Energy Saving Measures in Agriculture

National Reports

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Energy Saving Measures in Agriculture – Overview on the Basis of National Reports

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Key points

1. An overview list was produced that contains 481 energy efficiency improvement measures for the main energy consuming agricultural sectors as reported by the six EU partner countries. The list distinctly indicates the untapped potential for energy savings in agriculture.
2. At present energy efficiency in agriculture is not a policy priority in the EU and only partly so in member countries (an exception is energy use in greenhouses). Nevertheless, innovation and implementation of energy saving measures is already happening in all sectors of agricultural production. To stimulate this process it is estimated that research and innovation is required for at least 80% of the reported measures.
3. Sometimes isolated single-issue energy saving measures can offer a solution, but in other cases a set of coherent measures is necessary to be meaningful, especially when systems innovations are involved. Sometimes, the implementation of energy saving measures require a value chain approach, like precision agriculture, or sometimes require technologies that can be provided to the agricultural sector by supply companies, even in other sectors of the economy. The development and implementation of these measures can be quite complex and long term efforts are needed to realize its potentials.
4. Determination of a specific package of energy efficiency improvement measures for agricultural subsectors (to a great extent country-specific) enables for systemic/holistic research approach where total energy savings in a given production is considered as a synergistic (energy, economic, and environmental) effect.

Summary

The reduction of energy inputs in agricultural production is a process of practical implementation of a set of energy saving (ES) measures associated with a given type of production, farm infrastructure and managerial or organizational activities. In six national reports from Finland, Germany, Greece, the Netherlands, Poland and Portugal for 13 subsectors of agriculture, 481 ES measures in total were identified and classified into seven categories: 1) type of energy input: indirect, direct; 2) type of ES measure: operational level, systems level, process monitoring, farm management, market orientation, capital goods; 3) importance: from 1-low to 5-high; 4) R&D: yes, no; 5) potential of the measure: achievable at present or not immediately ready for implementation; 6) indication of an investment cost: from €1000 to over €1000000; 7) estimated payback time: from 1 to over 5 years.

– The general conclusions from the analysis are as follows.ES measures refer to the reduction of main energy inputs in agricultural production, including fertilizers and pesticides; fuels for powering tractors and other machinery; fuel use for heating, cooling, and ventilation in farm buildings and facilities; electricity use for pumping, lighting; and energy embodied in buildings and equipment.
– In general, the listed ES measures can reduce both direct and indirect energy inputs and the overwhelming majority of the ES measures (443 out of 481) were assessed in the range from 3 (moderate) to 5 (high) in terms of their importance for energy saving. The implementation of part of the ES measures in agricultural practice is achievable at present

(464 out of 481) but will require some advanced research (389 out of 481). In the highly industrialized production of pigs and broilers, there are many ES measures which may be implemented with technologies which are presently on the market such as improved heat insulation, more efficient ventilation, lighting and cooling systems, as well advanced control of the interior climate.

- R&D will be especially important for progress in attaining energy efficiency in agriculture when applied to systems involved in the production process, operational activity and capital goods/farm infrastructure engaged in production.
- The estimated categories of investment costs related to implementation of ES measures vary greatly between subsectors. 1/3 of the total number of the measures can be implemented at a cost under €1000, and 1/3 incur costs in the range from €1000 to €25000. The highest investment costs would be associated with saving energy and improving energy efficiency in greenhouses and livestock production. They are associated with improved heat insulation, more efficient ventilation, lighting and cooling systems, as well advanced control of the interior climate.
- In crop production, energy saving will be considerably affected by the ES measures associated with reduction of diesel fuel use by optimizing the parameters for tractor and machinery use in field operations, reduction of energy use for drying and in produce stores. On the other hand, reduction of indirect energy input is associated with implementation of ES measures related to advanced high-yield and disease-resistant cultivars, application of alternative sources of nutrients and plant protection (organic and green fertilizers, bioactive microorganisms), advanced monitoring of the production process and use of production means in accordance with the soil fertility and plant nutrient uptake (Precision Arable Agriculture with Variable Rate application). The importance of ES activities may be country-specific, e.g. in the southern EU countries more importance will be attributed to the ES measures associated with irrigation of cultivated crops while in the central and north-eastern countries – to the ES measures associated with energy effective drying techniques for the harvested crop..
- In perennial crop production, the majority of ES measures are connected with fertilization, plant protection and field operations.
- In greenhouse production, potential reduction of direct energy inputs is associated with the control of greenhouse atmosphere by energy efficient systems of heating, cooling and ventilation as well optimization of production processes. There are also important measures connected with new solutions for energy recovery and the use of other, alternative sources of energy.
- The structure of ES measures in livestock production depends on the country. In Portugal, Poland and Finland many ES measures are associated with the production of animal feed and the promotion of animal welfare. However in the Netherlands and Germany most of the reported ES measures are related to electricity use and to the buildings and associated infrastructure for livestock production. Energy use in livestock production may be reduced by increased efficiency of production inputs which require energy consumption, e.g. water use and cleaning, heat insulation, ventilation, reduction of amount of ammonia in buildings, heat recovery, energy use optimization for a given production system.

Table of Contents

The list of Tables

1. Introduction

The EU-27 agricultural production consumes around 1.07 EJ[1] of energy, including indirect energy embodied in production means (inorganic fertilizers, pesticides) and direct energy of fuels and electricity. In the total primary energy consumption, the percentage of direct energy use in agriculture is 61%, but in greenhouse production it may increase to 98%[2]. Improved energy efficiency of agricultural production is important for reducing energy consumption and energy related costs. Improvements may be achieved in the production process, in farm infrastructure or on an organizational level. At the pre-farm gate stage, the potential for energy saving may result from different approaches, including the two extreme ones, i.e. adaptation of a new energy efficient technology, which may be considered only in the case of newly established production, e.g. for pig or broiler production, and estimation of a set of energy efficiency improvement measures and ways of their implementation in farm production.

An energy efficiency indicator integrally shows the amount of energy used in the whole value chain up to the product in question. This includes direct energy as well as indircet energy associated with inputs to the production process under considerration. It may be used for 1) monitoring energy efficiency, 2) making an analysis and evaluation of the energy saving policy and 3) estimate the potential of a new, more efficient technology to be developed or implemented. In the energy efficiency indicator pyramid, energy efficiency indicators depend on the level of aggregation and start from operational efficiency of direct production to efficiency of a subsector, sector and the national economy (Phylipsen et al. 1998[3]).

Today, energy efficiency in agriculture is not a priority at the political and research agenda but the process of energy savings in agricultural production is already going on. However the present research activities are fragmented and require co-operation between institutes nationally and transnationally from a coherent and collective vision and approach. This report is an attempt to systematize the energy efficiency improvement measures and point out their potential for energy savings in agriculture.

In this report, energy saving measures specific for 13 subsectors of agricultural production were established and their importance, achievability, cost of implementation and payback time were roughly estimated (expert judgments) and categorized.

The analysis presented of ES measures in agriculture addresses the following objectives:

- to collect energy saving measures which may contribute significantly to energy savings in the most energy-consuming agricultural subsectors of the EU countries,
- to emphasize the importance of reported energy savings measures and which ones may be universal or specific to certain countries,
- to allocate an energy saving measure to the type of farm activity and to assess which of the farm activities is supported by a large set of energy saving measures,

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[1] Eurostat: Final energy consumption, by Agriculture/Forestry [tsdpc320]

[2] Estimation on the basis of the results presented in the agrEE Report: "State of the Art on Energy Efficiency in Agriculture. Country data on energy consumption in different agroproduction sectors in the European countries." 2012.

[3] Phylipsen, G.J.M., Blok, K. and Worrell, E. 1998, Handbook on International Comparisons of Energy Efficiency in the Manufacturing Industry, Department of Science, Technology and Society, Utrecht University.

– to get a rough indication of R&D needed to finally implement a given energy saving measure with sufficient potential to save energy,
– to indicate investment costs and to estimate payback time for implementation of energy saving measures

2. Data

Energy saving (ES) measures were lited in reports from six EU countries: Finland, Germany, Greece, the Netherlands, Poland, and Portugal (Annex). For a given agricultural production, the measures were collected by in-depth interviews with the experts from research institutions and finally formalized in the course of discussions with representatives of the agricultural practice (extension services, leading farms, etc.). It should be noted that this is not a complete and exhaustive list of measures and that the list should thus not be considered as such. It is merely a list to show the variability of measures and to get a good impression of the potential to make agro products more energy-efficient. It is also worthwhile notifying that the list(s) hold no prioritization of the measures involved. This aspect is dealt with in the stakeholder meetings of WP4.

Data from the countries were categorized into seven variables to indicate the potential for energy savings in agriculture. The variables specify the type of measure (scale level of implementation), the nature of the energy input (direct or indirect), an estimation of the potential of teh measure in question, an indication of the investment costs, and an estimation of the pay-back time. The other two variables address the potential of the measure for quick implementation and the need for research. The variables often show interaction, like variables IV and V. The variables do not always fully express the complexity of some ES measures directly, but in general the type of ES measure may coincide with increasing complexity as the scale level of the measure increases. In general, operational measures can be considered to be less complex than value chain based measures. Nevertheless, even operational measures can be complex when co-operation between the agricultural sector and other sectors of the economy are involved (like energy efficient machinery or energy efficient solutions for farm buildings). Farm management based measures may not appear to be simply implementable when training, guidance and knowledge are involved. . For example, a measure that requires advanced research will need extra funds and time for R&D and implementation of the measure into practice will thus be effective only on the longer run. Some of the potential energy saving technologies origin from other sectors of the economy like the Real Time Kinematic (RTK) satellite navigation technique. This can now be used to develop precision agriculture that holds the promise of substantial energy savings several inputs for field crops. Precision agriculture is an example of an innovation that affects not only crop management but also farm and value chain management. This multiscale character of the technology makes development and implementation complex and requires substantial time for the agricultural sector to take full advantage. The same goes for other systems innovations that hold great promise but are also associated with high complexity on different scale levels, like the biobased economy and the valorization of agro waste streams.

The variables are:

I. Type of energy input
 I – indirect energy input
 D – direct energy input

II. Type of ES measure
1. Operational level: an ES measure that is an improvement of a single production activity (production innovations).
2. Systems level: an ES measure that affects and alters the production system and/or its design and thus has implication to a series of activities (systems innovations).
3. Process monitoring: ES measures to monitor and regulate the production process in order to optimize the total process. Mostly, this refers to ICT solutions and management systems. The production system is not altered but the level of individual measures can be optimized.
4. Farm management: these measures refer to the organization of the farm and its activities.
5. Market orientation: these measures refer to production planning so as to match better production to demand, thus decreasing product losses and market research for better techniques or equipment.
6. Capital goods: these measures refer to investments in capital goods or improvements of these goods that lead to improved energy efficiency (buildings, machinery).

III. Importance for energy savings in a given production: this variable reflects the relative potential for energy efficiency improvement.
1 – low
2 – between low and medium
3 – medium
4 – between medium and high
5 – high

IV. Indication for the need of research and development (R&D)
Y – R&D is needed
N – R&D is not needed

V. Indication of whether the measure is achievable at present or whether it is not immediately ready for implementation
A – achievable at present
P – measure with potential but not immediately ready for implementation

VI. Indication of investment cost: there are categories depending on the amount of investment needed to implement a measure in a given subsector.
1. under €1000
2. in the range from €1000 to €25000
3. in the range from €25000 to €1000000
4. over €1000000
5. not applicable

VII. Estimated payback time: there are categories depending on the time when the money invested money for a given measure will give a break-even return.
1. 1 year
2. 1-5 years
3. over 5 years
4. not estimated

3. Results

3.1. General Categorization of Energy Saving Measures

481 ES measures were reported for 13 subsectors of agriculture. Out of that number, 93 were mentioned by more than one partner country (Table 1). These measures could give the indication of being of transnational importance and thus be subject to transnational co-operation. The list of the number of energy saving measures with comments on their implementation, as well their categorization in the seven categories is summarized in the national reports (Annex).

Table 1: The Number of Energy Saving Measures in Subsectors of Agricultural Production Reported by Countries.

	No of ES measures	Finland	Germany	Greece	Netherlands	Poland	Portugal	In total[1]
Wheat	58	9	14	20	16	21	13	93
Sugar beet	30		2		16	17		35
Potatoes	31		2		17	19		38
Sunflower	10		6				6	12
Cotton	19			19				19
Tomatoes	43		4	28	7		12	51
Cucumber	37		4	28	7			39
Sweet pepper	10		4		7			11
Vineyards	24		3	18			16	37
Olive groves	19			18			8	26
Dairy cows	37	7	4		16	7	7	41
Pigs	30	5	7		13	7	3	35
Broilers	40	4	7		21	7	5	44
Total	388	25	57	131	120	78	70	481

[1]the total number of measures includes duplicates as some ES measures were mentioned by more than one of the partner countries.

The seven categories were attributed to the reported ES measures in the agricultural subsectors and associated figures are presented in Table 2. In general, the ES measures have a potential for reducing both direct and indirect energy inputs – the number of ES measures associated with indirect energy inputs is similar to that of the ES measures associated with direct energy inputs (244 vs. 230). In the overwhelming majority of cases (443 out of 481), the importance of ES measures for energy saving was assessed in the range from 3 (moderate) to 5 (high).

All the individual country reports point out that implementation of the ES measures in agricultural practice is potentially achievable at present (464 out of 481) but most of the measures may benefit from further research (389 out of 481).

What is striking about the data concerning R&D is that in the highly industrialized production of pigs and broilers there is a relatively high number of ES measures which may be implemented on the basis of the present-day knowledge. These are measures associated mostly with the production infrastructure (buildings). The commonly reported ES measures are related to the improvement of heat insulation, more efficient ventilation, lighting, and cooling systems, as well control of the inside atmosphere.

Table 2: The Number of ES Measures in Agricultural Subsectors by Categorized Variables.

Variable/ Categories	Wheat	Sugar beet	Potato	Sunflower	Cotton	Tomato	Cucumber	Sweet pepper	Vineyards	Olive groves	Dairy cows	Pigs	Broilers	**In total**
Type of energy input														
Direct[1]	39	13	15	9	6	24+1	22+1	7+1	10	8	23+4	24	30	**230+7**
Indirect	54	22	23	3	13	26	16	3	27	18	14	11	14	**244**
Type of ES measure														
1. Operational	61	29	31	12	6	23	8	3	24	15	19	16	20	**267**
2. Systems	12	3	3		2							1		**21**
3. Monitoring	1	1	1			1	1	1				1	1	**8**
4. Management	2	1	1								3	1	1	**9**
5. Market													1	**1**
6. Capital goods		1	1		1	14	13	7			4	15	20	**76**
Mixed	17	0	1	0	10	13	17	0	13	11	15	1	1	**99**
Importance														
1	2	1							3			1	2	**9**
2	5	1	4	1		6	5			1	3	1	2	**29**
3	30	6	8	4	6	17	12	2	13	10	14	14	19	**155**
4	29	13	13	3	5	17	11	3	13	8	14	14	11	**154**
5	27	14	13	4	8	11	11	6	8	7	10	5	10	**134**
R&D														
Yes	76	28	31	12	16	48	36	10	33	24	35	19	21	**389**
No	17	7	7		3	3	3	1	4	2	6	16	23	**92**
Achievable or Theoretical														
A	89	34	37	12	18	49	38	11	36	25	39	34	42	**464**
P	4	1	1		1	2	1		1	1	2	1	2	**17**
Investment cost														
< 1000	25	14	15	2	11	25	14	1	18	15	7	2	7	**156**
1000-25000	33	16	16	3	4	16	15	5	13	7	12	16	16	**172**
25000-100000	20	2		2	3	8	8	5	4	4	13	11	13	**93**
> 100000	9	3	5		1	2	2				5	5	5	**37**
Not applicable	6		2	5					2		4	1	3	**23**
Payback time (in years)														
< 1 years	11	7	7	2	4	21	10	3	10	7	14	6	14	**116**
1-5 years	55	25	28	8	11	18	17	5	22	16	11	15	15	**246**
> 5 years	17	3	2	1	4	10	10	3	3	3	12	13	12	**93**

Not estimated	10	1	1	2	2	2	4	1	3	**26**

[1] Additional figures mean that the ES measures has the potential for energy saving in both direct and indirect energy input.

The research and development activity will be especially important in studies on energy saving on the operational level and capital goods (infrastructure) engaged in production (Table 4). It is worth noticing that there are 99 measures that cannot be classified in the six individual categories as they affect more scale levels at the same time. The ES measures on the operational level are associated with the production level in 18 cases and interact with process monitoring in 23 cases. The other 26 ES measures of high importance combine activity on the operational level with capital goods.

Table 4. The Number of ES Measures which Require Research by Type of ES Measure and Importance for Energy Saving.

Type of ES measures	Importance					In total
	1	2	3	4	5	
1. Operational level	7	16	83	89	72	267
2. Systems level	1	2	7	5	6	21
3. Process monitoring			3	5		8
4. Farm management			3	2	4	9
5. Market orientation			1			1
6. Capital goods	1	4	30	22	19	76
Mixed categories in total		7	28	31	33	99
1,2			11	6	1	18
1,2,4		1			1	2
1,2,5				1		1
1,2,6			5			5
1,3		2	1	3	17	23
1,3,6				1	3	4
1,4				3	1	4
1,4,6			1	1		2
1,5				1		1
1,6		1	9	8	8	26
2,4			1	1		2
4,5,6				2		2
4,6		2		3	2	7
5,6		1		1		2

The estimated categories of investment costs related to implementation of energy saving measures vary greatly between the subsectors . Despite this variation, most of the measures are estimated to require less than €25,000 of investment to be implemented. One third of the total number of measures could be implemented at a cost of less than €1000, and 1/3 would need €1000 to €25000 (Table 5). The highest investments are associated with saving energy and improving energy efficiency in the greenhouse and livestock production. Around 20% of energy saving measures in the greenhouse production and 50% in the livestock production would require an investment of over €25,000 (the third and fourth categories in the estimate). It should be noted that not all measures were included in the investment cost categories because some may be implemented just by operational or managerial activity at no direct investment cost. It is very promising that over 20% of the reported ES measures may reach break-even in 1 year and 66% of the total number of measures will reach break-even in less than 5 years. There is a longer payback time for implementation of ES measures in the greenhouse and livestock infrastructure and buildings. In general, the higher the investment associated with implementation of ES measure, the longer the payback time (Table 5) as can be expected.

Table 5. The Number of ES Measures Classified by Investment Cost and Payback Time.

Investment cost	Payback time			
	< 1 years	1 – 5 years	> 5 years	Not estimated
< 1000	94	67		
1000-25000	16	126	23	7
25000-100000	8	34	50	1
> 100000	2	15	20	
Not applicable		5		18

3.2. Energy Saving Measures by Subsectors of Agriculture

The ES measures which occur most often in the discussed agricultural subsectors and countries are associated with crop production and include activities which enable reduction of indirect energy inputs on production means such as fertilizers and pesticides, application of high quality sowing/planting material and bioactive microorganisms, as well as reduction of direct energy use in transportation and agricultural infrastructure engaged in production e.g. dryers, crop stores, cowsheds, piggeries, poultry sheds, etc. (Table 6). It should be noticed that the energy saving effects of the following ES measures are not always straightforward. Implementation of many of them require consideration in a broader context of good agricultural practice, precision agriculture, available machinery, and/or thorough calculation of economic and environmental consequences with estimation of trade-off effects.

Table 6. The ES Measures frequently mentioned Across Agricultural Subsectors and Countries.

	ES measure	No
1	Application in accordance with soil fertility and availability of the compounds	24
2	Reduced use of herbicides	18
3	Rational use of transportation	15
4	Appropriate power of the tractor and other machinery to the field operations	13
5	Reduced use of fungicides	12
6	Increased use of organic fertilizers	11
7	Reduced use of pesticides	11
8	Application of bioactive microorganisms/insects	10
9	Better heat insulation	10
10	High quality seeds	9
	Multi-compound fertilizer use	9
	No tillage	9
	Reduced use of synthetic fertilizers	9

The number of ES measures associated with direct and indirect energy inputs differs significantly depending on the agricultural subsectors (Table 7). In wheat, sugar beet, and potato production, as well as in sunflower production in Germany direct energy use shares about 30 % - 50 % of the total specific energy use[4]. This means that only a little higher potential for energy savings is associated with reduction of indirect energy use. The extremely high direct energy use, over 90%, is for sunflower production in Portugal and for cotton production in Greece. Thus, in these cases the inputs associated with direct energy use may contribute significantly to energy savings.

In the arable land production, the ES measures are mostly associated with saving energy in indirect energy inputs while in the greenhouse and livestock production, most of the ES measures are related to direct energy inputs. Across the EU countries, a high energy saving potential in the arable land production can be attributed to a reduction of diesel and fertilizers use. In the case of wheat, potato and sunflower production, significant energy savings may result from reduced direct energy use for drying, storage and irrigation.

Table 7: Direct and Indirect Energy Inputs in Association with the Number of ES Measures.

Subsector	Energy inputs and the number of associated ES measures (in brackets)	The number of ES measures in relation to energy input	
		Direct[1]	Indirect
Wheat	Diesel use (25); Nitrogen (15); Energy use (11); Fertilizers (9); Seeds (5); Herbicides (4); Irrigation (3); Pesticides (3); Bioactive microorganisms (2); Fertilizers in relation to crop rotation (2); Fungicides (2); Harvesting (2); Phosphorus (2); Potassium (2); Calcium (1); Energy use control (1); Limiting grain losses during harvest (1); Plant breeding (1); Storage (1); Sulfur (1)	39	54
Sugar beet	Diesel use (12); Nitrogen (9); Fertilizers (4); Seeds (3); Pesticides (2); Bioactive microorganisms (1); Energy use control (1); Fertilizers in relation to crop rotation (1); Phosphorus (1); Potassium (1)	13	22
Potato	Diesel use (11); Nitrogen (8); Fertilizers (7); Pesticides (4); Seeds (2); Storage (2); Bioactive microorganisms (1); Energy use control (1); Fertilizers in relation to crop rotation (1); Sorting (1)	15	23
Sunflower	Diesel use (6); Herbicides (2); Energy use (1); Nitrogen (1); Pesticides (1); Seeds (1)	9	3
Cotton	Fertilizers (7); Diesel use (4); Harvesting (2); Irrigation (2); Bioactive microorganisms (1); Fungicides (1); Herbicides (1); Seeds (1)	6	13
Tomatoes	Energy use (13); Building/Construction (10); Fertilizers (6); Irrigation (4); fungicides (3); Plant growth control (3); Herbicides	24(+1)	26

[4] Deliverable 2.1.

	(2); Pesticides (2); Diesel use (1); Insecticides (1); Nematocide (1); Nitrogen (1); Phosphorus (1); Potassium (1); Seeds (1); Substrate (1)		
Cucumber	Energy use (13); Building/Construction (9); Fertilizers (6); Irrigation (3); Plant growth control (3); Fungicides (2); Diesel use (1); Herbicides (1); Pesticides (1)	22(+1)	16
Sweet pepper	Energy use (10); Irrigation (1)	7(+1)	3
Vineyards	Fertilizers (10); Diesel use (8); Herbicides (4); Nitrogen (3); Irrigation (3); Fungicides (2); Insecticides (1); Pesticides (2); Seeds (1); Bioactive microorganisms (1); Phosphorus (1); Potassium (1)	10	27
Olive groves	Diesel use (6); Fertilizers (6); Herbicides (4); fungicides (2); Irrigation (2); Bioactive microorganisms (1); Insecticides (1); Nitrogen (1); Phosphorus (1); Potassium (1); Seeds (1)	8	18
Dairy cows	Feed (19); Energy use (12); Diesel use (5); Ventilation (2); Veterinary Drugs & Service (2); Water use (1); Building/Construction (1); Diesel and labour use (1); Feed additives (1); Lighting (1)	23(+4)	14
Pigs	Building/Construction (17); Feed (6); Energy use (6); Water use (1); Diesel use (1); Feed additives (1); Lighting (1); Ventilation (1); Veterinary Drugs & Service (1);	24	11
Broilers	Building/Construction (23); Feed (5); Energy use (6); Diesel use (3); Spatial planning (2); Water use (1); Feed additives (1); Lighting (1); Ventilation (1); Veterinary Drugs & Service (1);	30	14

[1] Figures in brackets mean that the ES measures has the potential for energy saving in both direct and indirect energy input.

Most of the ES measures reported for greenhouse production are associated with reduced energy use for production, modernization of greenhouses and then fertilizer use and irrigation. In Central Europe the direct energy input is predominant accounting for over 99% of the total energy input, while in the Southern countries it accounts for 10-40% of the total energy input.[5] Thus, the reduction of direct energy use in greenhouse production will be essential for energy savings in Central Europe while in the Southern countries a greater impact on energy savings will have reduction of indirect energy inputs.

In livestock production, the ES measures vary between the subsectors; for dairy cow production significant energy savings are anticipated from an improvement in feed quality and reduced use of energy to distribute the feed, followed by direct energy input associated

[5] Deliverable 2.1

with energy and diesel use; in pig and broiler production the dominant ES measures are related to refurbishment of buildings, followed by better feed quality and reduced direct energy use.

3.3. Energy Saving Measures in Annual Crop Production

In crop production, most ES measures are associated with fertilization and field operations, although a substantial potential for energy savings may also be assigned to the measures related to post-harvest activities (drying, storage) and other activities, e.g. application of bioactive organisms, change of agricultural systems (such as minimum tillage or controlled traffic farming) and implementation of a monitoring system over energy use (such as supervisory control and data acquisition).

Table 8: Crop production – the number of energy saving measures by process.

Process	Wheat	Sugar beet	Potatoes	Sunflower	Cotton	In total
Sowing	5	2	2	2	1	12
Fertilization	30	15	15	1	7	68
Plant protection	9	2	4	3	2	20
Irrigation	3				2	5
Field operation	26	12	11	6	4	59
Harvest	3	1	1		2	7
Post-harvest	12		2			14
Other	5	3	3		1	12

The list of measures with an acknowledged potential for energy saving in the crop production is shown in Table 9. Reduction of diesel use for tillage and other field operations as well as optimizing the use of tractors and machinery in field operations, energy saving in drying process and crop stores and improved production management are among the measures with high energy saving potential. Energy saving by reducing indirect energy input is associated with advanced, high-yield and disease-resistant cultivars, application of alternative sources of nutrients and plant protection (organic and green fertilizers, bioactive microorganisms), advanced monitoring of the production process and use of production means in accordance with the soil fertility and plant nutrient uptake. Independently of the energy inputs, high energy saving potential is anticipated from the research related to the systems innovations (measures on higher scale level than the operational level) The listed measures are universal but the importance may vary between countries with stronger or weaker impact on the total energy input for a given production type. In the southern EU countries, energy saving by reducing energy use for crop drying will be less important while energy saving associated with irrigation of cultivated crops will have more importance. Also, a country-specific crop, like cotton in Greece, may require special attention in order to improve water management by energy efficient drip irrigation systems.

Table 9: Crop production – measures with a potential for energy savings in direct and indirect energy inputs.

Factor of production	ES measures for reduction of direct energy inputs
Tillage	no tillage or minimum tillage systems; Controlled Traffic Farming; Autosteer with RTK
Tractors and machinery	matching of the power tractor and other machinery to what is neede in field operations and transportation; proper tire size, tire pressure and weight of front axle, machinery aggregation, combined application of production means;
Production system	modification to organic or integrated production system; Precision Arable Farming; Controlled Traffic Farming
Infrastructure	prevention of heat loss from dryers and crop stores; heat recovery using heat pumps, use of energy from farm residuals
Other	research on development of energy efficient process control, innovative drying and storage systems, optimization of dryer and crop store designs
Factor of production	**ES measures for reduction of indirect energy inputs**
Seeds/tubers	new cultivars with high yield potential and lower energy inputs per unit of production
Fertilizers	application of fertilizers in accordance with soil fertility and availability of the nutrients, dosing in relation to crop uptake; application of bioactive microorganisms, green fertilizer application, multi-compound fertilizers; organic fertilization on the basis of N fertilizer working coefficient; replacement of synthetic N fertilizer with biological nitrogen fixing; cultivation of green manure crops
Pesticides	bioactive microorganisms; site specific application of pesticides; disease resistant cultivars
Other	Improvement in management of fertilizers, pesticides, and water use; research and market research for energy efficient innovative solutions in production; yield mapping; proper plant rotation; reduced harvest and post-harvest losses

3.4. Energy Saving Measures in Perennial Crop Production

The ES measures in production of vineyards and olive groves were reported by Germany, Greece and Portugal. The ES measures in aspects of the production process are presented in Table 10. These are ES measures associated mostly with fertilization (24), plant protection (16) and field operations (12). Production in Greek vineyards and olive groves also includes 5 ES measures associated with irrigation.

Table 10: Perennial crop production – the number of energy saving measures by process and main ES measures in reduction of direct and indirect energy inputs.

Process	Vineyards	Olive groves	In total

	Germany	Greece	Portugal	Greece	Portugal	
Sowing			1		1	2
Fertilization		6	9	6	3	24
Plant protection	2	3	4	4	3	16
Irrigation		3		2		5
Field operation	1	4	2	4	1	12
Harvest		1		1		2
Other		1		1		2
The main ES measures in reduction of direct and indirect energy inputs.						
Direct energy use	no or reduced tillage, appropriate power for loaders, trucks and other machinery to harvest and transport olives and grapes; water management – soil coverage; use of energy efficient pumps					
Indirect energy use	High quality plants; reduced use of fertilizers, pesticides (by precision application); increased use of organic fertilizers; application of bioactive microorganisms; improved fertilizer management related mainly to nitrogen (division of dose, efficient utilization)					

3.5. Energy Saving Measures in Greenhouse Production

Most ES measures in the greenhouse production are associated with production operations and greenhouse design and process control (infrastructure) (Table 11). Subsequently there are ES measures associated with fertilization, plant protection and irrigation.

Table 11: Greenhouse Production – the Number of Energy Saving Measures by Process.

Process	Tomato	Cucumber	Sweet pepper	In total
Sowing	1			1
Fertilization	9	6		15
Plant protection	9	4		13
Irrigation	4	3	1	8
Field operation	1			1
Production operations	17	17	4	38
Greenhouse infrastructure	10	9	6	25

The ES measures which have potential for reduction of direct energy inputs are associated with the control of greenhouse atmosphere by energy efficient systems and/or new greenhouse designs related to heating, cooling and ventilation as well optimizing production processes. There are also important measures which refer to new solutions in energy recovery and the use of alternative sources of energy (e.g. geothermal energy, waste heat from industrial or other sources including Municipal Waste and Combined Heat and Power). The ES measures associated with greenhouse infrastructure are connected with reducing both direct and indirect energy use. They will mostly affect modernization of greenhouses and synchronization of the control system of greenhouse atmosphere with the physiology of plant growth and development. Among the ES measures which have potential for reduction of indirect energy use are measures associated with reducing fertilizer and pesticide use, application of bioactive microorganisms and management of the production processes. In the mentioned greenhouse production activities expressed in ES measures, R&D activity is also required.

Table 12: Greenhouse Production – the Main ES Measures in Reduction of Direct and Indirect Energy Inputs

Factor of production	ES measures associated with reduction of direct energy inputs
Energy use	optimization of energy parameters of the production process (heating/cooling/ventilation); heat recovery from exhaust air of ventilation; geothermal energy use; reduced use of fuel for heating; lowered temperature set point
Greenhouse infrastructure	double thermal screen; adaptive set-points; increased set point for air relative humidity; shading system during summer period; crop based humidity control, crop based use of energy screen
Production process	irrigation - optimal water input; energy efficient application of fertilizers and pesticides; reduction of crop transpiration
Other	R & D in greenhouse design and technologies; improved management of water use; fertilization and plant protection; decision support models
Factor of production	ES measures associated with reduction of indirect energy inputs
Seeds/	plant breeding, high quality seeds and seedlings
Production means	optimal fertilizer doses and division of doses; application of bioactive microorganisms; application of organic fertilizers; reduction of fertilizers and pesticides use
Greenhouse infrastructure	anti-reflection glass; greenhouse cover film with anti-drip coating that removes condensed water; wind brake at the north side of the greenhouse
Other	Market research and research on new solutions in greenhouse production

In greenhouse production ES measures have specific meaning depending on the geographical location of production. Firstly, improved energy efficiency in the central European countries, Germany and the Netherlands, is related to energy saving in direct energy inputs so the ES measures are associated with greenhouse infrastructure and optimization of production processes in relation to the atmosphere inside a greenhouse and to irrigation. In Southern Europe, i.e. Greece and Portugal, where greenhouse production is operated at higher ambient temperature and often directly on soil, together with the ES measures associated with greenhouse infrastructure and irrigation, there are many other measures which are quite commonly used for production of arable crops, including fertilization in accordance with soil fertility and nutrient availability as well as reduced use of production inputs (fertilizers, pesticides).

3.6. Energy Saving Measures in Livestock Production

There are different structures of ES measures depending on the country (Table 13). In Portugal, Poland and Finland, numerous ES measures are associated with the distribution of the feed and welfare of animals, while in the Netherlands and Germany most of the reported

ES measures are related to electricity use as well as buildings and associated infrastructure of the livestock production. Noteworthy are the unique measures on spatial planning reported by the Netherlands, which concern the applicability of animal manure in arable farming.

Table 13: The number of ES measures in livestock production by Process and Countries.

Process elements	Germany	Finland	Netherlands	Poland	Portugal
Feed (+feed additives)	4	6	6	3+3	7
Water use					3
Veterinary drugs & service	1			3	
Energy use	9		9	5	1
Diesel (+and labour) use	1	1	2+1	3	2
Building/Construction	3	2	30	4	2
Lighting		3			
Ventilation		4			
Spatial planning			2		
In total	18	16	50	21	15

Energy use in livestock production may be reduced by increasing the efficiency of production inputs which have impact on energy consumption, like water use and cleaning, heat insulation, ventilation, reduction of ammonia concentration in buildings, heat recovery, and optimizing energy use for a given production type (Table 14). In animal production, it is also important to decrease diesel use by matching the power of tractors and other machines to the production operations as well rationalizing the use of transportation. In the case of indirect energy inputs, there are many ways to save energy, e.g. by increasing feed quality and efficiency of feeding, which result in higher production at lower energy input. Other examples to maximize the use of feed include activity sensors to detect oestrus in dairy cattle, sows etc to optimize timing of insemination minimize breeding cycles and reduce unnecessary culling. Liveweight gain of meat animals can be monitored by Image Analysis, careful monitoring of water and feed intake and used with models to optimize feed conversion. Other sensors (acoustic, water consumption etc) can be used to indicate to the stockmen when animals are beginning to fail to thrive. Other important factors are fodder production from own feedstock, feed conservation methods and water management. Some other measures are associated with the conditions of maintenance and welfare of animals.

Table 14: Livestock Production – the Main ES Measures in Reduction of Direct and Indirect Energy Inputs

Factor of production	ES measures associated with reduction of direct energy inputs
Energy use	efficient water cleaning, pumping system, heating system, lighting with low energy consumption, optimization of production process, heat recovery, energy production from farm residuals
Diesel use	decreasing diesel use by appropriate power of the tractor and other machines to the production operations and rational use of transportation
Buildings	efficient heat insulation, ventilation, fans, lighting system, reduction of ammonia, use of recovery energy for drying of manure, use of heat exchangers,

	control of inside climate
Other	spatial planning, use of animal residues for energy production
Factor of production	ES measures associated with reduction of indirect energy inputs
Feed and feeding	higher quality of fodder, feeding in accordance with specific animal needs, better fodder utilization and less energy use for producing of young animals, improvement of feeding value, reduced use of concentrates, replacement of compound feed by home grown production, water management; cultivation of silage lays consisting of mixture of legumes and grasses
Vet & service	new drugs, maintenance of animals, service life of dairy cows

Recapitulation

The reduction of energy inputs in agricultural production is a process of practical implementation of a set of energy saving measures associated with a given type of production, farm infrastructure and managerial or organizational activities. Improvements in energy efficiency may be achieved in many areas of the production process, including operational level, farm or value chain level, process monitoring, market orientation, capital goods. All of these activities were pivotal categories for classification of ES measures. Furthermore, the ES measures were classified according to: type of energy input, importance of the measure, call for R&D activity, potential for implementation, indication on investment cost, and estimated pay-back time. In six national reports from Finland, Germany, Greece, the Netherlands, Poland and Portugal for 13 subsectors of agriculture 481 ES measures in total were identified and classified into seven categories with a country-specific meaning based on expert knowledge available. The ES measures refer to the reduction of main energy inputs, including fertilizers and pesticides; fuel use for tractors and other machinery; fuel and energy use for heating, cooling, and ventilation in farm buildings and facilities; electricity use for pumping, lighting; and energy embodied in buildings and equipment. In the highly industrialized production of pigs and broilers, there are many ES measures which may be implemented with technologies which are present on the market such as improved heat insulation, more efficient ventilation, lighting and cooling systems, as well advanced control of the interior climate. Over 80% of ES measures call for advanced research. However there is considerable overlap of ES measures that can be used now but that would also benefit from further research. R&D will be especially important for progress in realizing a higher level of energy efficiency in agriculture when applied at production level as well on farm or even value chain level and regarding capital goods/farm infrastructure. The estimated investment costs related to implementation of energy saving measures are estimated to vary greatly between subsectors. Two thirds of the total number of the measures are estimated to be implemented at a cost under €25,000 while the highest investment costs of a single ES measure are associated with improvements of energy efficiency in the greenhouse and livestock production.

Annex

Country Reports – Categorization of Energy Saving Measures

The following tables 1-6 contain data from country reports on potential ES measures in agriculture with categorization of seven variables. The ten columns of the tables include the following data:

No of column	Explanation
1	Agriculture subsector / Energy input
2	Type of energy input: I – indirect; D – direct
3	Type of ES measure: 1: Operational level; 2: Systems level; 3: Process monitoring; 4: Farm management; 5: Market orientation; 6: Capital goods
4	ES measure
5	Importance for energy saving in a given production: 1-low importance – 5-high importance
6	Indication for the need of research and development (R&D): Y – R&D is needed; N – R&D is not needed
7	Description of ES measures in the context of implementation
8	Indication if the measure is: A – achievable at present; P – with a potential but not immediately ready for implementation
9	Indication on investment cost: 1: under €1000; 2: in the range from €1000 to €25000; 3: in the range from €25000 to €1000000; 4: over €1000000; 5: not applicable
10	Estimated payback time: 1: 1 year; 2: 1-5 years; 3: Over 5 years; 4: Not estimated

Report 1: Energy Saving Measures Categorized for Chosen Subsectors of Finnish Agriculture

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Agricultural subsector/ Energy input	I/D	Type of ES measure	ES measure	Importance	R&D Y/N	Description of the needs in order to implement ES measure	A/P	Cost of implementation	Payback time
1	2	3	4	5	6	7	8	9	10

Wheat

Nitrogen	I	1	Reduced use of synthetic N fertilizer by site specific N application	3	Y	GPS, advanced application control, yield mapping	A	3	3
Nitrogen	I	2	Replacement of synthetic N fertilizer with biological nitrogen fixing	4	Y	education and economic baits for farmers to increase the share of leguminous plants in crop rotation	A	4	2
Pesticides	I	1	Reduced use of pesticides by site specific application	3	Y	GPS, advanced application control, premonitoring of weeds, diseases and insects	A	3	3
Plant breeding	I	4	Higher yields with lower energy inputs (plant breeding)	5	Y	Plant breeding	A	4	3
Diesel use	I	1	Lower specific energy consumption for field operation	4	Y	Replacement of old machinery with more energy efficient machinery, energy labels and certifications	A	4	2
Diesel use	D	1	No tillage	3	N	Direct drill	A	3	3
Diesel use	D	1	Reduction of tillage	5	N	A tillage implement for stubble cultivation and a seeding machine which can operate on trash covered soil	A	3	3
Diesel use	D	2	Training of fuel economic tractor operating manners	3	N	Online monitoring of fuel consumption l/ha or l/h	A	2	2
Energy use	D	1	Better heat insulation (prevention of heat losses from a grain dryer furnace and drying silo)	3	N	Purchase of heat insulation material and a few days of labour	A	2	2

1	2	3	4	5	6	7	8	9	10

Dairy cows

Feed	I	1	Cultivation of silage lays consisting of mixture of legumes and grasses (today mostly only grasses)	5	Y	Possibilities to control the variation of the yield year by year	A	1	1
Feed	I	1	Replacement of drying with fresh conservation methods in fodder (cereals) production	5	Y	Air tight silos or other storage facilities instead of grain driers.	A	3	3
Diesel use	D	1	Lower specific energy consumption	4	Y	Replacement of old machinery with more energy efficient machinery, energy labels and certifications	A	3	3
Ventilation	D	1	Heat recovery from outlet air	3	Y	A heat exchanger to the ventilation system	A	3	3
Lighting	D	1	Less energy for lightening	4	N	Replacement of old lamps with energy efficient light fittings	A	3	3
Ventilation	D	1	Reduced energy for ventilation	3	Y	Gravity ventilation instead of forced ventilation, automated inlet openings	A	3	3
Feed	I	4	Better fodder efficiency and less energy for producing young animals	5	Y	Market research	A	3	3

Pigs

Feed	I	1	Replacement of drying with fresh conservation methods in fodder (cereals) production	5	Y	Air tight silos or other storage facilities instead of grain driers.	A	3	3
Building/Construction	I	6	Better heat insulation	4	N	Stricter heat insulation requirements for new animal buildings	A	3	3
Ventilation	D	1	Heat recovery from outlet air	3	Y	A heat exchanger to the ventilation system	A	3	3
Lighting	D	1	Less energy for lightening	4	N	Replacement of old lamps with energy efficient light fittings	A	3	3
Feed	I	4	Better fodder efficiency and less energy for producing young animals	5	Y	Market research	A	3	3

1	2	3	4	5	6	7	8	9	10

Broilers

Feed	I	1	Replacement of drying with fresh conservation methods in fodder (cereals) production	5	Y	Air tight silos or other storage facilities instead of grain driers.	A	3	3
Building/Construction	I	6	Better heat insulation	4	N	Stricter heat insulation requirements for new animal buildings	A	3	3
Ventilation	D	1	Heat recovery from outlet air	3	Y	A heat exchanger to the ventilation system	A	3	3
Lighting	D	1	Less energy for lightening	4	N	Replacement of old lamps with energy efficient light fittings	A	3	3

Report 2: Energy Saving Measures Categorized for Chosen Subsectors of German Agriculture

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Agricultural subsector/ Energy input	I/D	Type of ES measure	ES measure	Importance	R&D Y/N	Description of the needs in order to implement ES measure	A/P	Cost of implementation	Payback time
1	2	3	4	5	6	7	8	9	10

Wheat

Seeds	I	1	Plant breeding	4	Y	Plant breeding	A	5	4
Nitrogen	I	1	Reduced N-input	4	Y	Advisory systems	A	5	4
Herbicides	I	1	Reduced use of herbicides	3	Y	Advisory systems	A	5	4
Pesticides	I	1	Reduced use of pesticides	1	Y	Advisory systems	A	5	4
Diesel use	D	1	No tillage	3	Y	Investment in chisel plow	A	2	2
Diesel use	D	1	Precision farming	3	Y	Decision to invest in; sufficient liquidity	A	3	2
Energy use	D	1	Active heat recovery using heat pumps	4	Y	Applied research, investment	A	3	2
Energy use	D	1	Basic research on agricultural drying	3	Y	Basic research	A	5	4
Energy use	D	1	Development of energy efficient process control	5	Y	Applied research, investment	A	3	2
Energy use	D	1	Development of innovative drying processes	4	Y	Applied research	A	5	4
Energy use	D	1	Development of new optimized dryer designs	5	Y	Applied research, investment	A	4	2
Energy use	D	1	Improved drying process	4	Y	Investment	A	4	3
Energy use	D	1	Passive heat recovery (heat exchangers, heat insulation)	4	N	Investment	A	3	2
Energy use	D	1	Utilization of waste heat from (e.g. biogas, combined heat & power plants)	4	N	Investment	A	3	2

1	2	3	4	5	6	7	8	9	10
Sugar beat									
Seeds	I	1	Plant breeding	4	Y	Plant breeding	A	4	3
Diesel use	D	1	Precision farming	3	Y	Investment in machinery	A	3	2
Potato									
Nitrogen	D	1	Reduced N-input	4	Y	Precision agriculture	A	5	2
Diesel use	I	1	Plant breeding	4	Y	Plant breeding	A	5	4
Sunflower									
Energy use	I	1	Plant breeding	4	Y	Sowing of high quality seeds	A	5	4
Nitrogen	D	1	Reduced N-input	4	Y	Precision agriculture	A	5	2
Herbicides	D	1	Reduced use of herbicides	3	Y	Rational use of pesticides	A	5	2
Pesticides	D	1	Reduced use of pesticides	3	Y	Rational use of herbicides	A	5	2
Diesel use	D	1	No tillage	3	Y	Improvement on efficiency of the production process	A	5	2
Diesel use	D	1	Precision farming	3	Y	Improvement on efficiency of the production process	A	3	2
Tomato									
Irrigation	D	1	Irrigation - optimal water input	5	Y	Research for optimal water input	A	2	2
Energy use	D	6	Energy efficient heat insulation	5	Y	Analysis of housing structure	A	2	2
Energy use	D	6	Heat recovery from exhaust air of ventilation	4	Y	installation of state of the art ventilation systems	A	3	2
Energy use	D	3	Optimization of energy parameters of the production process (heating/cooling)	4	Y	Monitoring of production process	A	2	1

1	2	3	4	5	6	7	8	9	10
Cucumber									
Irrigation	D	1	Irrigation - optimal water input	5	Y	Research for optimal water input	A	2	2
Energy use	I	6	Energy efficient heat insulation	5	Y	Analysis of housing structure	A	2	2
Energy use	D	6	Heat recovery from exhaust air of ventilation	4	Y	installation of state of the art ventilation systems	A	3	2
Energy use	D	3	Optimization of energy parameters of the production process (heating/cooling)	4	Y	Monitoring of production process	A	2	1
Sweet pepper									
Energy use	I	6	Energy efficient heat insulation	5	Y	Analysis of housing structure	A	2	2
Energy use	D	6	Heat recovery from exhaust air of ventilation	4	Y	installation of state of the art ventilation systems	A	3	2
Energy use	D	1	Irrigation - optimal water input	5	Y	Research for optimal water input	A	2	1
Energy use	D	3	Optimization of energy parameters of the production process (heating/cooling)	4	Y	Monitoring of production process	A	2	1
Vineyards									
Herbicides	I	1	Reduced use of herbicides	3	Y	Advisory systems	A	5	4
Pesticides	I	1	Reduced use of pesticides	1	Y	Advisory systems	A	5	4
Diesel use	D	1	Reduced tillage	3	N	Investment	A	2	2

1	2	3	4	5	6	7	8	9	10

Dairy cows

Feed	D/I	2,4	Efficient use of pasture	3	Y	efficient use of pasture	A	5	4
Feed	D/I	1,2,4	Feeding in accordance with specific animal needs	5	Y	optimizing of diet concerning performance of animal, it is to consider that roughage has in average a lower energy intensity for its production than concentrate	A	5	4
Feed	I	1	Optimization of application of fertilizers	5	Y	optimizing of plant production process	A	5	4
Veterinary drugs&Service	D/I	1,2	Service life of dairy cows	5	Y	improvement of animal welfare in barns to avoid diseases	A	5	4

Pigs

Feed	I	1	Energy efficient feed production	3	N	Precision farming, no tillage farming, low N-Input production system	A	3	2
Energy use	D	1	Manure management (biogas production)	4	Y	Investment in biogas technology	A	4	3
Energy use	D	3	Optimization of energy parameters of the production process (heating/cooling)	4	Y	Monitoring of production process	A	2	1
Building/Construction	D	6	Energy efficient heat use	5	N	Analysis of housing structure	A	2	3
Energy use	D	6	Heat recovery from exhaust air of ventilation	4	N	installation of advanced ventilation systems	A	3	2
Building/Construction	D	6	Housing tightness, no air leaks	5	N	Analysis of housing structure and identification of possible air leaks	A	2	2
Energy use	I	1	Animal breeding	3	Y	New breeding programms	A	5	4

1	2	3	4	5	6	7	8	9	10

Broilers

Diesel use	I	1	Energy efficient feed production	3	N	Precision farming, no tillage farming, low N-Input production system	A	3	2
Energy use	I	1	Manure management (Biogas production)	5	Y	Decision to invest in biogas technology; sufficient liquidity	A	4	3
Energy use	D	3	Optimization of production process	4	Y	Monitoring of production process	A	2	1
Energy use	D	6	Energy efficient heat use	5	N	Analysis of housing structure	A	2	3
Energy use	D	6	Heat recovery from exhaust air of ventilation	4	N	installation of state of the art ventilation systems	A	3	2
Building/Construction	I	6	Housing tightness, no air leaks	5	N	Analysis of housing structure and identification of possible air leaks	A	2	1
Energy use	I	1	Animal breeding	3	Y	New breeding programs	A	5	4

Report 3: Energy Saving Measures Categorized for Chosen Subsectors of Greek Agriculture

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Agricultural subsector/ Energy input	I/D	Type of ES measure	ES measure	Importance	R&D Y/N	Description of the needs in order to implement ES measure	A/P	Cost of implementation	Payback time
1	2	3	4	5	6	7	8	9	10

Wheat

Seeds	I	1	High quality seeds	4	Y	new breeding programs for new cultivars	A	4	3
Fertilizers	I	1,3	Application in accordance with soil fertility and availability of the compounds	5	Y	analysis of the content of macro and micronutrients - precision agriculture	A	1	1
Nitrogen	I	1,3	Division of N doses	5	Y	analysis of the content of macro and micronutrients - precision agriculture	A	1	2
Fertilizers	I	1	Improved fertilizer management - efficient application and utilization	4	Y	precision agriculture	A	3	3
Fertilizers	I	1	Increased use of organic fertilizers	3	Y	organic or integrated agriculture system; conservation tillage (left 30% of residues)	A	1	2
Fertilizers	I	1	Multi-compound fertilizer use	4	Y	new more effective forms of multi-compound-fertilizers fertilizers	A	1	2
Fertilizers	I	1	Reduced use of synthetic fertilizers	5	Y	integrated fertilization	A	1	2
fungicides	I	1,2	Reduced use of fungicides	3	Y	Organic or integrated agriculture system; proper crop rotation; cultivars	A	1	2
herbicides	I	1,2	Reduced use of herbicides	3	Y	organic or integrated agriculture system; proper crop rotation; cultivars	A	1	2

1	2	3	4	5	6	7	8	9	10
Irrigation	D	4, 6	Reduction of electricity use by use of energy efficient pumps	4	N	market research on high efficiency pumping systems	A	2	3
Irrigation	D	1,3, 6	Water management-drip irrigation	5	N	analysis of the exact irrigation needs per ha	A	2	2
Diesel use	D	1, 6	Appropriate power of the tractor and other machines to the field operations	5	Y	the proper power of tractor	A	3	3
Diesel use	D	1, 6	No tillage	3	Y	new "no till farming" crop production technologies; application of proper machinery	A	3	2
Diesel use	D	1	Rational use of transportation	3	Y	combined tillage operations to avoid multiple transports from the village to the field	A	1	1
Diesel use	D	1, 6	Reduction of tillage	5	Y	new "reduced tillage" crop production technologies; application of proper machinery	A	3	2
Harvesting	D	2	Less transport	3	N	organize sequential harvesting to many small scale fields	A	1	1
Harvesting	I	1, 6	Yield mapping	5	Y	precision agriculture	A	2	2
Storage	I	1, 6	Reduction of electricity use	3	Y	change or improve aeration system	A	2	2
Bioactive microorganis ms	I	1,2	Application of bioactive microorganisms/insects	4	Y	organic or integrated agriculture system	P	1	2
Fertilizers in relation to crop rotation	I	2	Proper plant rotation - reduction of fertilizer use	3	Y	organic or integrated agriculture system; conservation tillage (left 30% of residues)	A	2	2

Cotton

Seeds	I	1	High quality seeds	4	Y	new breeding programs for new cultivars	A	4	3
Fertilizers	I	1,3	Application in accordance with soil fertility and availability of the compounds	5	Y	analysis of the content of macro and micronutrients - precision agriculture	A	1	1
Fertilizers	I	1,3	Division of doses	5	Y	analysis of the content of macro and micronutrients - precision agriculture	A	1	2
Fertilizers	I	1	Improved fertilizer management - efficient application and utilization	4	Y	precision agriculture	A	3	3
Fertilizers	I	1	Increased use of organic fertilizers	3	Y	organic or integrated agriculture system; conservation tillage (left 30% of residues)	A	1	2
Fertilizers	I	1	Multi-compound fertilizer use	4	Y	new more effective forms of multi-compound-fertilizers fertilizers	A	1	2
Fertilizers	I	2	Proper plant rotation - reduction of fertilizer use	3	Y	organic or integrated agriculture system; conservation tillage (left 30% of residues)	A	2	2
Fertilizers	I	1	Reduced use of synthetic fertilizers	5	Y	integrated fertilization	A	1	2
Fungicides	I	1,2	Reduced use of fungicides	3	Y	Organic or integrated agriculture system; proper crop rotation; cultivars	A	1	2
Herbicides	I	1,2	Reduced use of herbicides	3	Y	organic or integrated agriculture system; proper crop rotation; cultivars	A	1	2
Irrigation	I	4, 6	Reduction of electricity use	4	N	market research on high efficiency pumping systems	A	2	3
Irrigation	D	1,3, 6	Water management-drip irrigation	5	N	analysis of the exact irrigation needs per ha	A	2	2
Diesel use	D	6	Appropriate power of loaders and trucks to transport seed cotton	5	Y	the proper power of loaders and trucks	A	1	1

1	2	3	4	5	6	7	8	9	10
Diesel use	D	1, 6	Appropriate power of the tractor and other machines to the field operations	5	Y	the proper power of tractor	A	3	3
Diesel use	D	1	Rational use of transportation	3	Y	combined tillage operations to avoid multiple transports from the village to the field	A	1	1
Diesel use	D	1, 6	Reduction of tillage	5	Y	new "reduced tillage" crop production technologies; application of proper machinery	A	3	2
Harvesting	D	2	less transport	3	N	organize sequential harvesting to many small scale fields	A	1	1
Harvesting	I	1, 6	yield mapping	5	Y	precision agriculture	A	2	2
Bioactive microorganisms	I	1,2	Application of bioactive microorganisms/insects	4	Y	organic or integrated agriculture system	P	1	2

Tomatoes

Fertilizers	I	1,3	Application in accordance with soil fertility and availability of the compounds	5	Y	analysis of the content of macro and micronutrients - precision agriculture	A	1	1
Fertilizers	I	1,3	Division of doses	5	Y	analysis of the content of macro and micronutrients - precision agriculture	A	1	2
Fertilizers	I	1, 6	Improved fertilizer management - efficient application and utilization	4	Y	precision agriculture	A	3	3
Fertilizers	I	1	Increased use of organic fertilizers	3	Y	organic or integrated agriculture system;	A	1	2
Fertilizers	I	1	Multi-compound fertilizer use	4	Y	new more effective forms of multi-compound-fertilizers fertilizers	A	1	2
Fertilizers	I	1	Reduced use of synthetic fertilizers	5	Y	integrated fertilization	A	1	2
Pesticides	I	1,2	Application of bioactive microorganisms/insects	4	Y	organic or integrated agriculture system	P	1	2

1	2	3	4	5	6	7	8	9	10
Fungicides	I	1,2, 6	Reduced use of fungicides	3	Y	Better aerization	A	1	2
Fungicides	I	1,3, 6	Reduced use of fungicides	4	Y	Dehumidification	A	2	2
Herbicides	I	1,2, 6	Reduced use of herbicides	3	Y	solarization film on the soil	A	2	2
Irrigation	I	4, 6	Reduction of electricity use	4	N	market research on high efficiency pumping systems	A	2	3
Irrigation	D	1,3	Water use management	5	N	analysis of the exact irrigation needs per ha	A	2	2
Diesel use	D	1, 6	Rational use of transportation	3	Y	post-harvest facilities to store tomatoes until they are enough for a full truck load	A	1	1
Plant growth control	D	1	Crop-based RH control	2	Y	organizational of greenhouse production	A	1	1
Plant growth control	D	1	Crop-based use of the energy screen	2	Y	organizational of greenhouse production	A	1	1
Energy use	D	1, 3	Increased set point for air relative humidity	2	Y	monitoring and control system	A	1	1
Energy use	D	1, 3	Lowered temperature set point	4	Y	monitoring and control system	A	1	1
Plant growth control	D	1	Reduction of crop transpiration	3	Y	climate control in properties optimum for this plant	A	1	1
Energy use	D	1	Temperature integration	2	Y	more sensors	A	2	1
Building/Construction	D	1	Better ventilation	3	Y	electronic control windows, new design	A	2	4
Building/Construction	D	6	Geothermal application	3	Y	pipes circuit in low depth	A	3	3
Building/Construction	I	6	Greenhouse cover film with antidrip coating that removes condensed water	4	Y	purchase - greenhouse cover film with antidrip coating	A	2	2
Building/Construction	D	1	Less fuel for heating	3	Y	new high-tech boilers (high efficiency, other fuel)	A	2	4
Building/Construction	D	6	Precision farming	3	Y	precision farming	A	4	3
Building/Construction	D	6	R & D in greenhouse design and technologies	3	Y	R&D on new construction technologies	A	4	3

1	2	3	4	5	6	7	8	9	10
Building/Construction	D	6	Shading during summer period	5	Y	new technologies in plastic cover production	A	3	3
Building/Construction	D	6	Thermal storage systems	2	Y	installment of thermal storage system	A	2	3
Building/Construction	I	1, 6	Wind brake at the north side of the greenhouse	4	Y	investment in wind brake at the north side of the greenhouse	A	2	2

Cucumber

Fertilizers	I	1,3	Application in accordance with soil fertility and availability of the compounds	5	Y	analysis of the content of macro and micronutrients - precision agriculture	A	1	1
Fertilizers	I	1,3	Division of doses	5	Y	analysis of the content of macro and micronutrients - precision agriculture	A	1	2
Fertilizers	I	1, 6	Improved fertilizer management - efficient application and utilization	4	Y	precision agriculture	A	3	3
Fertilizers	I	1	Increased use of organic fertilizers	3	Y	organic or integrated agriculture system;	A	1	2
Fertilizers	I	1	Multi-compound fertilizer use	4	Y	new more effective forms of multi-compound-fertilizers fertilizers	A	1	2
Fertilizers	I	1	Reduced use of synthetic fertilizers	5	Y	integrated fertilization	A	1	2
Pesticides	I	1,2	Application of bioactive microorganisms/insects	4	Y	organic or integrated agriculture system	P	1	2
Fungicides	I	1,2	Reduced use of fungicides	3	Y	Better aerization	A	1	2
Fungicides	I	1,3	Reduced use of fungicides	4	Y	Dehumidification	A	2	2
Herbicides	I	1,2, 6	Reduced use of herbicides	3	Y	solarization film on the soil	A	2	2
irrigation	I	4, 5, 6	Reduction of electricity use	4	N	market research on high efficiency pumping systems	A	2	3
Irrigation	D	1,3	Water use management	5	N	analysis of the exact irrigation needs per ha	A	2	2

1	2	3	4	5	6	7	8	9	10
Plant growth control	D	1	Crop-based RH control	2	Y	organizational of greenhouse production	A	1	1
Plant growth control	D	1	Crop-based use of the energy screen	2	Y	organizational of greenhouse production	A	1	1
Energy use	D	1, 3	Increased set point for air relative humidity	2	Y	monitoring and control system	A	1	1
Energy use	D	1, 3	Lowered temperature set point	4	Y	monitoring and control system	A	1	1
Diesel use	D	1, 6	Rational use of transportation	3	Y	post-harvest facilities to store tomatoes until they are enough for a full truck load	A	1	1
Plant growth control	D	1, 6	Reduction of crop transpiration	3	Y	climate control in properties optimum for this plant	A	1	1
Energy use	D	1, 6	Temperature integration	2	Y	more sensors	A	2	1
Building/Construction	D	1, 6	Better ventilation	3	Y	electronic control windows, new design	A	2	4
Building/Construction	D	6	Geothermal application	3	Y	pipes circuit in low depth	A	3	3
Building/Construction	I	6	greenhouse cover film with antidrip coating that removes condensed water	4	Y	purchase - greenhouse cover film with antidrip coating	A	2	2
Building/Construction	D	1, 6	Less fuel for heating	3	Y	new high-tech boilers (high efficiency, other fuel)	A	2	4
Building/Construction	D	6	Precision farming	3	Y	precision farming	A	4	3
Building/Construction	D	6	R & D in greenhouse design and technologies	3	Y	R&D on new construction technologies	A	4	3
Building/Construction	D	6	Shading during summer period	5	Y	new technologies in plastic cover production	A	3	3
Building/Construction	D	6	Thermal storage Systems	2	Y	installment of thermal storage system	A	2	3
Building/Construction	I	1, 6	Wind brake at the north side of the greenhouse	4	Y	investment in wind brake at the north side of the greenhouse	A	2	2

1	2	3	4	5	6	7	8	9	10

Vineyards

Fertilizers	I	1,3	Application in accordance with soil fertility and availability of the compounds	5	Y	analysis of the content of macro and micronutrients - precision agriculture	A	1	1
Fertilizers	I	1,3	Division of doses	5	Y	analysis of the content of macro and micronutrients - precision agriculture	A	1	2
Fertilizers	I	1, 6	Improved fertilizer management - efficient application and utilization	4	Y	precision agriculture	A	3	3
Fertilizers	I	1	Increased use of organic fertilizers	3	Y	organic or integrated agriculture system; conservation tillage (left 30% of residues)	A	1	2
Fertilizers	I	1	Multi-compound fertilizer use	4	Y	new more effective forms of multi-compound-fertilizers fertilizers	A	1	2
Fertilizers	I	1	Reduced use of synthetic fertilizers	5	Y	integrated fertilization	A	1	2
Fungicides	I	1,2	Reduced use of fungicides	3	Y	Organic or integrated agriculture system; proper crop rotation; cultivars	A	1	2
Herbicides	I	1,2	Reduced use of herbicides	3	Y	organic or integrated agriculture system; proper crop rotation; cultivars	A	1	2
Herbicides	I	1,2, 6	Reduced use of herbicides	3	Y	mulch film on soil	A	2	2
Irrigation	I	5, 6	Reduction of electricity use by pumps (water pumping)	4	N	market research on high efficiency pumping systems	A	2	3
Irrigation	D	1,3	Water management-drip irrigation	5	N	analysis of the exact irrigation needs per ha	A	2	2
Irrigation	D	1,3, 6	Water management-soil coverage	5	N	mulching film on the soil	A	2	2
Diesel use	D	1, 6	Appropriate power of the tractor and other machines to the field operations	5	Y	proper power of tractor	A	3	3
Diesel use	D	1, 6	No tillage	3	Y	mulching film	A	3	2

1	2	3	4	5	6	7	8	9	10
Diesel use	D	1	Rational use of transportation	3	Y	combined tillage operations to avoid multiple transports from the village to the field	A	1	1
Diesel use	D	1	Reduced tillage	5	Y	new "reduced tillage" crop production technologies	A	3	2
Diesel use	D	4, 6	Appropriate power of loaders and trucks to transport	5	Y	the proper power of loaders and trucks	A	1	1
Bioactive microorganisms	I	1,2	Application of bioactive microorganisms/insects	4	Y	organic or integrated agriculture system	P	1	2

Olive groves

Fertilizers	I	1,3	Application in accordance with soil fertility and availability of the compounds	5	Y	analysis of the content of macro and micronutrients - precision agriculture	A	1	1
Fertilizers	I	1,3	Division of doses	5	Y	analysis of the content of macro and micronutrients - precision agriculture	A	1	2
Fertilizers	I	1, 6	Improved fertilizer management - efficient application and utilization	4	Y	precision agriculture	A	3	3
Fertilizers	I	1	Increased use of organic fertilizers	3	Y	organic or integrated agriculture system; conservation tillage (left 30% of residues)	A	1	2
Fertilizers	I	1	Multi-compound fertilizer use	4	Y	new more effective forms of multi-compound-fertilizers fertilizers	A	1	2
Fertilizers	I	1	Reduced use of synthetic fertilizers	5	Y	integrated fertilization	A	1	2
Fungicides	I	1,2	Reduced use of fungicides	3	Y	Organic or integrated agriculture system; proper crop rotation; cultivars	A	1	2
Herbicides	I	1	Reduced use of herbicides	3	Y	cattle or sheep pasture in the olive grove	A	2	2

1	2	3	4	5	6	7	8	9	10
Herbicides	I	1,2	Reduced use of herbicides	3	Y	organic or integrated agriculture system; proper crop rotation; cultivars	A	1	2
Herbicides	I	1,2, 6	Reduced use of herbicides	3	Y	mulch film on soil	A	2	2
Irrigation	D	4, 5, 6	Reduction of electricity use by pumps (water pumping)	4	N	market research on high efficiency pumping systems	A	2	3
Irrigation	D	1,3	Water management-drip irrigation	5	N	analysis of the exact irrigation needs per ha	A	2	2
Diesel use	D	1,6	Appropriate power of the tractor and other machines to the field operations	5	Y	the proper power of tractor	A	3	3
Diesel use	D	1	No tillage	3	Y	weed cutting	A	3	2
Diesel use	D	1	Rational use of transportation	3	Y	combined tillage operations to avoid multiple transports from the village to the field	A	1	1
Diesel use	D	1	Reduced tillage	5	Y	new "reduced tillage" crop production technologies	A	3	2
Diesel use	D	4, 6	Use of appropriate power of loaders and trucks to transport olives	5	Y	the proper power of loaders and trucks	A	1	1
Bioactive microorganis ms	I	1,2	Application of bioactive microorganisms/insects	4	Y	organic or integrated agriculture system	P	1	2

Report 4: Energy Saving Measures Categorized for Chosen Subsectors of Dutch Agriculture

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Agricultural subsector/ Energy input	I/D	Type of ES measure	ES measure	Importance	R&D Y/N	Description of the needs in order to implement ES measure	A/P	Cost of implementation	Payback time
1	2	3	4	5	6	7	8	9	10

Wheat

Seeds	I	1	High quality seeds	4	Y	new breeding programs for new cultivars	A	4	3
Nitrogen	I	1	Anorganic fertilizer	5	Y	Split up the anorganic fertilizer application	A	2	2
Nitrogen	I	2	Cultivation of green manuring crops	5	Y	Use of green manuring crops	A	2	2
Nitrogen	I	2	Fertilizer dose in relation to crop uptake	5	Y	Fertilizer use corresponds to crop uptake (e.g. plant sap analysis and/or sensor techniques)	A	1	1
Nitrogen	I	1	Improved fertilizer management	4	Y	precision agriculture; automated application based on plant requirement and soil samples / measurements (sensors)	A	2	2
Nitrogen	I	2	Improved soil fertility (living organisms)	4	Y	Use of (good) compost (with bio activators) improves soil life and stimulate the uptake of fertilizer by the plants	A	2	2
Nitrogen	I	1	Organic fertilization on the basis of N fertilizer working coefficient	5	Y	Factor in the working coefficient of organic manure	A	1	1
Herbicides	I	1	Reduced use of herbicides	3	Y	precision agriculture; use of GEWIS and models (diseases and weather) to determine need for spraying and amount	A	2	2

1	2	3	4	5	6	7	8	9	10
Diesel use	D	1	Less tillage of the soil	5	N	Different of less soil tillage can reduce fuel consumption	A	2	2
Diesel use	D	1	Shut down tractors	5	N	Tractors are 25% of the time turning idle. It can be reduced to 15%	A	1	1
Diesel use	D	1	tire pressure	5	N	Proper tire pressure is 20% more speed and 10% fuel improvement	A	2	2
Diesel use	D	1	tire size	5	N	15 till 30% of the fuel is used to transfer the power to the surface. A bigger tire size improves the transfer of power and saves fuel	A	2	2
Diesel use	D	1	Tractor machine combination	5	N	Use a tractor that does not exceed the capacity requirement of the machine by 15%. A bigger tractor consumes more fuel even if it is used a 75% of its capacity	A	1	1
Diesel use	D	1	Trimmed soil tillage machinery	5	N	Soil tillage is responsible for most of the fuel consumption. Better trimmed soil machinery reduces fuel consumption	A	1	1
Diesel use	D	1	Weight front axle	5	N	Saving 1 till 5 liters per hectare is possible by adjusting weight to front axle (max.) 25% of the total weight	A	1	1
Energy use control	D	3	Measurements of energy use	3	Y	Measure energy use on the farm (e.g. electricity not only the total but per activity / building a measurement)	A	1	1

1	2	3	4	5	6	7	8	9	10
Sugar beet									
Seeds	I	1	High quality seeds	4	Y	new breeding programs for new cultivars	A	4	3
Nitrogen	I	1	Anorganic fertilizer	5	Y	Split up the anorganic fertilizer application	A	2	2
Nitrogen	I	2	Cultivation of green manuring crops	5	Y	Use of green manuring crops	A	2	2
Nitrogen	I	2	Fertilizer dose in relation to crop uptake	5	Y	Fertilizer use corresponds to crop uptake (e.g. plant sap analysis and/or sensor techniques)	A	1	1
Nitrogen	I	1	Improved fertilizer management	4	Y	precision agriculture; automated application based on plant requirement and soil samples / measurements (sensors)	A	2	2
Nitrogen	I	2	Improved soil fertility (living organisms)	4	Y	Use of (good) compost (with bio activators) improves soil life and stimulate the uptake of fertilizer by the plants	A	2	2
Nitrogen	I	1	Organic fertilization on the basis of N fertilizer working coefficient	5	Y	Factor in the working coefficient of organic manure	A	1	1
Pesticides	I	1	Reduced use of pesticides	3	Y	precision agriculture; use of GEWIS and models (diseases and weather) to determine need for spraying and amount	A	2	2
Diesel use	D	1	Less tillage of the soil	5	N	Different of less soil tillage can reduce fuel consumption	A	2	2
Diesel use	D	1	Shut down tractors	5	N	Tractors are 25% of the time turning idle. It can be reduced to 15%	A	1	1
Diesel use	D	1	tire pressure	5	N	Proper tire pressure is 20% more speed and 10% fuel improvement	A	2	2

1	2	3	4	5	6	7	8	9	10
Diesel use	D	1	tire size	5	N	15 till 30% of the fuel is used to transfer the power to the surface. A bigger tire size improves the transfer of power and saves fuel	A	2	2
Diesel use	D	1	Tractor machine combination	5	N	Use a tractor that does not exceed the capacity requirement of the machine by 15%. A bigger tractor consumes more fuel even if it is used a 75% of its capacity	A	1	1
Diesel use	D	1	Trimmed soil tillage machinery	5	N	Soil tillage is responsible for most of the fuel consumption. Better trimmed soil machinery reduces fuel consumption	A	1	1
Diesel use	D	1	Weight front axle	5	N	Saving 1 till 5 liters per hectare is possible by adjusting weight to front axle (max.) 25% of the total weight	A	1	1
Energy use control	D	3	Measurements of energy use	3	Y	Measure energy use on the farm (e.g. electricity not only the total but per activity / building a measurement)	A	1	1

Potatoes

Seeds	I	1	High quality tubers	4	Y	new breeding programs for new cultivars	A	4	3
Nitrogen	I	1	Anorganic fertilizer	5	Y	Split up the anorganic fertilizer application	A	2	2
Nitrogen	I	2	Cultivation of green manuring crops	5	Y	Use of green manuring crops	A	2	2
Nitrogen	I	2	Fertilizer dose in relation to crop uptake	5	Y	Fertilizer use corresponds to crop uptake (e.g. plant sap analysis and/or sensor techniques)	A	1	1

1	2	3	4	5	6	7	8	9	10
Nitrogen	I	1	Improved fertilizer management	4	Y	precision agriculture; automated application based on plant requirement and soil samples / measurements (sensors)	A	2	2
Nitrogen	I	2	Improved soil fertility (living organisms)	4	Y	Use of (good) compost (with bio activators) improves soil life and stimulate the uptake of fertilizer by the plants	A	2	2
Nitrogen	I	1	Organic fertilization on the basis of N fertilizer working coefficient	5	Y	Factor in the working coefficient of organic manure	A	1	1
Pesticides	I	1	Reduced use of pesticides	3	Y	precision agriculture; use of GEWIS and models (diseases and weather) to determine need for spraying and amount	A	2	2
Diesel use	D	1	Less tillage of the soil	5	N	Different of less soil tillage can reduce fuel consumption	A	2	2
Diesel use	D	1	Shut down tractors	5	N	Tractors are 25% of the time turning idle. It can be reduced to 15%	A	1	1
Diesel use	D	1	tire pressure	5	N	Proper tire pressure is 20% more speed and 10% fuel improvement	A	2	2
Diesel use	D	1	tire size	5	N	15 till 30% of the fuel is used to transfer the power to the surface. A bigger tire size improves the transfer of power and saves fuel	A	2	2
Diesel use	D	1	Tractor machine combination	5	N	Use a tractor that does not exceed the capacity requirement of the machine by 15%. A bigger tractor consumes more fuel even if it is used a 75% of its capacity	A	1	1

1	2	3	4	5	6	7	8	9	10
Diesel use	D	1	Trimmed soil tillage machinery	5	N	Soil tillage is responsible for most of the fuel consumption. Better trimmed soil machinery reduces fuel consumption	A	1	1
Diesel use	D	1	Weight front axle	5	N	Saving 1 till 5 liters per hectare is possible by adjusting weight to front axle (max.) 25% of the total weight	A	1	1
Storage	D	6	Saving energy in storage room	2	Y	25% energy saving by improved air flow in the storage	A	2	2
Energy use control	D	3	Measurements of energy use	3	Y	Measure energy use on the farm (e.g. electricity not only the total but per activity / building a measurement)	A	1	1

Tomato

Energy use	D	1	Adaptive set-points	5	Y	less rigid climate control	A	1	1
Energy use	I	6	Anti-reflection glass	3	Y	anti-reflection cover	A	3	3
Energy use	D	6	Better heat insulation	5	Y	double glazing/low emission	A	3	3
Energy use	I	6	Diffuse glass	3	Y	light diffusive cover	A	3	3
Energy use	D	6	Double thermal screen	5	N	one screen is standard; more screens insulate better	A	2	2
Energy use	D	6	Heat recovery from exhaust air of ventilation	4	Y	installation of state of the art ventilation systems	A	3	2
Energy use	D/I	1	Smart irrigation	5	Y	closed loop irrigation or smart irrigation	A	2	2

1	2	3	4	5	6	7	8	9	10
Cucumber									
Energy use	D	1	Adaptive set-points	5	Y	less rigid climate control	A	1	1
Energy use	I	6	Anti-reflection glass	3	Y	anti-reflection cover	A	3	3
Energy use	D	6	Better heat insulation	5	Y	double glazing/low emission	A	3	3
Energy use	I	6	Diffuse glass	3	Y	light diffusive cover	A	3	3
Energy use	D	6	Double thermal screen	5	N	one screen is standard; more screens insulate better	A	2	2
Energy use	D	6	Heat recovery from exhaust air of ventilation	4	Y	installation of state of the art ventilation systems	A	3	2
Energy use	D/I	1	Smart irrigation	5	Y	closed loop irrigation or smart irrigation	A	2	2
Sweet pepper									
Irrigation	D/I	1	Irrigation	5	Y	closed loop irrigation or smart irrigation	A	2	2
Energy use	D	1	Adaptive set-points	5	Y	less rigid climate control	A	1	1
Energy use	I	6	Anti-reflection glass	3	Y	anti-reflection cover	A	3	3
Energy use	D	6	Better insulation	5	Y	double glazing/low emission	A	3	3
Energy use	I	6	Diffuse glass	3	Y	light diffusive cover	A	3	3
Energy use	D	6	Double thermal screen	5	N	one screen is standard; more screens insulate better	A	2	2
Energy use	D	6	Heat recovery from exhaust air of ventilation	4	Y	Installation of state of the art ventilation systems	A	3	2

1	2	3	4	5	6	7	8	9	10

Dairy cows

Feed	D	4	In total less concentrates per kg milk	4	N	concentrate feeders and daily milk yield measurements for individual cows	A	2	1
Feed	D	1,5	Less energy in feed	4	N	Concentrate compounds should be available in the own country	A	2	1
Feed	I	1	More energy for process, replacement of concentrates	3	Y	optimization of the process, equipment for industrial or on-farm use	A	3	3
Diesel use	D	1,2,5	Decrease of diesel usage for external transport	4	N	Compound feed/dairy industry should have a local focus on marketing	A	2	1
Diesel and labour use	D	2,4	Decrease of diesel use and labour	4	Y	Applicability of new innovative grazing systems	A	2	2
Energy use	D/I	1,2,4	Less energy input but more energy / kg milk	2	N	Not easy to implement, must be a switch to organic farming	P	2	3
Energy use	D	1,6	Decrease energy using solar panels for manure scraper	3	Y	Solar panel and an automatic manure scraper	A	2	3
Diesel use	D	1,4,6	Efficiency in roughage storage and feeding strategy	3	N	Investment of a central feed centre and feeding machines to mix and transport the rations	A	3	2
Energy use	D	1,3	Efficient cleaning less water and lower temperature	3	Y	With new technics and other chemicals maybe we can use less water en energy A	A	2	2
Energy use	D	1,6	Efficient lighting with low energy consumption	4	Y	Several types of lamps (TL /LED /high press lamps)	A	2	2
Energy use	D	1,4,6	Efficient lighting with low energy consumption	4	Y	automatic turn on /off from individual lamps driven by light intensity sensor	A	2	2
Energy use	D	1,6	Heat recovery from milk cooling	4	Y	new technical process(cooling with water, system eco 200), new cooling engine	A	3	2

1	2	3	4	5	6	7	8	9	10
Energy use	D	1,4	Optimization of automatic milking systems	5	Y	we have more than 2500 farms with an AMS, they used 1,5 times more energy than traditional milking systems, We must optimized that energy used	A	2	2
Energy use	D	1	Use of the warm water released by heat recovery from cooling milk	5	Y	Isolated pumping system for transport the warm water to several parts of the farm where used warm water	A	2	2
Energy use	D	1	Use the heat from manure	2	Y	heat exchanger in manure cellar	A	3	3
Feed	I	4	Better fodder efficiency and less energy for producing young animals	5	Y	also mentioned by FL	A	3	3

Pigs

Feed	I	1	Improvement of feeding value	3	Y	Improvement of the quality of feed production	A	2	2
Building/Construction	D	6	Better heat insulation	3	N	Calculation on ROI (gas)	A	2	3
Building/Construction	D	6	Better heat insulation	4	N	Calculation on ROI (electricity)	A	2	3
Building/Construction	D	6	Daylight instead of artificial light	4	N	Calculation on ROI	A	2	2
Building/Construction	D	6	Efficient lighting systems; High Frequency FL, LED, Induction	4	N	Calculation on ROI	A	2	2
Building/Construction	D	6	Fans using less energy per 1000m3 air	4	N	Fans that use less energy	A	2	2
Building/Construction	D	6	Floor cooling at heavy pigs, heating at small pigs	2	N	water pipes in the floor	A	2	3
Building/Construction	D	1	Heat/cold storage in soil	3	N	Calculation on ROI	A	2	3
Building/Construction	D	1	Heat/cold storage in soil; constant temperature of incoming air; lower ventilation rate	3	N	Calculation on ROI	A	2	3
Building/Construction	D	6	Natural ventilation	3	Y	improvement of systems with natural ventilation	A	2	2

1	2	3	4	5	6	7	8	9	10
Building/Construction	D	1	Use of heat exchanger	3	Y	Calculation on ROI	A	3	2
Building/Construction	D	1	Using of frequency controlled regulators	3	N	Calculation on ROI	A	2	2
Building/Construction	D	2	Yearly control of climate equipment	3	N	contract for yearly control	A	1	2

Broilers

Feed	I	1	Replacement of 10-15 % compound feed by home grown cereal grain	2	Y	Decrease feed costs	A	2	2
Building/Construction	D	6	At high temperatures: evaporative cooling of incoming air (nozzles, cooling pads)	5	N	Increased weight gain, less mortality	A	2	1
Building/Construction	D	6	Better heat insulation	3	N	Decrease of energy consumption (gas/electricity)	A	2	3
Building/Construction	D	6	Combination of natural and forced ventilation (automated hybrid ventilation)	3	Y	Decrease of energy consumption	A	2	2
Building/Construction	D	6	Drying of manure with ventilation air for reduction of transport and/or for processing of manure (incineration, pelletizing)	3	N	Decrease of transport / increase of value	A	3	2
Building/Construction	D	6	Efficient lighting systems; sodium lamps, metal halide lamps, HighFrequency FL, LED, Induction, reflecting fittings	4	N	Decrease of energy consumption	A	2	2
Building/Construction	D	6	Energy efficient emission reduction systems for ammonia, particulate matter (notably use of heat exchangers that lower ventilation rate)	3	Y	Decrease of energy consumption	A	5	4
Building/Construction	D	1	Heat/cold storage in soil in combination with heat pump for heating ventilation air	3	N	Decrease of energy consumption	A	2	3
Building/Construction	D	6	Local heating of chicks with infrared heating lamps, using less gas for spatial heating	3	N	Decrease of gas consumption	A	1	1
Building/Construction	D	6	Low temperature (< 50 oC) warm water heating in combination with floor/wall heating	4	N	Decrease of energy consumption	A	2	2
Building/Construction	D	6	Motion detector connected to lighting switch in often used rooms	1	N	Decrease of energy consumption	A	1	1
Building/Construction	D	1	Regular cleaning of ventilation fans	3	N	Decrease of energy consumption	A	1	1

1	2	3	4	5	6	7	8	9	10
Building/Construction	D	6	Shuttered windows in roof/wall for daylight provision with additional artificial lighting	4	N	Decrease of energy consumption	A	2	2
Building/Construction	D	1	Underground tubes (heat exchanger) for cooling of incoming air and lower ventilation rate	3	N	Decrease of energy consumption	A	2	3
Building/Construction	D	1	Use of energy efficient direct current ventilation fans / frequency controlled and/or cascade controlled ventilation fans	3	N	Decrease of energy consumption	A	2	2
Building/Construction	D	1	Use of heat exchanger unit with ventilator	3	Y	Decrease of energy consumption	A	3	2
Building/Construction	D	6	Use of surplus heat from neighbouring activity	3	N	Increased energy efficiency	A	3	3
Building/Construction	D	6	Vertical ventilation shafts bringing warm air from the ridge down to chicks	4	N	Decrease of energy consumption	A	2	1
Building/Construction	D	5	Yearly control of climate equipment	3	N	Decrease of energy consumption	A	1	2
Spatial planning	I	4	Spatial planning: Arable farm with poultry branch uses poultry manure to replace chemical fertilizer	4	N	Decrease of fertilizer use	A	3	3
Spatial planning	D	1	Spatial planning: Poultry farm with sufficient arable land to apply manure (grain for manure)	5	N	Decrease of energy consumption	A	5	4

Report 5: Energy Saving Measures Categorized for Chosen Subsectors of Polish Agriculture

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Agricultural subsector/ Energy input	I/D	Type of ES measure	ES measure	Importance	R&D Y/N	Description of the needs in order to implement ES measure	A/P	Cost of implementation	Payback time
1	2	3	4	5	6	7	8	9	10

Wheat

Seeds	I	1	High quality seeds	4	Y	new breeding programs for new cultivars	P	4	3
Calcium	I	2	Application in accordance with soil fertility and availability of the compounds	2	Y	analysis of the content of macro and micronutrients - precision agriculture	A	2	2
Potassium	I	2	Application in accordance with soil fertility and availability of the compounds	2	Y	analysis of the content of macro and micronutrients - precision agriculture	A	2	2
Phosphorus	I	2	Application in accordance with soil fertility and availability of the compounds	3	Y	analysis of the content of macro and micronutrients - precision agriculture	A	2	2
Sulfur	I	2	Application in accordance with soil fertility and availability of the compounds	1	Y	analysis of the content of macro and micronutrients - precision agriculture	A	2	2
Nitrogen	I	1,3	Division of N doses	5	Y	analysis of the content of macro and micronutrients - precision agriculture	A	2	2
Nitrogen	I	2	Improved management of N fertilization	4	Y	precision agriculture; proper crop rotation	A	2	2
Fertilizers	I	1	Increased use of organic fertilizers	3	Y	organic or integrated agriculture system; conservation tillage (left 30% of residues)	A	1	2

1	2	3	4	5	6	7	8	9	10
Fertilizers	I	1	Multi-compound fertilizer use	4	Y	new more effective forms of multi-compound-fertilizers fertilizers	A	1	2
Fertilizers	I	1	Reduced use of synthetic fertilizers	5	Y	integrated fertilization	A	1	2
fungicides	I	1,2	Reduced use of fungicides	3	Y	Organic or integrated agriculture system; proper crop rotation; cultivars	A	1	2
herbicides	I	1,2	Reduced use of herbicides	3	Y	organic or integrated agriculture system; proper crop rotation; cultivars	A	1	2
Diesel use	D	1	Appropriate power of the tractor and other machines to the field operations	4	Y	the proper power of tractor	A	3	2
Diesel use	D	1	No tillage	3	Y	new "no till farming" crop production technologies; application of proper machinery	A	3	2
Diesel use	D	1	Rational use of transportation	3	Y	combined tillage operations	A	3	2
Diesel use	D	1	Reduction of tillage	5	Y	new "reduced tillage" crop production technologies; application of proper machinery	A	3	2
Limiting losses	I	1	Reduced pre-harvest, harvest, and post-harvest losses	3	N	many organizational activities (proper drying temperatures,	A	4	2
Energy use	D	4,6	Use of post-harvest residuals for energy generation for drying	2	Y	saving energy by on-farm energy production	P	3	3
Energy use	D	4,6	Use of post-harvest residuals for energy generation for drying	2	Y	saving energy by on-farm energy production	P	3	3
Bioactive microorganis ms	I	1	Application of bioactive microorganisms/insects	4	Y	organic or integrated agriculture system	A	1	2
Fertilizers in relation to crop rotation	I	4	Proper plant rotation - reduction of fertilizer use	3	Y	organic or integrated agriculture system; conservation tillage (left 30% of residues)	A	2	2

1	2	3	4	5	6	7	8	9	10
Sugar beet									
Seeds	I	1	High quality seeds	4	Y	new breeding programs for new cultivars	P	4	3
Potassium	I	1	Application in accordance with soil fertility and availability of the compounds	2	Y	analysis of the content of macro and micronutrients - precision agriculture	A	2	2
Phosphorus	I	1	Application in accordance with soil fertility and availability of the compounds	3	Y	analysis of the content of macro and micronutrients - precision agriculture	A	2	2
Fertilizers	I	1	Application in accordance with soil fertility and availability of the compounds	1	Y	analysis of the content of macro and micronutrients - precision agriculture	A	1	2
Nitrogen	I	1	Division of N doses	4	Y	analysis of the content of macro and micronutrients - precision agriculture	A	2	2
Nitrogen	I	1	Efficient N application and utilization	4	Y	precision agriculture; proper crop rotation	A	2	2
Nitrogen	I	1	Improved fertilizer management	4	Y	precision agriculture	A	1	2
Fertilizers	I	1	Increased use of organic fertilizers	4	Y	organic or integrated agriculture system; conservation tillage (left 30% of residues)	A	1	2
Fertilizers	I	1	Multi-compound fertilizer use	4	Y	new more effective forms of multi-compound-fertilizers fertilizers	A	1	2
Fertilizers	I	1	Reduced use of synthetic fertilizers	5	Y	integrated fertilization	A	1	2
Pesticides	I	1	Reduced use of pesticides	3	Y	organic or integrated agriculture system; proper crop rotation; cultivars	A	1	2
Diesel use	D	1	Appropriate power of the tractor and other machines to the field operations	4	Y	the proper power of tractor	A	2	2
Diesel use	D	1	Rational use of transportation	4	Y	combined tillage operations	A	2	2

1	2	3	4	5	6	7	8	9	10
Diesel use	D	1	Reduction of tillage	5	Y	new "reduced tillage" crop production technologies; application of proper machinery	A	3	2
Diesel use	D	6	Use of appropriate power of loaders and trucks to transport roots to sugar plant	5	Y	the proper power of loaders and trucks	A	2	2
Bioactive microorganisms	I	1	Application of bioactive microorganisms/insects	4	Y	organic or integrated agriculture system	A	1	2
Fertilizers in relation to crop rotation	I	4	Proper plant rotation - reduction of fertilizer use	3	Y	organic or integrated agriculture system; conservation tillage (left 30% of residues)	A	2	2

Potato

Seeds	I	1	High quality tubers	4	Y	new breeding programs, new cultivars	P	4	3
Fertilizers	I	1	Application in accordance with soil fertility and availability of the compounds	2	Y	precision agriculture	A	2	2
Fertilizers	I	1	Application in accordance with soil fertility and availability of the compounds	3	Y	precision agriculture	A	2	2
Nitrogen	I	1	Division of N doses	4	Y	precision agriculture	A	2	2
Fertilizers	I	1	Efficient fertilizers application and utilization	4	Y	precision agriculture	A	2	2
Fertilizers	I	1	Improved fertilizer management	4	Y	precision agriculture	A	1	2
Fertilizers	I	1	Increased use of organic fertilizers	4	Y	organic or integrated agriculture system; conservation tillage (left 30% of residues)	A	1	2
Fertilizers	I	1	Multi-compound fertilizer use	4	Y	new more effective forms of multi-compound-fertilizers fertilizers	A	1	2
Fertilizers	I	1	Reduced use of synthetic fertilizers	5	Y	organic or integrated agriculture system; conservation tillage (left 30% of residues)	A	1	2

1	2	3	4	5	6	7	8	9	10
Pesticides	I	1	Reduced use of pesticides	3	Y	integrated agriculture system; proper rotation; ne cultivars	A	1	2
Pesticides	I	1	Reduced use of pesticides	3	Y	integrated agriculture system; proper rotation; ne cultivars	A	1	2
Pesticides	I	1	Reduced use of pesticides	3	Y	integrated agriculture system; proper rotation; ne cultivars	A	1	2
Diesel use	D	1	Appropriate power of the tractor and other machines to the field operations	4	Y	the proper power of tractor	A	4	2
Diesel use	D	1	Rational use of transportation	3	Y	combined tillage operations	A	4	2
Diesel use	D	1	Reduction of tillage	5	Y	new "reduced tillage" crop production technologies; application of proper machinery	A	4	2
Sorting	D	1	Effective sorting of potatoes	2	Y	energy saving methods of sorting	A	2	2
Storage	D	5,6	Saving energy in storage room	2	Y	saving energy by on-farm energy production	A	2	2
Bioactive microorganis ms	I	1	Application of bioactive microorganisms/insects	4	Y	integrated agriculture system	A	1	2
Fertilizers in relation to crop rotation	I	4	Proper plant rotation - reduction of fertilizer use	3	Y	organic or integrated agriculture system; conservation tillage (left 30% of residues)	A	2	2

Dairy cows

Feed	I	1	Improvement of feeding value	5	Y	Modification of technologies of fodder production, feed preparation and dosage	A	4	2
Feed additives	I	1	Improvement of feeding value	4	Y	Application of milticompound feed with high coefficient of digestibility	A	4	1
Diesel use	D	1,4	Rational use of transportation	4	Y	Better organization of fodder transportation, feed preparation and dosage, application of new equipment	A	4	2

1	2	3	4	5	6	7	8	9	10
Energy use	D	6	Efficient pumping	3	Y	Modification of water pumping system	A	3	1
Energy use	D	6	Heat recovery from milk cooling	3	Y	Application of heat exchanger to recover the heat from milk cooling	A	4	1
Building/Construction	D	6	New ventilation systems	3	Y	Modernization of ventilation system - new low energy consuming ventilators combined with gravitational ventilation	A	3	1
Veterinary drugs&Service	I	1	New drugs and treatments	3	Y	Application of new animal medicaments with effective drug release	P	4	3

Pigs

Feed	I	1	Improvement of feeding value	5	Y	Modification of technologies of fodder production, feed preparation and dosage	A	4	2
Feed additives	I	1	Improvement of feeding value	4	Y	Application of milticompound feed with high coefficient of digestibility	A	3	1
Diesel use	D	1,4	Rational use of transportation	4	Y	Better organization of fodder transportation, feed preparation and dosage, application of new equipment	A	4	2
Energy use	D	6	Efficient pumping	3	Y	Modification of water pumping system	A	3	1
Building/Construction	D	6	New ventilation systems	4	Y	Modernization of ventilation system - new low energy consuming ventilators combined with gravitational ventilation	A	3	1
Energy use	D	6	Use of energy for heating from farm residuals	3	Y	Heat production from farm resources in high performance boilers	A	4	2

1	2	3	4	5	6	7	8	9	10
Veterinary drugs&Service	I	1	New drugs and treatments	4	Y	Application of new animal medicaments with effective drug release	P	4	3

Broilers

Feed	I	1	Improvement of feeding value	5	Y	Modification of technologies of fodder production, feed preparation and dosage	A	4	2
Feed additives	I	1	Improvement of feeding value	4	Y	Application of milticompound feed with high coefficient of digestibility	A	3	1
Diesel use	D	1,4	Rational use of transportation	4	Y	Better organization of fodder transportation, feed preparation and dosage, application of new equipment	A	4	2
Energy use	D	6	Efficient pumping	3	Y	Modification of water pumping system	A	3	1
Building/Construction	D	6	Energy generation from farm residues (boiler)	3	Y	Heat production from farm resources in high performance boilers, minimization of energy loses	P	4	2
Building/Construction	D	6	Modernisation of ventilation system	5	Y	Modernization of ventilation system - new low energy consuming ventilators combined with gravitational ventilation	A	3	1
Veterinary drugs&Service	I	1	New drugs and treatments	5	Y	Application of new animal medicaments with effective drug release	P	4	3

Report 6: Energy Saving Measures Categorized for Chosen Subsectors of Portuguese Agriculture

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Agricultural subsector/ Energy input	I/D	Type of ES measure	ES measure	Importance	R&D Y/N	Description of the needs in order to implement ES measure	A/P	Cost of implementation	Payback time
1	2	3	4	5	6	7	8	9	10

Wheat

Seeds	I	1	High quality seeds	4	Y	new breeding programs, new cultivars	A	1	1
Phosphorus	I	1	Application in accordance with soil fertility and availability of the compounds	4	Y	analysis of the content of macro and micronutrients - precision agriculture	A	2	2
Potassium	I	1	Application in accordance with soil fertility and availability of the compounds	4	Y	analysis of the content of macro and micronutrients - precision agriculture	A	2	2
Nitrogen	I	1	Division of N doses	4	Y	analysis of the content of macro and micronutrients - precision agriculture	A	2	2
Nitrogen	I	1	Efficient N application and utilization	4	Y	precision agriculture; proper crop rotation	A	2	3
Nitrogen	I	1	Improved fertilizer management	4	Y	precision agriculture	A	2	3
Fertilizers	I	1	Increased use of organic fertilizers	3	Y	organic or integrated agriculture system; conservation tillage (left 30% of residues)	A	2	3
Pesticides	I	1	Reduced use of pesticides	2	Y	organic or integrated agriculture system; proper crop rotation; cultivars	A	1	2
Irrigation	I	1	Water use management	3	Y	improvement of the production process	A	2	2

1	2	3	4	5	6	7	8	9	10
Diesel use	D	1	Appropriate power of the tractor and other machines to the field operations	4	Y	the proper power of tractor	A	3	4
Diesel use	D	1	No tillage	5	Y	new "no till farming" crop production technologies; application of proper machinery	A	2	4
Diesel use	D	1	Rational use of transportation	3	Y	combined tillage operations	A	2	4
Diesel use	D	1	Reduction of tillage	5	Y	new "reduced tillage" crop production technologies; application of proper machinery	A	2	4

Sunflower

Seeds	I	1	High quality seeds	4	Y	new breeding programs, new cultivars	A	1	1
Herbicides	I	1	Reduced use of herbicides	2	Y	organic or integrated agriculture system; proper crop rotation; cultivars	A	1	1
Diesel use	D	1	Appropriate power of the tractor and other machines to the field operations	5	Y	the proper power of tractor	A	3	3
Diesel use	D	1	No tillage	5	Y	new "no till farming" crop production technologies; application of proper machinery	A	2	2
Diesel use	D	1	Rational use of transportation	5	Y	combined tillage operations	A	2	2
Diesel use	D	1	Reduction of tillage	5	Y	new "reduced tillage" crop production technologies; application of proper machinery	A	2	2

1	2	3	4	5	6	7	8	9	10
Tomatoes									
Seeds	I	1	High quality plants	4	Y	new breeding programs, new cultivars	A	1	1
Phosphorus	I	1	Application in accordance with soil fertility and availability of the compounds	3	Y	analysis of the content of macro and micronutrients	A	1	1
Potassium	I	1	Application in accordance with soil fertility and availability of the compounds	3	Y	analysis of the content of macro and micronutrients	A	1	1
Nitrogen	I	1	Efficient N application and utilization	4	Y	analysis of the content of macro and micronutrients	A	1	1
pesticides	I	1	Application of bioactive microorganisms/insects	3	Y	integrated agriculture system	P	1	1
fungicides	I	1	Reduced use of fungicides	2	Y	Integrated agriculture system	A	1	1
herbicides	I	1	Reduced use of herbicides	3	Y	integrated agriculture system	A	1	1
Insecticides	I	1	Reduced use of insecticides	4	Y	integrated agriculture system	A	1	1
Nematicide	I	1	Reduced use of neamatocides	3	Y	integrated agriculture system	A	1	1
Irrigation	I	1	Water use management	4	Y	recycling system	A	1	1
Substract	I	1	Extending the shelf life	4	Y	studies of behavior and durability	A	1	1
Building/Construction	D	3	Reduced use of pesticides, fertilizers, irrigation water	4	Y	environmental control systems	A	2	2

1	2	3	4	5	6	7	8	9	10

Vineyards

Seeds	I	1	High quality seeds	4	Y	new breeding programs, new cultivars	A	1	2
Fertilizers	I	1	Application in accordance with soil fertility and availability of the compounds	3	Y	analysis of the content of macro and micronutrients - precision agriculture	A	2	2
Phosphorus	I	1	Application in accordance with soil fertility and availability of the compounds	3	Y	analysis of the content of macro and micronutrients - precision agriculture	A	2	2
Potassium	I	1	Application in accordance with soil fertility and availability of the compounds	3	Y	analysis of the content of macro and micronutrients - precision agriculture	A	2	2
Nitrogen	I	1	Division of N doses	4	Y	analysis of the content of macro and micronutrients - precision agriculture	A	2	2
Fertilizers	I	1	Efficient fertilizers application and utilization	4	Y	precision agriculture;	A	2	2
Nitrogen	I	1	Efficient N application and utilization	4	Y	precision agriculture;	A	2	2
nitrogen	I	1	Improved fertilizer management	1	Y	precision agriculture	A	2	2
Fertilizers	I	1	Improved fertilizer management - efficient application and utilization	1	Y	precision agriculture	A	2	2
Fertilizers	I	1	Increased use of organic fertilizers	4	Y	organic or integrated agriculture system; conservation	A	1	1
Diesel use	D	1	Appropriate power of the tractor and other machines to the field operations	4	Y	the proper power of tractor	A	1	1
Diesel use	D	1	Rational use of transportation	4	Y	combined tillage operations	A	1	1
fungicides	I	1	Reduced use of fungicides	4	Y	Organic or integrated agriculture system;	A	1	1
herbicides	I	1	Reduced use of herbicides	3	Y	organic or integrated agriculture system;	A	1	1
Insecticides	I	1	Reduced use of insecticides	3	Y	organic or integrated agriculture system;	A	1	1
Pesticides	I	1	Reduced use of pesticides	4	Y	organic or integrated agriculture system;	A	1	1

1	2	3	4	5	6	7	8	9	10

Olive groves

Seeds	I	1	High quality seeds	4	Y	new breeding programs, new cultivars	A	1	2
Phosphorus	I	1	Application in accordance with soil fertility and availability of the compounds	3	Y	analysis of the content of macro and micronutrients - precision agriculture	A	2	2
Potassium	I	1	Application in accordance with soil fertility and availability of the compounds	2	Y	analysis of the content of macro and micronutrients - precision agriculture	A	2	2
Nitrogen	I	1	Division of N doses	4	Y	analysis of the content of macro and micronutrients - precision agriculture	A	2	2
fungicides	I	1	Reduced use of fungicides	4	Y	Organic or integrated agriculture system; cultivars	A	1	1
herbicides	I	1	Reduced use of herbicides	3	Y	organic or integrated agriculture system; cultivars	A	1	1
Insecticides	I	1	Reduced use of insecticides	3	Y	organic or integrated agriculture system; cultivars	A	1	1
Diesel use	D	1	Appropriate power of the tractor and other machines to the field operations	4	Y	the proper power of tractor	A	1	1

Dairy cows

Feed	I	1	High quality dried green fodder	3	Y	new breeding programs for new cultivars	A	1	1
Feed	I	1	High quality feed	4	Y	complete feeds	A	1	1
Feed	I	1	High quality feed concentrates	4	Y	complete feeds	A	1	1
Feed	I	1	High quality green fodder and silage	3	Y	new breeding programs for new cultivars	A	1	1
Water use	I	1	Water management	2	Y	mechanisms for recycling the washing water	A	2	2
Diesel use	D	1	Appropriate power of the tractor and other machines to the field operations	4	Y	the proper power of tractor	A	1	1
Energy use	D	6	Appropriate sizing of the milking machine	3	Y	market research	A	1	1

1	2	3	4	5	6	7	8	9	10
Pigs									
Feed	I	1	High quality feed concentrates	4	Y	complete feeds	A	1	1
Water use	I	1	Water management	1	Y	mechanisms for recycling the washing water	A	2	2
Building/Construction	D	6	Better heat insulation	3	Y	good thermal insulators	A	2	1
Broilers									
Feed	I	1	Better heat insulation	3	Y	good thermal insulators	A	1	1
Feed	I	1	High quality feed concentrates	5	Y	complete feeds	A	1	1
Water use	I	1	Water management	1	Y	mechanisms for recycling the washing water	A	2	2
Diesel use	D	1	Appropriate power of the tractor and other machines to the field operations	2	Y	the proper power of tractor	A	1	1
Building/Construction	D	6	Better heat insulation	3	Y	good thermal insulators	A	2	1