Decision Support Toolkit

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Abstract

A decision support toolkit based on Artificial Intelligence is designed and realized and will be able to address coherently qualitative and quantitative variables. A well-established approach based on Fuzzy Cognitive Maps is implemented. First the most appropriate parameters are identified, then indicators are set for each parameter, the AI tool is developed and finally hosted on the platform. A questionnaire is developed and filled out by project's participants (at least 20 questionnaires) in order to properly map expert knowledge which will be the backbone of the tool. Essentially, the AI tool will mimic the consultation process if these experts were in the same room evaluating the input data provided by the end-user to propose the most effective action. This document is a working document; the first version is prepared for month 12 containing the background, it will be updated in M24 with description of the realized tool on the web platform and finalized in M36 upon optimization based on real use.

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1. Context

1.1. The AgroFossilFree project

The main objective of AgroFossilFree 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 framework will contribute in 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.

Fossil-Energy-Free Technologies and Strategies (FEFTS) refers to the tools that are required to address clean energy production and use in agriculture including Renewable Energy Sources (RES), Energy Efficiency Technologies, Agricultural Constructions Management Systems, Biofuel production and use, Agricultural Machinery using biofuels, electrified implements, Smart Farming Technologies, Conservation agriculture methods and Best Energy Management Practices for rational use of energy and reduced GHG emissions. The benefits of FEFTS are related to cleaner and more efficient energy production and use, resulting in economic, agronomic and environmental benefits. Stakeholders and end-users in the value chain have different needs with regards to FEFTS for agriculture. Arable farming, orchards, vineyards, open-field vegetables, greenhouses and livestock facilities are the agricultural subsectors, where energy is extensively used to maintain acceptable production levels. AgroFossilFree addresses agricultural energy needs, allowing farmers to optimize agricultural production.

1.2. FEFTS types

In line with work performed in Work Package 2 and presented in Deliverable 2.1 Report on methodology and standards the four level of specification of FETS are presented in Table 1. The work on this deliverable builds upon this specification in order to be fully in line with it both content-wise but also programming-wise.

Table 1. Four levels of specifications of FEFTS

Question	Question	Answer
A	What kind of agricultural technology applications is it for?	✓ *Heating and cooling of agricultural constructions* ➔ *Stables* ➔ *Greenhouses* ➔ *Farmer's buildings* ➔ *Cultivations (small scale construction, nylon)* ✓ *Process heat/cold* ➔ *Drying of commodities* ➔ *Pre-processing of agricultural goods* ➔ *Hygenisation* ➔ *Cold storages* ✓ *Lighting* ➔ *Architecture using daylight* ➔ *Energy efficient light bulbs* ✓ *Agricultural field practices*

		➔ *Tilling/ploughing* ➔ *Planting/seeding* ➔ *Fertilizing* ➔ *Pest control (crop protection)* ➔ *Irrigation* ➔ *Harvesting* ✓ *Vehicles* ➔ *Electric tractors* ➔ *Biogas/biomethane tractors* ➔ *Biodiesel/PPO tractors* ➔ *Combine harvester* ➔ *Trailers and tractor tools* ➔ *Wheel-loaders* ✓ *Tools* ➔ *Milking robots* ➔ *Feeding robots* ➔ *Conveyors* ➔ *Mills/grinders* ➔ *Dryers* ✓ *Energy sales to external consumers* ➔ *Solid biomass* ➔ *Biogas/biomethane* ➔ *Bioliquids* ➔ *Crops* ➔ *Electricity feed-in* ✓ *Heat sales to District Heating*
B	What is the type of FEFTS?	✓ *Clean Energy Production (Questionnaire moves to Question C)* ✓ *Energy Efficiency Improvement (Questionnaire moves to Question D)* ✓ *Soil Carbon Sequestration (Questionnaire moves to Question E)*
C	What type of system is this FEFTS?	✓ *Energy Production System (Questionnaire moves to C1, C2 and C3)* ✓ *Energy Storage System (Questionnaire moves to C4)*
C1	What Type of Renewable Energy Source does it use?	✓ *Solar* ✓ *Wind* ✓ *Hydro* ➔ *Kinetic* ➔ *Potential* ✓ *Biomass* ➔ *Pellets* ➔ *Woodchips* ➔ *Logwood* ➔ *Energy crops* ➔ *Agricultural residues* ✓ *Landfill gas* ✓ *Sewage treatment plant gas and biogases* ✓ *Geothermal* ➔ *Solid/ground* ➔ *Fluids* ✓ *Aerothermal* ➔ *Ambient air*

		✓ *Hydrothermal* ➔ *Groundwater* ➔ *Water bodies* ✓ *Marine energy* ➔ *Wave energy* ➔ *Tidal energy*
C2	What is the energy type that it produces?	✓ *Heating* ➔ *Heat for agri-processes* ➔ *Buildings* ✓ *Cooling* ➔ *Cooling for agri-processes* ➔ *Cooling for buildings* ✓ *Electricity* ➔ *AC* ➔ *DC* ✓ *Mechanical energy* ➔ *Stationary applications* ➔ *Mobile applications* ✓ *Chemical energy* ➔ *Gaseous fuels* ➔ *Liquids fuels* ➔ *Solids fuels*
C3	What is the specific technology used to produce this type of energy?	✓ *Photovoltaics* ➔ *PV-arrays* ➔ *Agri-PV systems* ➔ *PV on tools and vehicles* ✓ *Solar thermal* ➔ *Flat plate collectors* ➔ *Evacuated tube collectors* ➔ *Concentrated* ➔ *Thermosiphon systems* ➔ *Photovoltaic and thermal collectors (PVT)* ➔ *Ground mounted solar collectors* ✓ *Wind turbines* ➔ *Small wind turbines (1-50 kw)* ➔ *Medium wind turbines (50-999 kw)* ➔ *Large wind turbines (<1 MW)* ➔ *Water wind pumps* ✓ *Hydropower* ➔ *Micro (1-10 kw)* ➔ *Mini (10-100 kw)* ➔ *Small (100-1000 kw)* ➔ *Run-of-the-river* ✓ *Heat pumps* ➔ *Ground source heat pump* ➔ *Water heat pump (surface and ground water)* ➔ *Ambient air heat pump* ➔ *Other heat pumps* ✓ *Geothermal* ➔ *Shallow geothermal (until 400 m)* ➔ *Deep geothermal (deeper than 400 m)* ✓ *Solid biomass conversion* ➔ *Woodchip boilers* ➔ *Wood log boilers*

		➔ *Pellet boilers* ➔ *Woodchip gasifiers (CHP)* ➔ *Pellet gasifiers (CHP)* ✓ *Biogas / biomethane production* ➔ *Anaerobic digestion technologies* ➔ *Bio methane upgrading technologies* ✓ *Liquid biofuels production* ➔ *Oil presses* ➔ *Biodiesel plants* ➔ *Distilleries*
C4	What type of energy storage system is?	✓ *Heat storage* ➔ *Buffer tanks* ➔ *Seasonal heat storage systems* ➔ *Latent heat storages (pcm)* ➔ *Thermo-chemical storages* ✓ *Electricity storage* ➔ *Lithium-ion batteries* ➔ *Redox flow batteries* ➔ *Zinc-hybrid batteries* ➔ *Lead–acid batteries* ➔ *Hydrogen (subsystem)* ✓ *Cold storage* ➔ *Ice/slurry storage systems* ➔ *Other cold storage systems* ✓ *Intermediate bioenergy carriers* ➔ *Pellets* ➔ *Wood chips* ➔ *Wood log* ➔ *Torrefied biomass* ➔ *Charcoal* ➔ *Oils* ✓ *Other intermediate bioenergy carriers*
D	What kind of energy efficiency improvement is it?	✓ *Efficient buildings* ➔ *Building wall insulation* ➔ *Roof insulation* ➔ *Cellar insulation* ➔ *Windows* ➔ *Building management systems* ➔ *Efficient lighting* ✓ *Efficient vehicles* ➔ *Maintenance (e.g. Tyre pressure)* ➔ *Logistics/planning* ✓ *Efficient tools* ➔ *Irrigation (pumps, drip systems etc)* ➔ *Conveyors* ➔ *Milking machines* ➔ *Refrigerators* ➔ *Feeding* ✓ *Precision agriculture* ➔ *Seed reduction* ➔ *Fertilizer reduction* ➔ *Pesticide reduction* ➔ *Lime reduction* ➔ *Manure reduction*

		➔ *Water reduction* ✓ *Precision livestock farming* ➔ *Feed reduction* ➔ *Medicine reduction* ➔ *Animal healthcare* ➔ *Manure reduction* ✓ *Conservation agriculture* ➔ *Crop rotation* ➔ *Soil coverage* ➔ *No/minimum-tillage* ✓ *Efficient postharvest technologies*
E	Which carbon sequestration technique is used?	✓ *Soil organic matter* ➔ *Terra preta* ➔ *Compost* ➔ *Harvest residues* ✓ *Tillage (conservation agriculture + CTF)* ✓ *Nutrient management* ✓ *Crop diversification* ✓ *Soil and water conservation techniques* ✓ *Fire management* ✓ *Grassland management*

1.3. AgroFossilFree Platform

AgroFossilFree has implemented an online and interactive approach to communication, interaction and knowledge sharing and exchanging through the use of a specifically designed ICT tool, the **"AgEnergy Platform"**, which will deploy the collected information and knowledge on FEFTS in the form of easily accessible end-user material following the EIP-Service Point format[1].The AgEnergy Platform will be the tool for online assessment of the inventoried FEFTS by stakeholders across Europe, will allow for the crowdsourcing of grassroots-level ideas and needs for research

1.4. Why a decision support toolkit?

A user visiting the AgroFossilFree platform will find a wealth of information regarding FEFTS. The website is developed having user experience at its core. The filters that can be applied can be used in many combinations in order to reveal the FEFTS database's content that is stored on the platform. Still, how can you choose which one is the most appropriate one or the most cost-effective one. The answer to that in reality comes after a detailed study on a per farm basis. But we wanted to develop an intermediate level, a level that can provide a first insight on which FEFTS probably suits best to the needs of a farm. If 10 agricultural experts are in the same room, they could have a discussion given a minimum amount of info and could be based on experience highlight the FEFTS with most applicability to the farm at hand. This would act of course only as the first step in study process that would evaluate different options and provide the optimal investment for each farm. The consortium decided to use Artificial Intelligence to provide this first step that goes beyond an advanced database search. The Decision Support Toolkit will be integrated seamlessly within the AgroFossilFree platform and allow users to get a ranking of the technologies most suitable for each farm. In reality the tool represents the collected knowledge of at least 20 experts working in the consortium and beyond. The knowledge is collected through questionnaires and essentially,

[1] Guidelines on Programming for Innovation and the Implementation of the EIP. Programming period 2014-2020.Version July 2014.

the AI tool will mimic the consultation process if these experts were in the same room evaluating the input data provided by the end-user to propose the most effective action.

2. Theoretical background

2.1. Decision Support Systems

Decision making is an inherently human activity. Decisions span the whole spectrum of human activity and as such it is not surprising that numerous researchers have tried to improve the quality of decisions in different fields by providing tools to support the decision-making process. Further to that effort has been made to develop computer-based technologies that can augment and extend human capabilities. The development of Artificial Intelligence tools has found application in decision support systems in many sectors like finance, healthcare, marketing, commerce, command and control, and cybersecurity. The term intelligent refers to systems aiming at mimicking human cognitive capabilities to an extent and the decision support systems employing such technologies have been referred to as Intelligent Decision Support Systems (IDSS)[1].
IDSS utilize Artificial Intelligence paradigms to reason, learn, remember plan and analyze. Decisions are referred to as structured, unstructured or semi-structured depending on the degree of certainty of the problem representation and solution. The decision making process described by Simon [2] is generally accepted by researchers who develop DSS as consisting of four phases:

1. **Intelligence:** the decision maker gathers information and develops an understanding of the problem
2. **Design:** the decision maker identifies criteria, develops the model and investigates alternatives
3. **Choice:** a selection or decision is made
4. **Implementation:** The decision maker acts on the decision and learns

The process is at a large extent sequential with feedback loops between phases. As mentioned before, IDSS are intelligent when they express intelligent behavior. Intelligent behavior includes among others[3, 4]:

- Learn or understand from experience;
- Make sense out of ambiguous or contradictory messages;
- Respond quickly and successfully to a new situation;
- Use reasoning in solving problems;
- Deal with perplexing situations;
- Understand and infer in ordinary, rational ways;
- Apply knowledge to manipulate the environment;
- Think and reason;
- Recognize the relative importance of different elements in a situation

AI paradigms can be utilized in all stages of a DSS implementation. These include:

- Machine learning algorithms [5]
- Neural Networks[6]
- Case based reasoning [7]
- Expert systems [8]
- Genetic algorithms [9]
- Fuzzy Logic [10]

- Intelligent Agents [11]
- Intelligent Multi-agent systems [12]
- Neural Networks [13]
- Fuzzy Cognitive Maps [14]

2.2. Fuzzy Cognitive Maps

As research has been advancing in IDSS e Effort has been made in bridging the gap between qualitative and quantitative models through the use of such soft computing techniques [15, 16]. Qualitative variables can be expressed through the use of linguistic variables. The linguistic variables in turn can be expressed by fuzzy sets. The quantitative variables can also be expressed by fuzzy sets, with emphasis given to their uncertainty [15]. Fuzzy cognitive maps (FCM) are able to deal with processes like decision making that is based on human reasoning process [17]. Because of this, FCMs have been used successfully in different fields. Many applications have been presented in the medical field [18, 19], in agricultural applications [20, 21], in environmental applications [22] and in energy applications [14, 23].
Decision support systems can be represented through FCMs. FCMs are graphs which represent cause and effect relationships and are used for computational inference processing [24]. Systems can be symbolically represented through FCMs. Concepts are used to present different aspects of the modeled system such as inputs, outputs, rules or intermediate states.

$$C_i,\ i = 1,\ldots,N$$

where N is the total number of nodes.
The value of each concept is fuzzified in the space [0,1].

$$A_i \in [0,1], i = 1,\ldots,N$$

These node-concepts are interconnected with arcs which have different weights in order to express their relations. One FCM is depicted in Figure 1.

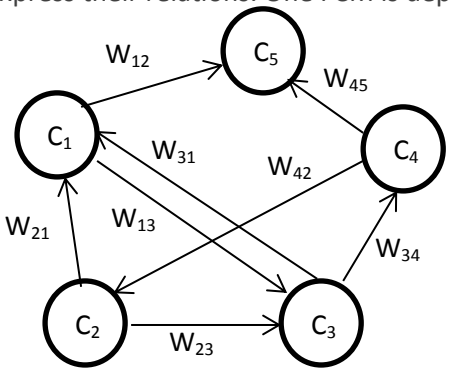

Figure 1. A Fuzzy Cognitive Map

In order to give values to the weights human knowledge and experience is used. The weights are:

$$W_{i,j} \in [-1,1],\ i = 1,\ldots,N \text{ and } j = 1,\ldots,N$$

When the weight expresses positive causality, the weight is positive, when the weight expresses negative causality, it is negative and zero declares no relation between the concepts. The weights can be presented in a matrix as below:

$$W_{i,j} = \begin{pmatrix} W_{11} & W_{12} & W_{13} & W_{14} & W_{15} \\ W_{21} & W_{22} & W_{23} & W_{24} & W_{25} \\ W_{31} & W_{32} & W_{33} & W_{34} & W_{35} \\ W_{41} & W_{42} & W_{43} & W_{44} & W_{45} \\ W_{51} & W_{52} & W_{53} & W_{54} & W_{55} \end{pmatrix}$$

This matrix can be simplified by substituting the weights of the Concepts which present no relation with zeros.

$$W_{i,j} = \begin{pmatrix} 0 & W_{12} & W_{13} & 0 & 0 \\ W_{21} & 0 & W_{23} & 0 & 0 \\ W_{31} & 0 & 0 & 0 & 0 \\ 0 & W_{42} & 0 & 0 & W_{45} \\ 0 & 0 & 0 & 0 & 0 \end{pmatrix}$$

According to Kosko [25] the values of the concepts are influenced by the rest concepts according to equation 1. The FCM reaches a converged state after a number of iterations.

$$A_i(k+1) = f\left(A_i(k) + \sum_{\substack{j=1 \\ j \neq i}}^{n} W_{ji} A_j(k) \right)$$, (EQ 1)

where:

k is the iteration counter.

Function f is the activation function. Four functions have been proposed: the sigmoid function, the hyperbolic tangent function, the step function and the threshold linear function [26].

- The sigmoid function is presented in EQ 2 where $c \in (0, +\infty)$ is a steepness parameter. For a small c value (e.g., c=1) it approximates a linear function and for large values (c=10) it approximates a discrete function [26].

$$f(x) = \frac{1}{1 + e^{-cx}}$$ (EQ 2)

- The hyperbolic tangent function is presented in EQ 3. It maps its output in the range [-1,1] for a c value close to 5 [26].

$$f(x) = \frac{e^{cx} - e^{-cx}}{e^{cx} + e^{-cx}}$$ (EQ 3)

- The step function is presented in EQ 4. In order to decrease the subjectivity of the of the step function a value of T equal to 0.5 is proposed [26].

$$f(x) = \begin{cases} 0 & if \quad x \leq T \\ 1 & if \quad x > T \end{cases}$$ (EQ 4)

- The threshold linear function is a derivative of the step function and is presented in EQ 5 [29].

$$f(x) = \begin{cases} 0 & if \quad x \leq T \\ (x - T) & if \quad x > T \end{cases}$$ (EQ 5)

According to [26] the sigmoid function presents specific advantages than the other concepts. Also, the needed output needs to be mapped in the space [0,1]. This is why it has been used in many applications comparable to the AgroFossilFree one.
In order to model a process or a controller with an FCM, expert knowledge is needed.
An FCM is usually constructed by a knowledge engineer who acquires domain knowledge from systems experts and uses that knowledge to define the concepts, causal directions and linguistic variables of the edges of the graph. The domain experts identify of causal relationships among the concepts and estimate of causal link strengths with linguistic variables [19] .
Experts decide on the important aspects of the system which become the concepts and the weights are set according to the interrelations of the concepts [27]. Linguistic variables can be used by the experts in order to express the relations of the concepts in a simplified way. First of all, negative, positive or no causality is set. After that the influence is described with variables like very weak, weak, strong, very strong etc. [24].
Due to the flexibility and versatility of FCM, along with the very good matching with the application at hand, it was decided to utilize them in AgroFossilFree.

3. AgroFossilFree IDSS

3.1. Design

In order to design the DST, at first all the parameters that affect the decision were investigated and are presented. Then for each parameter corresponding indicators were selected. These indicators are in essence the inputs of the DST. An FCM approach was chosen based on its ability to address coherently qualitative and quantitative variables. The FCM, which is the backbone of the approach, is designed and its parameters are set by experts, along with the fuzzification and defuzzification functions.

3.2. Implementation methodology

The methodology approach followed for the implementation of the IDSS consists of four discrete stages:
Stage A: Parameters' identification.
All the parameters that can affect the evaluation of FEFTS are investigated and presented. The parameters are broken down in five distinct categories; legal/ regulative/ administrative, financial, technical, social and environmental and climate action. The chosen parameters are the result of interviews with experts and stakeholders.
Stage B: Indicators' choice.
The parameters that were chosen in Stage A need to be assessed. Relevant indicators are selected from OECD, FAO, International Energy Agency, Eurostat and international literature [35].
Stage C: FCM implementation.
Based on the results of Stages A and B the FCM used to evaluate the investment is designed and its parameters are set.
Stage D: Implementation of the DST.
The IDSS is integrated with the AgroFossilFree platform.

3.3. Stage A: Parameters' identification

3.3.1. Legal/ regulative/ administrative context (P1)

P1.1 Licensing burden
A number of whether licenses, permits, contracts, certificates etc. could be required in order to employ a FEFTS. This parameter investigates whether any licenses are needed and also the difficulty related to obtaining them (this parameter focuses on effort required).
P1.2 Coherence with EU defossilization policies and binding targets
This parameter investigates the extent each FEFTS contributes to EU policies targeting defossilization.
P1.3 Level of bureaucracy involved in deploying the investment.
This parameter investigates how time consuming is the deployment of a FEFTS. For example, in order to produce biogas and sell electricity to the grid, you need a number of licenses and permits which also take time to get. Contrary if you decide to invest in a heat pump, you simply have to decide on which heat pump to get and then it is a matter of installation only. This parameter focuses on the time required.

3.3.2. Financial context (P2)

P2.1 Investment appraisal
This is related to the predicted profitability of the investment. This parameter investigates the extent a FEFT can have on the farmer's income.
P2.2 Access to financing
This is related to the ease of obtaining financing for the investment and can include subsidies, low interest financing, loans, etc.

3.3.3. Technical Context (P3)

P3.1. Technology potential based on location
This investigates the fitting of the technology to the location. For example, PVs and Solar Thermal applications have an increased technical potential going from North to South in the EU.
P3.2 Technical applicability
This parameter is related to the maturity of the FEFTS. More mature technologies have lower risks in relation to the expected outcome. New products and technologies that have not been evaluated for longer periods of time can present a high risk.
P3.3 Location constraints
The distance from the road network and electricity grid can play a role for the deployment of some FEFTS.

3.3.4. Social context (P4)

P4.1 Social acceptability
Some FEFTS can be more acceptable than others and there are cases of false perceptions in local communities.
P4.2. Creation of new jobs
Depending on the FEFTS evaluated there can be an increase or decrease of jobs or it might not affect jobs at all.
P4.3 Distress factors (e.g., noise, shadowing / odors etc.)

There are some factors that can objectively cause distress to the local population, because of the operation of a RES investment and should always be considered by the investor.

P4.4 Education impact

The impact a FEFTS can have on education is multi-level and can play an important role to the investor. Visits to the site from school students can affect them in their further studies at the university or technical school in the relevant field. Also, the existence of universities located close to the installation of a FEFTS might lead to synergies for improvement and future upgrades.

P5. Environmental and Climate Action context

P5.1 Land use

FEFTS for defosilizing agriculture ought not to have an impact on high productivity agricultural land. The FEFTS that can have a win-win outcome in improving agricultural yields and decreasing the carbon footprint ought to be promoted.

P5.2 Effect on wildlife / protected areas

There are many endangered species on the earth. In order to sustain our environmental heritage certain protected areas have been set [28]. Big installations in these areas ought to be prohibited. Also, the proximity of the installation in such an area is important for the investor, since animals and plants do not abide to humanly created border lines on a map. Big FEFTS Investments near protected areas should take into consideration special aspects like not cutting mobility routes of animals and so on.

P5.3 Effect on archaeological and cultural heritage sites

Big FEFTS investments are to be avoided if they are visible from such sites.

3.4. Stage B: Indicators' choice

The above parameters can provide the basis of the evaluation of RES investments. In order, though, to be able to compare different investments collectively or for specific parameters of it, common ground has to be found. This can be accomplished through the use of relevant indicators. These indicators can provide the framework for direct comparisons between different RES investments. The parameters are assessed using both of qualitative and quantitative Indicators. The quantitative indicators are based on databases of official statistical sources, GIS systems, maps, legal and administration documents, incentives, programs, procedures etc. The Qualitative Indicators are based on the expertise of different key actors such

- Farmers
- Agricultural experts
- Industrial /SME actors
- Academic institutions
- Local communities
- Environmental groups

For each of the parameters that were described in the previous section, the relevant indicators were chosen. In some occasions more than one indicator are used for a single parameter. This is implemented because of the significance of the respective parameters. The parameters along with the corresponding indicators are presented in Table 2.

Table 2. Parameters and relevant indicators

Parameter Category	**Parameter**	**Indicator**
P1. Legal/ regulative/ administrative context	P1.1 Licensing burden	I1.1. Process steps
	P1.2 Coherence with EU defossilization policies and binding targets	I1.2 Defossilization potential
	P1.3 Level of bureaucracy involved in deploying the investment.	I1.3 Lead time
P2. Financial context	P2.1 Investment appraisal	I2.1 Increase in income
	P2.2 Access to financing	I2.2 Number of tools available
P3. Technical Context	P3.1. Technology potential based on location	I3.1. Suitability of location to FEFT
	P3.2 Technical applicability	I3.2. Technology readiness level
	P3.3 Location constraints	I3.3.1. Distance from road network
		I3.3.2. Distance from electrical grid
P4. Social context	P4.1 Social acceptability	I4.1. Community Acceptance
	P4.2. Creation of new jobs	I4.2. # of created jobs
	P4.3 Distress factors (e.g., noise, shadowing / odors etc.)	I4.3 Distress index
	P4.4 Education impact	I4.4 Education impact index
P5. Environmental and Climate Action context	P5.1 Effect on wildlife / protected areas	I5.1 Distance from protected areas
	P5.2 Effect on archaeological and cultural heritage sites	I5.2 Visibility index from archaeological / cultural heritage sites

3.5. Stage C: FCM Implementation

A five-step procedure takes place in the development of the FCM to be used in the DST toolkit.
Step 1: Definition of the inputs the user has to supply.
Step 2: Definition of concepts.
Step 3: Fuzzification of the inputs.
Step 4: Definition of weights.
Step 5: Defuzzification of the output.
Depending on the main application of the FEFTS, i.e., open field agriculture, livestock production and greenhouses the FCM needs to be accordingly modified.

Step 1: Definition of the user inputs.
The user inputs that are needed in order to calculate all the relevant Indicators are presented in Table 3, Table 4Table 5 depending on application category (open field agriculture, greenhouses and livestock facilities). These tables also present the list of choices to be ranked per application category.

Table 3. Choices to be ranked per application category and needed user inputs for open field agriculture

No of FEFTS	FEFTS	No of Question	User inputs	Possible answers
	Renewable energy generation			
1	PV		-	
2	Wind turbines		-	
3	Electricity Storage		-	
4	Biomass for local heat production		-	
5	Improved agricultural practices incl. precision agriculture?	1	Do you employ precision agriculture techniques?	1. Yes 2. No
	Vehicles			
6	Tractors	2	Do you use a tractor?	1. Yes – Less than 3 years old 2. Yes – Between 3 and 10 years old 3. Yes – Older than 10 years 4. No
7	Harvesters	3	Do you use a harvester?	1. Yes, but I do not own it 2. Yes – Less than 3 years old 3. Yes – Between 3 and 10 years old 4. Yes – Older than 10 years 5. No
8	Wheel loaders	4	Do you use a wheel loader?	1. Yes, but I do not own it 2. Yes – Less than 3 years old 3. Yes – Between 3

				and 10 years old 4. Yes – Older than 10 years 5. No
	Post-processing equipment (storage, cold storage, drying, milling / oil extraction / threshing / etc.)			
9	Cold storage	5	Do you use cold storage facilities?	1. Yes, but I do not own it 2. Yes – Less than 5 years from installation 3. Yes – Between 5 and 10 from installation 4. Yes – More than 10 years from installation 5. No
10	Drying	6	Do you use drying facilities?	1. Yes, but I do not own it 2. Yes – Less than 5 years from installation 3. Yes – Between 5 and 10 from installation 4. Yes – More than 10 years from installation 5. No
11	Mechanical work related (e.g., milling / oil extraction / threshing / etc.)	7	Do you use mechanical work related facilities (e.g., milling / oil extraction / threshing / etc.)?	1. Yes, but I do not own it 2. Yes – Less than 5 years from installation 3. Yes – Between 5 and 10 from installation 4. Yes – More than 10 years from installation 5. No
12	Conservation agriculture / carbon sequestration	8	Do you know what carbon sequestration is?	1. Yes 2. No
		9	Do you employ conservation agriculture techniques?	1. Yes 2. No
General inputs				
		10	Type of crops (multiple selection possible)	• Cereals • Seeds • Pulses

				• Fruits • Vegetables • Spices
		11	Area	1. 0 – 9.9 he 2. 10 – 99 he 3. 99 < he
		12	Location	Dropdown list of all countries, possibly making differentiations for big countries e.g. North and South.
		13	Distance from roads (m)	1. <100 2. 100–500 3. 500–1000 4. 1000–5000 5. >5000
		14	Distance from electricity grid (m)	1. <100 2. 100–500 3. 500–1000 4. 1000–5000 5. >5000
		15	Distance from protected areas (km)	1. >1 2. 1–5 3. 5–10 4. >10
		16	Distance from Archaeological / Cultural Heritage sites (km)	1. >1 2. 1–5 3. 5–10 4. >10

Table 4. Choices to be ranked per application category and needed user inputs for greenhouses

No of FEFTS	**FEFTS**	**No of Question**	**User inputs**	**Possible answers**
	Renewable energy generation			
1	PV		-	
2	Wind turbines		-	
3	Electricity Storage		-	
4	Biomass for local heat production		-	
	On-site thermal energy generation			
5	Geothermal energy	1	Do you use geothermal energy for heating purposes?	1. Yes 2. No, but I know there is a geothermal source nearby 3. No
6	Improved burners / boilers	2	Do you use a burner/boiler?	4. Yes – Uses fossil fuels 5. Yes – Uses renewable fuels (e.g. biomass) 6. No
7	Heat pumps	3	Do you use heat-	1. Yes

			pumps for heating purposes?	2. No
8	Cooling / Air conditioning	4	Do you use any type of cooling / air conditioning?	1. Yes, evaporative cooling 2. Yes, heat pump 3. Yes, desiccant technology 4. Yes, only ventilation 5. No
9	Lighting	5	Do you use lighting for plant growth?	1. Yes, LED type 2. Yes, other type 3. No
10	Intelligent Management Systems / Automation	6	Do you use any type of intelligent management system incl. hydroponics, aeroponics, etc.	1. Yes 2. No
General inputs				
		7	Area	4. 0 – 0.09 he 5. 0.10 – 0.99 he 6. 1< he
		8	Location	Dropdown list of all countries, possibly making differentiations for big countries e.g. North and South.
		9	Distance from roads (m)	6. <100 7. 100–500 8. 500–1000 9. 1000–5000 10. >5000
		10	Distance from electricity grid (m)	6. <100 7. 100–500 8. 500–1000 9. 1000–5000 10. >5000
		11	Distance from protected areas (km)	5. >1 6. 1–5 7. 5–10 8. >10
		12	Distance from Archaeological / Cultural Heritage sites (km)	5. >1 6. 1–5 7. 5–10 8. >10

Table 5. Choices to be ranked per application category and needed user inputs for livestock facilities

No of FEFTS	**FEFTS**	**No of Question**	**User inputs**	**Possible answers**
	Renewable energy generation			
1	PV		-	
2	Wind turbines		-	
3	Electricity Storage		-	
4	Biogas	1	Do you produce	1. Yes

			biogas?	2. No, but there is an arrangement to utilize the farm's waste elsewhere 3. No
	On-site thermal energy generation			
5	Geothermal energy	2	Do you use geothermal energy for heating purposes?	1. Yes 2. No, but I know there is a geothermal source nearby 4. No
6	Improved burners / boilers	3	Do you use a burner/boiler?	1. Yes – Uses fossil fuels 2. Yes – Uses renewable fuels (e.g. biomass) 3. No
7	Heat pumps	4	Do you use heat-pumps for heating purposes?	1. Yes 2. No
8	Cooling / Air conditioning	5	Do you use any type of cooling / air conditioning?	1. Yes, evaporative cooling 2. Yes, heat pump 3. Yes, desiccant technology 4. Yes, only ventilation 5. No
9	Lighting	6	What type of lighting do you use?	1. LED type 2. Other type
10	Intelligent Management Systems / Automation	7	Do you use any type of intelligent management system incl. environmental control?	1. Yes 2. No
11	Waste for energy generation	8	Do you use waste for energy generation purposes?	1. Yes, on-site 2. Yes, through a third party 3. No
General inputs				
		9	Animal	1. Pigs 2. Bovine animals 3. Sheep and goats 4. Chickens 5. Other
		10	Herd size	1. <250 2. Between 250 and 1000 3. Above 1000
		11	Location	Dropdown list of all countries, possibly making differentiations

				for big countries e.g. North and South.
		12	Distance from roads (m)	11. <100 12. 100–500 13. 500–1000 14. 1000–5000 15. >5000
		13	Distance from electricity grid (m)	11. <100 12. 100–500 13. 500–1000 14. 1000–5000 15. >5000
		14	Distance from protected areas (km)	9. >1 10. 1–5 11. 5–10 12. >10
		15	Distance from Archaeological / Cultural Heritage sites (km)	9. >1 10. 1–5 11. 5–10 12. >10

Step 2: Definition of concepts.
Two types of concepts are going to be used in the proposed FCM; input and output concepts. The output concept will be the overall evaluation for each FEFTS category. The input concepts are the indicators presented in the previous section. The FCM inputs are in essence the indicators as described in the previous section and are presented in Tables 2, 3 and 4. The output is concepts are 10 for open field agriculture, 7 for greenhouses and 8 for greenhouses. The values of these output concepts are going to be ranked by value and this is how the ranking of the FEFTS categories takes place. The different concepts are calculated from data available in a data base using the user supplied inputs which are also presented in Tables 2, 3 and 4. The database is compiled by data found in relevant laws, publications simulation software packages etc.

Step 3: Fuzzification of the FCM inputs.
The fuzzification of the inputs is essentially a mapping of quantitative and qualitative variables in the space [0,1]. The exact process will be finalized after the expert questionnaires have been filled out. The questionnaires are presented in Annex 1.

Step 4: Definition of the FCM weights.
The definition of weights is carried out according to the methodology presented in [14]. A questionnaire is being prepared to be distributed among at least 15 experts of this field. The experts will answer the questions using linguistic variables. The experts will include experts from the AgroFossilFree project partners and experts from academia, who all have considerable experience in the field of FEFTS. These values are then defuzzified in the space [0,1]. Using the centroid defuzzification method the linguistic values are transformed in numerical values using the membership function presented in Figure 2.

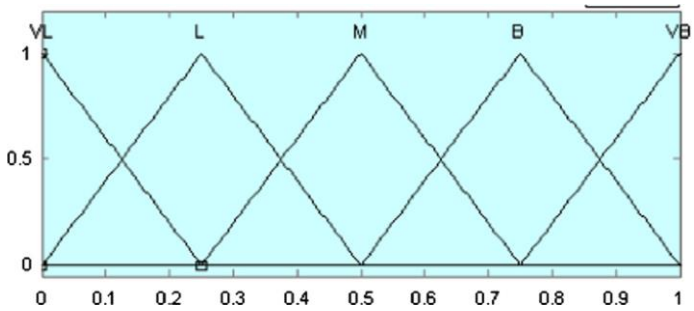

Figure 2. Membership function for the defuzzification of weights

4. Next steps

The next steps include:

1. Distribution of questionnaires and collection of responses (first half of October 2021)
2. Finalization of the design i.e., definition of the FCM weights (November 2021)
3. Algorithms' development (December 2021)
4. Integration of the tool on the AgroFossilFree platform (March 2022)
5. Test operation (March 2022 – August 2022)
6. Preparation of the second version of this deliverable which will include the presentation of the Graphical User Interface on the AgroFossilFree platform and evaluation of the test operation (August 2022)
7. Optimization of the tool and web interface and evaluation of use (September 2022 – August 2023)
8. Final version of this deliverable which will include the overall evaluation of the tool.

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6. Annex 1. Questionnaires

There are 3 main questionnaires developed, one for each of the main application categories, i.e., Open-field agriculture, Greenhouses and Live-stock.
Each of the questionnaires will have to be filled in for each of the FEFTS categories investigated in each application category.
Table 6 refers to open-field agriculture and will have to be filled in for the 12 FEFTS categories related to open-field agriculture:

1. PV
2. Wind turbines
3. Electricity Storage
4. Biomass for local heat production
5. Improved agricultural practices incl. precision agriculture?
6. Tractors
7. Harvesters
8. Wheel loaders
9. Cold storage
10. Drying
11. Mechanical work related (e.g., milling / oil extraction / threshing / etc.)
12. Conservation agriculture / carbon sequestration

Table 6. Questionnaire for open-field agriculture

No	Question	VL	L	M	B	VB
1	What is the licensing burden for **(FEFTS)**?					
2	What is the defossilization potential for **(FEFTS)**?					
3	How much time is needed from making the decision and securing the budget to have the investment in **(FEFTS)** ready to use (please consider below 1 month as very low, between 1-3 months low, between 4 and 6 months Medium, between 6 and 9 months big, more than 9 months very big)					
4	How much is the farmer's income expected to grow after investing in **(FEFTS)** in your opinion? (Please take in account both the investment cost and the actual expected increase in income)					
5	How easy do you consider is it to secure financing for investing in **(FEFTS)**? (please consider very low to be very hard to secure financing and very big to be very easy to secure financing)					
6	How suitable is the investment in **(FEFTS)** for a farmer cultivating cereals?					
7	How suitable is the investment in **(FEFTS)** for a farmer cultivating seeds?					
8	How suitable is the investment in **(FEFTS)** for a farmer cultivating pulses?					
9	How suitable is the investment in **(FEFTS)** For a farmer cultivating fruits?					
10	How suitable is the investment in **(FEFTS)** For a farmer cultivating vegetables?					
11	How suitable is the investment in **(FEFTS)** For a farmer cultivating spices?					
12	Is the investment in **(FEFTS)** suitable for small-holders (0-9.9 he)?					
13	Is the investment in **(FEFTS)** suitable for small-holders (10-99 he)?					
14	Is the investment in **(FEFTS)** suitable for small-holders (99<)?					
15	Is the distance from the point of installation and/or point of use of **(FEFTS)** from a paved road important? (Please consider for this question very low to be it practically is not affected by distance and very big that a new road will have to be built)					
16	Is the distance from the point of installation and/or point of use of **(FEFTS)** from the electricity grid important? (Please consider for this question very low to be it practically is not affected by distance and very big that a grid extension will have to be built)					

17	How acceptable by local communities do you consider **(FEFTS)** to be?					
18	Do you expect that an investment in **(FEFTS)** will lead to new jobs?					
19	Do you believe that an investment in **(FEFTS)** will create distress (e.g., noise, shadowing, odors) to the local population? (Please consider for this question that very low is no distress at all and very big, very big distress)					
20	Do you believe that and investment in **(FEFTS)** will have an impact on education of the local community (from school students, to vocational training participants)?					
21	Do you believe than an investment in **(FEFTS)** will affect negatively a nearby wildlife / protected area (e.g. natura)? (Please consider for this question very low to be no negative effect and very big to be very big negative effect)					
22	Do you believe than an investment in **(FEFTS)** will affect negatively a nearby cultural and/or archaeological site? (Please consider for this question very low to be no negative effect and very big to be very big negative effect)					
Legend: VL: Very Low L: Low M: Medium B: Big VB: Very big						

Table 7 refers to greenhouses and will have to be filled in for the 10 FEFTS categories related to greenhouses:

1. PV
2. Wind turbines
3. Electricity Storage
4. Biomass for local heat production
5. Geothermal energy
6. Improved burners / boilers
7. Heat pumps
8. Cooling / Air conditioning
9. Lighting
10. Intelligent Management Systems / Automation

Table 7. Questionnaire for greenhouses

No	Question	VL	L	M	B	VB
1	What is the licensing burden for **(FEFTS)**?					
2	What is the defossilization potential for **(FEFTS)**?					
3	How much time is needed from making the decision and securing the budget to have the investment in **(FEFTS)** ready to use (please consider below 1 month as very low, between 1-3 months low, between 4 and 6 months Medium, between 6 and 9 months big, more than 9 months very big)					
4	How much is the farmer's income expected to grow after investing in **(FEFTS)** in your opinion? (Please take in account both the investment cost and the actual expected increase in income)					
5	How easy do you consider is it to secure financing for investing in **(FEFTS)**? (Please consider very low to be very hard to secure financing and very big to be very easy to secure financing)					
6	Is the investment in **(FEFTS)** suitable for small-holders (0-0.9 he)?					
7	Is the investment in **(FEFTS)** suitable for small-holders (0.10-0.99 he)?					
8	Is the investment in **(FEFTS)** suitable for small-holders (1<)?					
9	Is the distance from the point of installation and/or point of use of **(FEFTS)** from a paved road important? (Please consider for this question very low to					

	be it practically is not affected by distance and very big that a new road will have to be built)					
10	Is the distance from the point of installation and/or point of use of **(FEFTS)** from the electricity grid important? (Please consider for this question very low to be it practically is not affected by distance and very big that a grid extension will have to be built)					
11	How acceptable by local communities do you consider **(FEFTS)** to be?					
12	Do you expect that an investment in **(FEFTS)** will lead to new jobs?					
13	Do you believe that an investment in **(FEFTS)** will create distress (e.g., noise, shadowing, odors) to the local population? (Please consider for this question that very low is no distress at all and very big, very big distress)					
14	Do you believe that and investment in **(FEFTS)** will have an impact on education of the local community (from school students, to vocational training participants)?					
15	Do you believe than an investment in **(FEFTS)** will affect negatively a nearby wildlife / protected area (e.g., natura)? (Please consider for this question very low to be no negative effect and very big to be very big negative effect)					
16	Do you believe than an investment in **(FEFTS)** will affect negatively a nearby cultural and/or archaeological site? (Please consider for this question very low to be no negative effect and very big to be very big negative effect)					
Legend: VL: Very Low L: Low M: Medium B: Big VB: Very big						

Table 8 refers to livestock farming and will have to be filled in for the 12 FEFTS categories related to livestock farming:

1. PV
2. Wind turbines
3. Electricity Storage
4. Biogas
5. Geothermal energy
6. Improved burners / boilers
7. Heat pumps
8. Cooling / Air conditioning
9. Lighting
10. Intelligent Management Systems / Automation
11. Waste for energy generation

Table 8. Questionnaire for livestock farming

No	Question	VL	L	M	B	VB
1	What is the licensing burden for **(FEFTS)**?					
2	What is the defossilization potential for **(FEFTS)**?					
3	How much time is needed from making the decision and securing the budget to have the investment in **(FEFTS)** ready to use (please consider below 1 month as very low, between 1-3 months low, between 4 and 6 months Medium, between 6 and 9 months big, more than 9 months very big)					
4	How much is the farmer's income expected to grow after investing in **(FEFTS)** in your opinion? (Please take in account both the investment cost and the actual expected increase in income)					
5	How easy do you consider is it to secure financing for investing in **(FEFTS)**?					

	(Please consider very low to be very hard to secure financing and very big to be very easy to secure financing)					
6	How suitable is the investment in **(FEFTS)** for a farmer growing pigs?					
7	How suitable is the investment in **(FEFTS)** for a farmer growing bovine animals?					
8	How suitable is the investment in **(FEFTS)** for a farmer growing sheep and goats?					
9	How suitable is the investment in **(FEFTS)** For a farmer growing chickens?					
10	Is the investment in **(FEFTS)** suitable for a herd of below 250 animals?					
11	Is the investment in **(FEFTS)** suitable for a herd between 250 and 1000 animals?					
12	Is the investment in **(FEFTS)** suitable for a herd of above 1000 animals?					
13	Is the distance from the point of installation and/or point of use of **(FEFTS)** from a paved road important? (Please consider for this question very low to be it practically is not affected by distance and very big that a new road will have to be built)					
14	Is the distance from the point of installation and/or point of use of **(FEFTS)** from the electricity grid important? (Please consider for this question very low to be it practically is not affected by distance and very big that a grid extension will have to be built)					
15	How acceptable by local communities do you consider **(FEFTS)** to be?					
16	Do you expect that an investment in **(FEFTS)** will lead to new jobs?					
17	Do you believe that an investment in **(FEFTS)** will create distress (e.g., noise, shadowing, odors) to the local population? (Please consider for this question that very low is no distress at all and very big, very big distress)					
18	Do you believe that and investment in **(FEFTS)** will have an impact on education of the local community (from school students, to vocational training participants)?					
19	Do you believe than an investment in **(FEFTS)** will affect negatively a nearby wildlife / protected area (e.g. natura)? (Please consider for this question very low to be no negative effect and very big to be very big negative effect)					
20	Do you believe than an investment in **(FEFTS)** will affect negatively a nearby cultural and/or archaeological site? (Please consider for this question very low to be no negative effect and very big to be very big negative effect)					
Legend: VL: Very Low L: Low M: Medium B: Big VB: Very big						