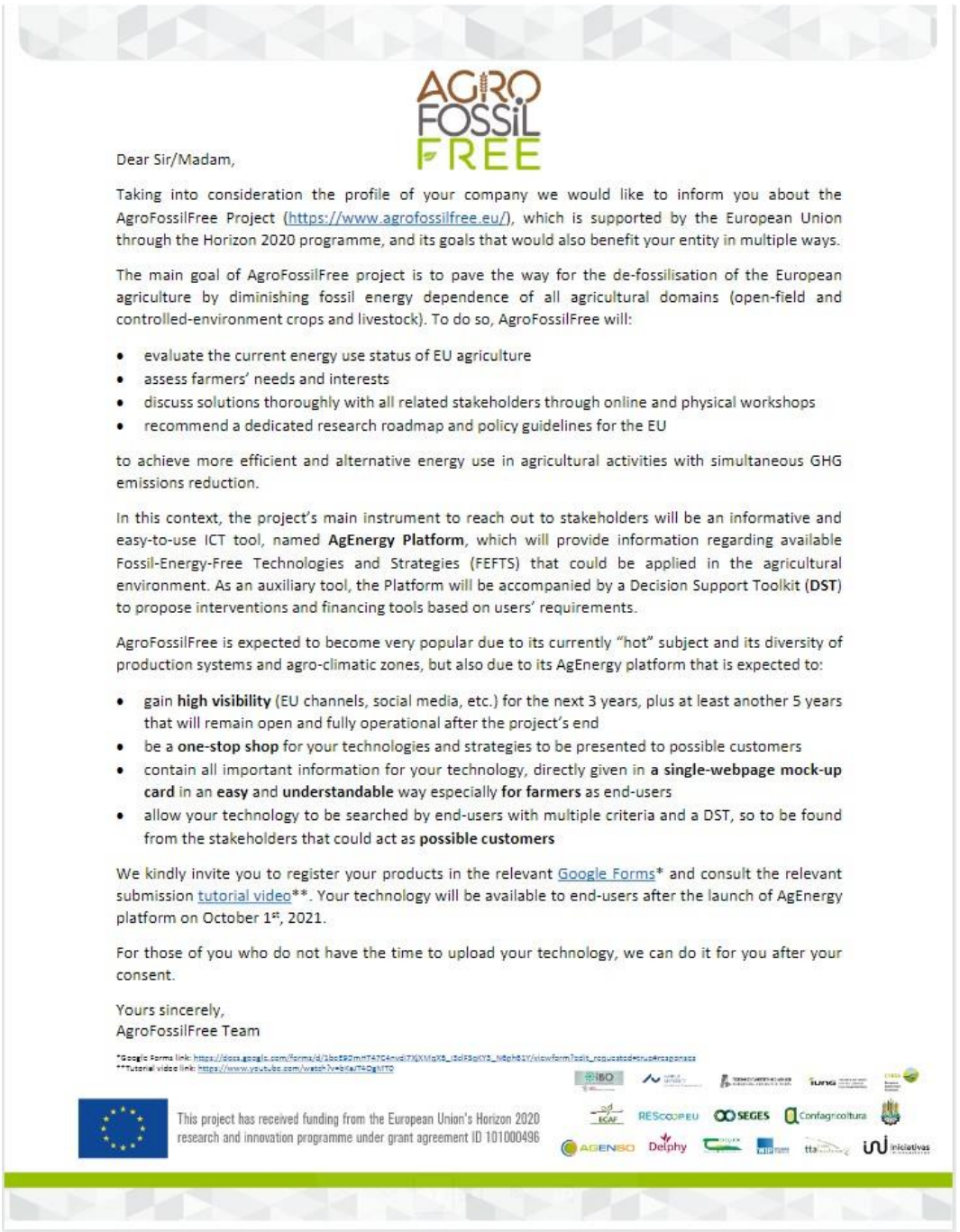
The following link is the online spreadsheet which contains all the commercial products retrieved from all three batches.
https://docs.google.com/spreadsheets/d/1pu-yQRCg1xHgXnSTXdjVwpn7soJp1BQTzs81jb1qe9M/edit#gid=0

Annex B: Commercial Products Survey

As it is mentioned in the report, with the official launch of the AgEnergy platform the use of the Google forms survey was discontinued. Instead, all interested users can now submit their FEFTS directly in the platform's survey by simply creating a free account first. The following link is the AgEnergy platform.

https://platform.agrofossilfree.eu/en

Annex C: Promotional letter for the companies to register their commercial products



Dear Sir/Madam,

Taking into consideration the profile of your company we would like to inform you about the AgroFossilFree Project (https://www.agrofossilfree.eu/), which is supported by the European Union through the Horizon 2020 programme, and its goals that would also benefit your entity in multiple ways.

The main goal of AgroFossilFree project is to pave the way for the de-fossilisation of the European agriculture by diminishing fossil energy dependence of all agricultural domains (open-field and controlled-environment crops and livestock). To do so, AgroFossilFree will:

- evaluate the current energy use status of EU agriculture
- assess farmers' needs and interests
- discuss solutions thoroughly with all related stakeholders through online and physical workshops
- recommend a dedicated research roadmap and policy guidelines for the EU

to achieve more efficient and alternative energy use in agricultural activities with simultaneous GHG emissions reduction.

In this context, the project's main instrument to reach out to stakeholders will be an informative and easy-to-use ICT tool, named **AgEnergy Platform**, which will provide information regarding available Fossil-Energy-Free Technologies and Strategies (FEFTS) that could be applied in the agricultural environment. As an auxiliary tool, the Platform will be accompanied by a Decision Support Toolkit (**DST**) to propose interventions and financing tools based on users' requirements.

AgroFossilFree is expected to become very popular due to its currently "hot" subject and its diversity of production systems and agro-climatic zones, but also due to its AgEnergy platform that is expected to:

- gain **high visibility** (EU channels, social media, etc.) for the next 3 years, plus at least another 5 years that will remain open and fully operational after the project's end
- be a **one-stop shop** for your technologies and strategies to be presented to possible customers
- contain all important information for your technology, directly given in **a single-webpage mock-up card** in an **easy** and **understandable** way especially **for farmers** as end-users
- allow your technology to be searched by end-users with multiple criteria and a DST, so to be found from the stakeholders that could act as **possible customers**

We kindly invite you to register your products in the relevant Google Forms* and consult the relevant submission tutorial video**. Your technology will be available to end-users after the launch of AgEnergy platform on October 1st, 2021.

For those of you who do not have the time to upload your technology, we can do it for you after your consent.

Yours sincerely,
AgroFossilFree Team

*Google Forms link: https://docs.google.com/forms/d/1boE9DmHT47C4rvdI7KXMqX5_i3oIF5qtY3_N6ph81Y/viewform?edit_requested=true#responses
**Tutorial video link: https://www.youtube.com/watch?v=bKeJT4DgMTQ

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

Annex D: Video on FEFTS registration

The following link is the video that INI created to attract companies and stakeholders to register their FEFTS. https://www.youtube.com/watch?v=ouquCgDuFsY&ab_channel=AgrofossilFree