EIP-AGRI Focus Group
Enhancing production and use of renewable energy on the farm

STARTING PAPER

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1. Introduction

The European Innovation Partnership for Agricultural productivity and Sustainability (EIP-AGRI) Focus Groups collect and summarise knowledge on best practices in a specific field, listing problems as well as opportunities by taking stock of the state-of-the-art in research and practice. The Focus Groups subsequently suggest and prioritise innovative actions. They identify ideas for applied research and for testing solutions in the field, involving farmers, forestry stakeholders, advisers, the industry and other players. They also propose ways to disseminate good practices. Focus Group results provide new and useful ideas to solve practical problems and start new Operational Groups and Research projects and, in some cases, new Focus Groups when specific sub-themes appear large enough to do so.

The Paris agreement gives a clear and ambitious direction for investment in low carbon innovation. The implementation of the European Union`s (EU) ambitious Paris climate change commitments is now a priority and its success is depending to a large extent on the successful transition to a clean energy system as two thirds of GreenHouse Gas (GHG) emissions result from energy production and use.
In the EU 2030 Energy Strategy, EU countries have agreed on a new 2030 Framework for climate and energy, including EU-wide targets and policy objectives for the period between 2020 and 2030. The targets for 2030 include:

- a 40% cut in greenhouse gas emissions compared to 1990 levels
- at least a 27% share of renewable energy consumption
- at least 27% energy savings compared with the business-as-usual scenario.

The EU has set itself a long-term goal of reducing greenhouse gas emissions by 80-95%, compared to 1990 levels, by 2050. The Energy Roadmap 2050 explores the transition of the energy system in ways that would be compatible with this greenhouse gas reductions target while also increasing competitiveness and security of supply.

The share of renewable energy (RES) should rise substantially in the various scenarios explored, achieving at least 55% in gross final energy consumption in 2050, up 45 percentage points from today's level at around 10% [EU Energy Roadmap 2050, 2012]. The share of RES in electricity consumption reaches 64% in a High Energy Efficiency scenario and 97% in a High Renewables Scenario that includes significant electricity storage to accommodate varying RES supply. [EU Energy Roadmap 2050, 2012]. Furthermore, the EU is committed to the UN Sustainable Development Goals and has advanced an EU energy package which covers a range of directives on energy efficiency, renewable energy, as well as governance of the Energy Union, etcetera).

The Europe 2020 bioeconomy Strategy calls for a bioeconomy as a key element for smart and green growth in Europe. Advancements in bioeconomy research and innovation uptake will allow Europe to improve the management of its renewable biological resources and to open new and diversified markets in food and bio-based products. Furthermore, there is an EU circular economy initiative.

There are no specific targets defined for the agricultural sector with respect to renewable energy. However, given the importance of bioenergy, the availability of locations for wind energy and solar capacity, the agricultural sector has an important contribution to make to achieving these mid and long-term goals.

2. Context and Scope of the Focus Group

The agricultural sector has an impact on climate change and it has a role to play in mitigation of GHG emissions. At the same time, it is also heavily affected by the impacts of climate change, as farming activities depend directly on climatic conditions. The agricultural sector itself contributes significantly to greenhouse gas emissions, due to fossil fuel use and agricultural practices that reduce soil capacity, inputs like fertilisers and agrochemicals which cause GHG emissions increases, and methane and other GHG emissions from livestock rearing. Good agricultural practices can contribute to balancing the overall agricultural contribution to climate change. For example, precision farming techniques allow for reduced agricultural inputs such as fertilisers and agrochemicals for pest control while yields are increased and soil fertility improved.

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At the same time, the agricultural sector which represents the most important land use in many regions has a large potential for delivering and utilising renewable energy. The agricultural sector has surpluses of crop residues and can deliver biomass by producing dedicated crops for bioenergy, biofuels or feedstock for biomaterials. Biomass represents a large techno-economic renewable energy potential in Europe [see e.g. de Wit et al., 2010], but these potentials depend strongly on the extent to which agriculture can improve efficiency and release land for biomass production on top of meeting food demand. If not, additional land use for biomass production can lead to indirect land use and carbon stock change, potentially off-setting (part of the) mitigated fossil fuel emissions that are avoided by bioenergy, biofuels and biomaterials. Finally, the sheer land surface involved implies that wind energy represents important technical and economic potential. The same is true for solar energy parks.

Many different forms of renewable energy are produced in rural areas and many small and medium-scale installations provide opportunities for new cooperation in production, selling and distribution of renewable energy. They bring employment and economic development in rural regions, replace fossil fuels and contribute to energy security. This ranges from wind, solar, geothermal, to different forms of bioenergy. The latter represents a large proportion of our current renewable energy mix and will continue to do so in the future. Energy production at local and regional level ranges from local Combined Heat and Power (CHP) plants to biogas using different feedstocks and feedstock mixes.

On farm, many technologies are or could be deployed to meet energy use for heating, cooling, traction and other energy functions. Besides bioenergy (heat, power, biogas, biofuels such as vegetable oils or bioethanol), solar (electricity and heat) and wind, these can also include geothermal heat and heat recovery systems from e.g. cooling systems and manure storage. In various settings, farmers combine different technologies and can deliver renewable energy to power or gas grids. Overall, there are many options and potentials for on-farm renewable energy generation and deployment with a potential major contribution to Europe's energy mix.

This large portfolio of options however also creates complex questions, because the potentials, performance and impacts of renewable energy technologies depend on natural conditions (climate), type of farm (small – large scale, management techniques), geographic conditions (including infrastructure) and socio-economic factors as well as the surrounding energy system and energy infrastructure.
The Focus Group will address ways to enhance the production and use of energy at farm level and in rural areas and to seek best solutions and innovative approaches, including close cooperation in this field between farmers and other actors in rural areas.

The main question for this Focus Group is: How to enhance production and use of renewable energy on the farm. Key attention should be paid to opportunities for farmers, but also trade-offs that emerge once renewable energy is produced and used & delivered at larger scale, as is intended in the coming decades to meet the renewable energy and GHG mitigation targets.

The Focus Group tasks are:

- Identify main practical challenges and opportunities posed by the production and use of renewable energy at farm level.
- Identify main practical barriers to sourcing of biomass feedstocks (forest biomass, agricultural biomass, solar, geothermal and wind), logistics & infrastructure (e.g. on farm biogas, grid connection, etc.) transformation to energy and distribution to farms and on farms as well as to public grids.
- Identify best practices and tools that can be applied at farm level to increase both the production and self-consumption of renewable energy in a cost-efficient manner, while ensuring that renewable energy sourcing meets applicable sustainability criteria.
- Examine the trade-offs between all types of on-farm energy production and alternative uses (food, feed, other non-food).
- Analyse possible synergies between use of various energy sources (agriculture, forest, solar, wind) and demand on farm level (constant and stable supply systems).

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- Propose potential innovative actions to stimulate the knowledge and use of management practices and strategies for improving uptake of renewable energy and provide inspiration and ideas for Operational Groups and other innovative projects.
- Develop collective selling approaches for farm produced energy, linked to economic opportunities for territorial developments and networking activities for dissemination of these approaches.
- Identify remaining research, innovation, advisory and other needs coming from farm level to improve the use as well as the production of renewable energy on farm holdings.
- Provide examples of practices and tools that are already applied, including through better stakeholder involvement and synergies with other sectors such as tourism.

Another aspect that is important to consider for this Focus Group is the transition of the whole European energy system. Renewable Energy Technology (RET) deployment in rural settings is part of a far larger energy system change and it is affected by this (in terms of scale, infrastructure and competitiveness). This should always be acknowledged to avoid promoting isolated initiatives that could be affected or outcompeted by other developments and options. For example, RET deployment in power generation may increase up to 80% by 2050. Furthermore, biomass is expected to play a major role in delivering renewable feedstocks for industry, advanced fuels (e.g. for aviation, shipping and freight transport) and negative emissions with biorefineries in combination with Carbon Capture Storage (CCS).

Finally, combined modernisation of agriculture (and livestock) in Europe can facilitate sustainable production of biomass for energy and materials, which can deliver a major contribution to the European energy mix. Given the central role for the agricultural sector for biobased options, this also deserves special attention.

3. Experiences and Renewable Energy Technology options

3.1 Renewable energy technologies and factors and trends in performance.

This section lists the key options for renewable energy generation and factors that affect deployment in rural settings. There are many technologies and systems that are deployed to generate and use renewable energy in general (see figure 3.1) many of which are also produced on farms or have relevance for farms.

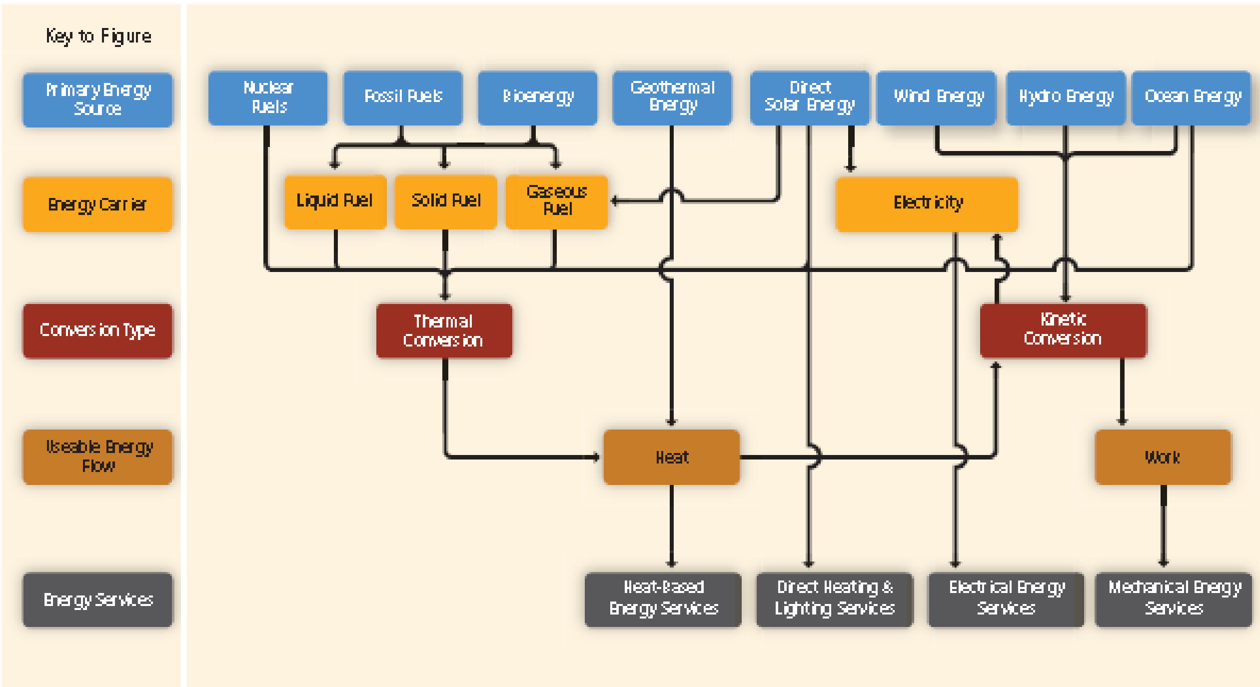

Figure 3.1: Illustrative paths of energy from source to service [IPCC-SRREN, 2011]

Further technological progress will enhance these possibilities. For wind energy (on land), PhotoVoltaic (PV), biogas and other technologies impressive cost reductions have been achieved over the past 10 years or so, leading to cost parity with fossil energy alternatives in various settings (illustrated by figure 3.2 for power generation from different renewable energy technologies). Figure 3.3, (IPCC-SRREN, 2011] presents similar information for a range of commercially available RET's for power generation, heat and transportation fuels. The key message from these figures is twofold: first, there is a range of renewable energy technologies available that can already compete against fossil fuels for supplying power, heat and transport fuels. Second, the range of cost levels is wide (both for renewable energy and fossil energy) which is caused by a range of factors, such as the scale of the technology, the climatic conditions (wind regime, solar radiation, costs of biomass supplies). Furthermore, the costs of fossil energy carriers also depend on available infrastructure and markets. Therefore, competitive deployment depends on those factors and is site specific.

In the coming decade, the competitiveness of RET options will further increase due to a combination of technology improvement and expected strong market growth that both contribute to technological learning.

Technological learning and the resulting decrease in costs is observed for all renewable energy options. Typically, each doubling of capacity has led to 20-25% decrease in costs. Although these observations give confidence for future developments, extrapolation of cost decreases may lead to overly optimistic forecasts. For instance, market feedbacks and increasing energy system integration costs or moving towards more expensive parts of the potential (e.g. for biomass resources, or less favourable locations for wind energy) may cause less cost reduction than expected. At the same time, strong market growth and combined innovation strategies can accelerate cost declines as observed in recent years for solar PhotoVoltaic (PV) and wind off-shore. Furthermore, prolonged Research, Development, Demonstration and Deployment (RDDD) is always needed to drive down costs of energy technologies. Stagnation of such efforts and investments will also slow down learning.

In addition, the combination of different (renewable) energy technologies in systems often leads to synergies and complementary characteristics, such as production patterns of solar and wind energy power generation. Combined use of technologies (solar, wind, biogas) on farms is common practice in several countries. Combination with energy efficiency measures, energy storage and conversion (e.g. heat pumps, cooling, use of waste heat) requires system integration and optimisation that depend on the energy demand patterns of a farm, energy infrastructure, costs of equipment, a.o.

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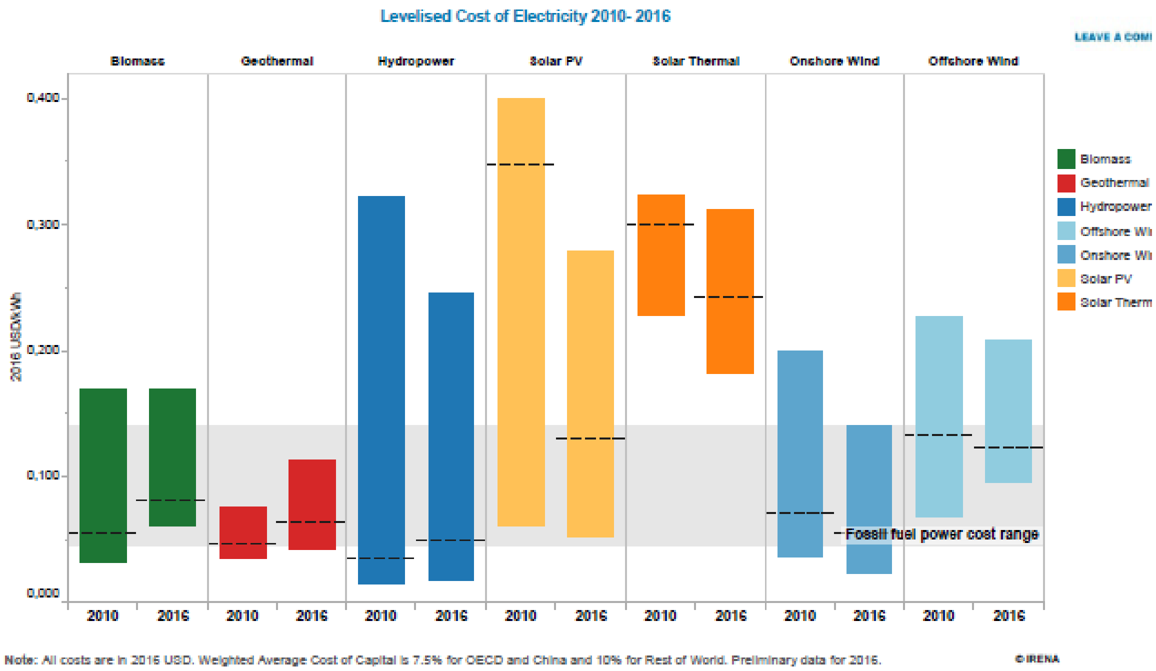

Figure 3.2: Current cost ranges of key renewable energy electricity options [IRENA]

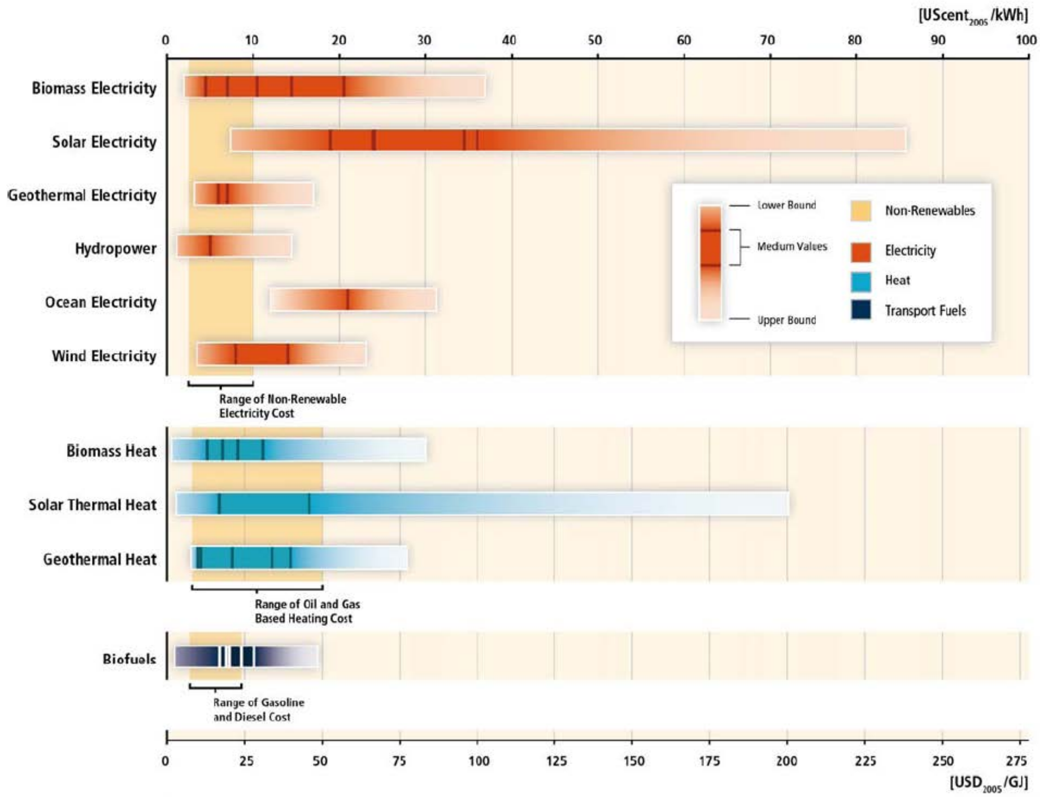

Figure 3.3: Cost of commercially available renewable energy technologies versus fossil reference (ranges) as compiled in the IPCC-SRREN report [IPCC-SRREN, 2011].

3.2: Renewable energy technologies on farms; key opportunities and challenges

The Focus Group is required to identify key opportunities and barriers for Renewable Energy Technology (RET) options in farms. The obvious physical conditions (climate, crop yields, wind regime, etc.), but especially the type of agricultural systems and key socio-economic characteristics of the agricultural regions are to be acknowledged and considered.

The large number of options and technological developments (with expected future cost reductions), the specificity of the farm type and regional conditions as well as the larger trends in the surrounding (national) energy system may complicate the choice for RET projects and investments. The types of projects will also be very diverse. Furthermore, at farm level the combined use of various technologies (both RET options and energy efficiency improvements) may provide synergies and opportunities. A key question is therefore how a farmer or a group of farmers can determine the most promising options and systems.

At present, there are no comprehensive studies analysing this wealth of options, and their complexity, from the farmers` point of view. Below, several considerations pointing at the most important opportunities and potential risks of the main options for renewable energy technology on farms are presented:

Solar PV electricity generation: many examples exist of integrated systems on farms, which often have large roof surfaces at their disposal. Countries with proper incentives have seen wide deployment of PV systems in the agricultural sector. Continuous cost declines of PV systems have made this option more and more attractive and this trend is expected to continue. In sunny climates, LCOE may approach grid prices. Key challenges are grid capacity and dealing with fluctuations over the year, which also affects market prices. The profitability of PV systems will heavily depend on (future) market design and incentives.
Furthermore, larger PV systems on land (or even floating on surface water) are emerging with farmers leasing land to power companies. Depending on climatic conditions and incentives, this can be lucrative. Impacts on landscape as well as suitable electricity infrastructure are challenges for future growth. Competition with good quality farmland can increase and requires further attention.

Solar thermal (warm/hot water): solar heaters are widely available. Performance and economic attractiveness strongly depend on climatic conditions and energy demand on the farm. Variability during the year is a challenge and solar thermal systems are typically deployed in combination with other heat supply options.

Wind energy: wind energy has become competitive on land areas with good wind regimes (typically coastal areas) [IPCC-SRREN, 2011]. Larger wind turbines (e.g. 2-3 MWe at about as low as 1000 Euro/kWe) require large investments and are often realised by energy companies with famers leasing their land. Smaller turbines (e.g. up to 0.5 MWe) are more popular at individual farms, but these often have lower revenues and return on investment. Furthermore, electrical infrastructure most be sufficient.

A key issue with wind energy on land are landscape impacts and the resulting opposition by home owners and other actors. Spatial planning, good stakeholder engagement, cooperative models (sharing revenues with local communities) are crucial aspects for successful implementation.

Biogas systems: There is considerable commercial experience with biomass digestors, in particular for manure as well as for co-digestion with organic wastes, and digestion of cultivated crops (e.g. fodder maize). The scale of these systems differs from farm size (typically for manure treatment in intensive livestock farming; dairy and pigs) up to large, centralised digestors that convert different biomass feedstocks from a supply area. Typically, smaller scale digestors require policy incentives to be profitable. Biogas revenues alone are often not sufficient, but in combination with awards for methane emission reduction and nutrient recycling and/or solving organic waste treatment, sound business models can emerge [Junginger et al., 2006]. Farmers that include digestors in closing nutrient cycles can substantially improve the environmental performance of farm operations.

Biogas digestion of cultivated crops, which require farmland and elaborate logistics, is more controversial. The overall GHG balance of such schemes depends on land management and competition and the efficiency of the chain.

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Biogas can be used directly (e.g. for heating) and on-site power generation (or combined heat and power generation) with dedicated gas engines. In some cases, biogas (roughly half methane and half $CO2$) is upgraded to natural gas quality and injected into the gas grid. Liquefaction to Liquefied Natural Gas (LNG) is also possible, allowing for production of transportation fuel. Upgrading and liquefaction imply additional investments and efficiency losses; these are reduced when done at a larger scale.

The performance of biogas digestors has continuously improved over the years and further innovations (e.g. pressurized digestion) will bring down costs even more in the future.

Biomass heat (boilers, drying): generation of heat from biomass is possible with a wide range of technologies that are commercially available. Boilers for the use of wood chips or straw (e.g. baled) pellets, are available at a wide range of capacities. They can produce hot water as well as heat for drying or other requirements. Costs of heat supplied mostly depend on the costs of the biomass resource, which can be as low as the costs of on farm transport, or much higher when high quality pellets produced elsewhere are used. Furthermore, biomass prices depend on overall demand for biomass for energy, including large-scale applications. Nevertheless, when farms need (higher temperature) heat or hot water, and biomass residues are available on farm, biomass boilers can be an attractive renewable energy option. A drawback is the amount of time needed to supply enough biomass, and possibly competing demand for biomass resources (e.g. centralised conversion) that may also be more efficient and competitive than on farm use.

Biomass electricity: Production of electricity from biomass is in principle possible with many technologies, both commercial (boilers with steam cycles) and at demonstration level (e.g. gasification-based in combination with engines or small turbines,or use of pyrolysis oil in engines). However, for on farm use, generally smaller capacities (e.g. below 1 MWe) are desired, which leads to higher costs, unless combined heat and power generation is attractive due to specific on-farm energy needs. For electricity production alone, overall energy efficiency is fairly low for combustion systems at the capacities mentioned (e.g. about 25% electrical efficiency). Gasifier-engine combinations could do better, but are complex to operate (e.g. with respect to required gas cleaning and/or constant highquality biomass feed). Furthermore, the overall costs and environmental performance depends strongly on biomass resources and availability as discussed before.

Biofuels: A wide range of biofuels can be produced with ethanol (from sugar beet, maize or cereals) and biodiesel (from esterified vegetable oil from e.g. rapeseed, camelina and other oil crops). They are commercially available and their use depends on policy targets and incentives, because such so-called ''first generation'' biofuels are generally not competitive against fossil fuels in the European context. Improvements in performance have been achieved over time as with any other renewable energy technology, but the main cost factor for such biofuels is the feedstock, the prices of which in turn depend on food and fodder markets. A complex debate is ongoing about biofuel production competing with food and leading to displacement in land use (indirect land use change) with possible indirect GHG emissions as a result. The Renewable Energy Directive has included thresholds for the GHG performance of biofuels and limitations (under debate) about their future deployment in the transport fuel mix. Generally, only smaller-scale pressing of oil crops (possibly combined with esterification) is suitable at farm level. This offers an interesting option of supply biofuels on farm, e.g. for machinery. It is however not widely deployed in Europe.

So-called second-generation biofuels are produced from lignocellulosic material (which can be crop or forest residues or cultivated trees and grasses), via either biochemical (hydrolysis and fermentation) and thermochemical processes (gasification, pyrolysis or liquefaction based) and converted to amongst others ethanol, butanol, synthetic diesel (Fischer-Tropsch, DiMethylEther (DME), synthetic methane (natural) gas (SNG), methanol and hydrogen. These technologies are at demonstration phase and they can have a large deployment potential due to the more diverse biomass resource base (perennial crops, residues and organic wastes) that can be used.
However, the conversion technology is complex, capital-intensive and generally not suitable for farm scale deployment.

Geothermal energy: geothermal energy is less common among the renewables and that also applies for deployment in the agricultural sector. However, for instance in the Netherlands there are some greenhouse horticultural enterprises that are using geothermal heat. The costs and potentials of geothermal energy logically depend on the underground situation and especially the depth at which good quality heat is available. Depth in turn determines the costs of drilling wells which is the main cost factor for geothermal schemes. Furthermore, extraction rates per unit of area differ from place to place. The option holds considerable potential, especially when lower temperature heat (e.g. below 100oC) is required and experience is growing, bringing down costs and increasing implementation experience. Generally, geothermal projects are complex and typically realised with specialised expertise from dedicated companies. Establishing wells always comes with a level of uncertainty about actual delivery and considerable capital-intensive infrastructure is required. Also, legislation can be an issue and groundwater resources need to be protected, and conflicts with other underground activities are to be avoided.

Heat recovery systems; For saving of energy or supply of lower-temperature heat to farming operations and buildings, heat pumps can be suitable and are commercially available. When these can be combined with cooling (dairy, cool storage of products), manure storage, heat pumps can be very effective and efficient.

Many examples of renewable energy technologies on farm can be found in Europe, illustrating the diversity, as well as striking examples of how renewable energy can be used in the agricultural sector, including small-scale solutions for heat production, cooling, specific solutions in Southern Europe for more arid conditions and dealing with water availability and efficiency of use, etc.
One of the Focus Group main tasks is to gather such examples, which will be presented and annexed to the final report of the Focus Group

4. Questionnaire results

4.1 Questionnaire results; exploring key issues concerning opportunities and prospects.

The results of a questionnaire which was completed by all the Focus group experts provided impressions on the prospects and opportunities for generation of renewable energy on farms in Europe. Figure 4.1 depicts the opinions given, concerning the prospects for bioenergy, geothermal, solar energy and wind energy, with respect to the total amount of energy that can be delivered, cost reduction potential and improved competitiveness and implementation. Solar energy is seen as most promising, followed by bioenergy, with variable scores for the three aspects included.

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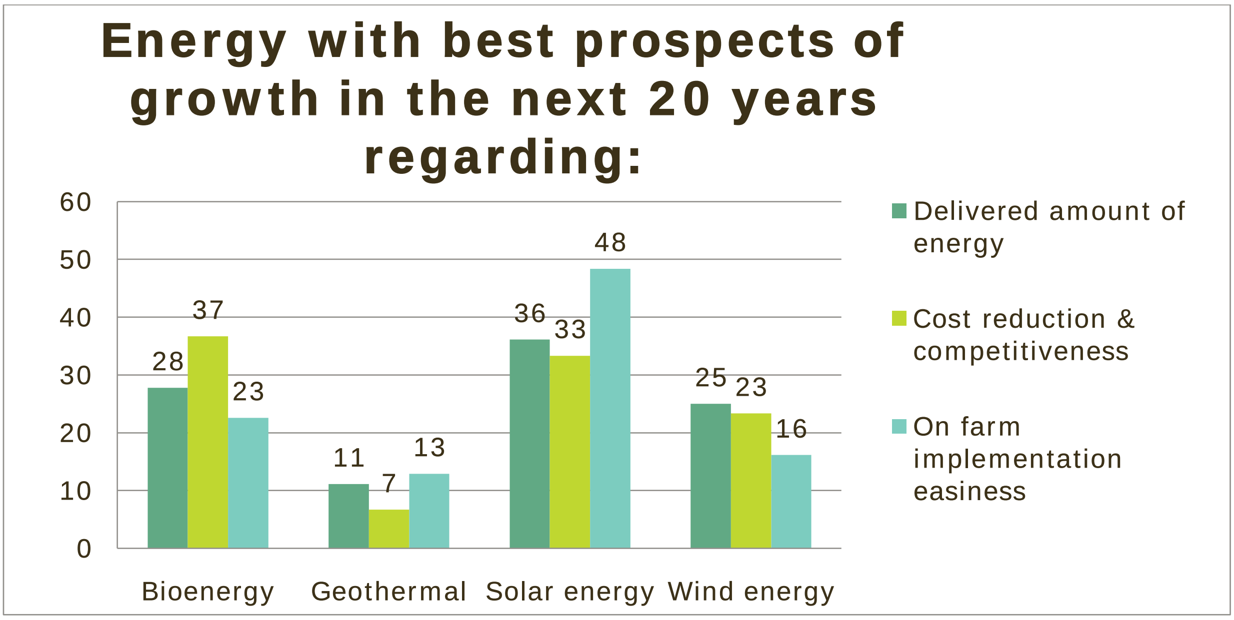

Figure 4.1: Opinions on prospects for the coming 20 years for the use of key renewable energy options in the agricultural sector, differentiating between total potential realisation, competitiveness, and implementation. The graph shows the percentage of times each type of energy was selected for each of the 3 options.

Figure 4.2 presents opinions given on the opportunities for different renewable energy options in the agricultural sector, differentiating between `contributing to farmers income`, `energy self-sufficiency of farms`, `societal and community benefits`, `environmental and climate sustainability` and other factors. This resulted in a quite even distribution over the different benefits considered. This may indicate that renewable energy technologies are implemented on farms for multiple reasons, and a following a more integrated strategy, not merely for energy generation.

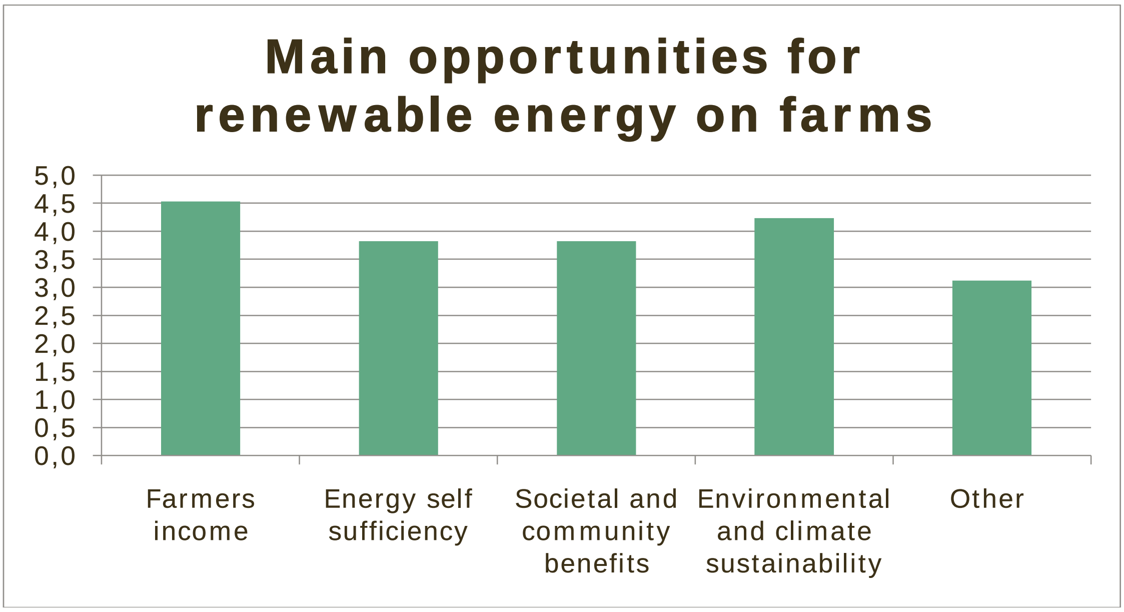

Figure 4.2: Opinions on the main opportunities and impacts of renewable energy generation on farms, differentiating between contributing to farmers income, energy self-sufficiency of farms, societal and community benefits, environmental and climate sustainability, other. The graph shows the average rating between 1 to 5 that experts provided to assess the opportunities of RE for each option

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Figure 4.3 summarises the perception of the Focus Group experts on which countries are considered to have a leading position in the use of renewable energy technologies in the agricultural sector. Germany, Denmark and the Netherlands are ranked 1-3. Except for Estonia, Eastern European countries were not mentioned in this list.

Figure 4.4 presents the results of the expert consultation with respect to which farmers or farm types are leading or have more experience with renewable energy technologies. The livestock sector (dairy and pigs) clearly stand out, perhaps partly because such (intensive) farm types use more energy for various specific operations (e.g. cooling, manure treatment) than arable farming, although the ranking of the latter is not much lower than the livestock sectors.

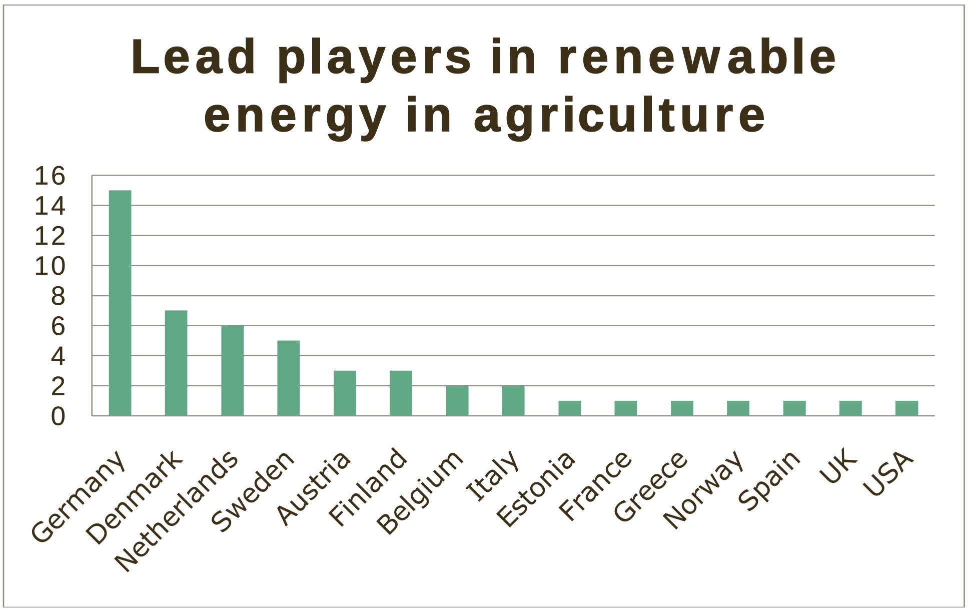

Figure 4.3: Perception on the position of countries and experience with deployment of renewable energy in the agricultural sector. The graph shows the number of times each country was selected by experts

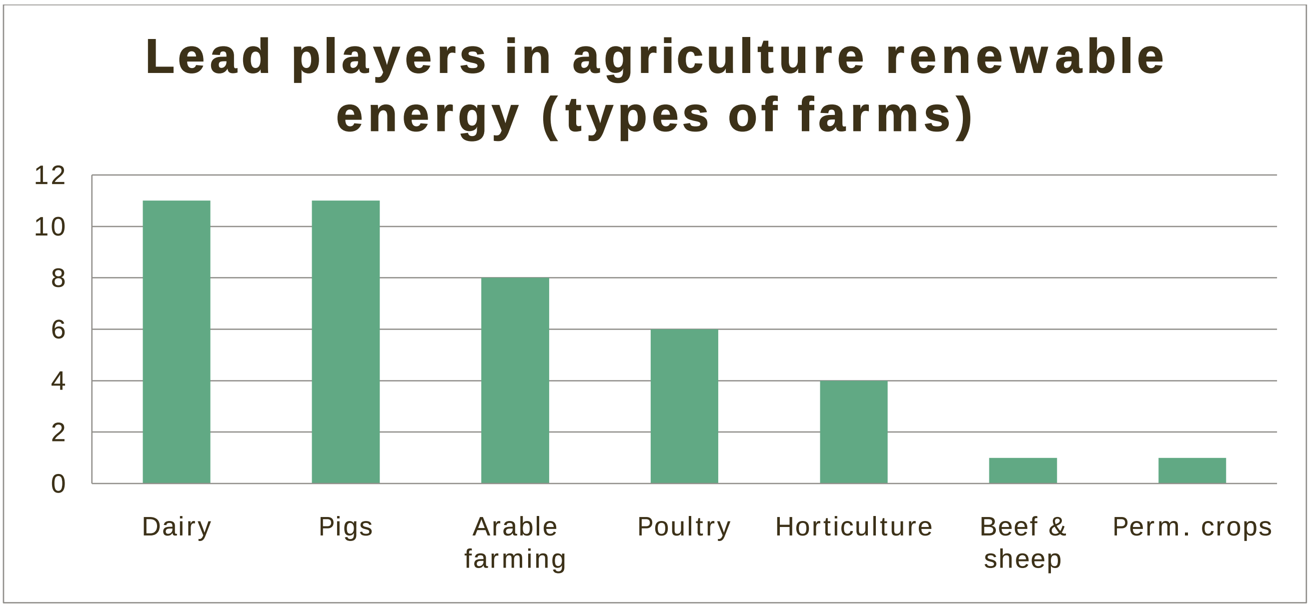

Figure 4.4: Perception on the position of farm types and their position and experience with deployment of renewable energy technologies. The graph shows the number of time each type of farm has been selected by experts.

4.2 Key barriers

This section indicates the main obstacles perceived for further development and deployment of RET's on farms and by the agricultural sector and covers:

- **Technical barriers:** Complexity and reliability of technologies, deviations from projected performance due to specific local conditions, capabilities and service by technology suppliers.
- **Economic barriers:** Technologies that are more expensive than the conventional alternatives require subsidies to be made attractive. Such incentives are subject to policy changes, therefore uncertain and present a (real) risk to farmers who invest.
- **Societal resistance:** deployment of RET's often has an impact on the landscape (larger solar energy installations, wind turbines, biomass production), may cause noise (wind energy, transport of biomass) or smell (biogas), or otherwise impact the environment. In various situations societal resistance can hamper deployment.
- **Regulations:** obtaining permits to realise RET systems is often complex and time-consuming. Various regulations may conflict (especially with respect to spatial planning, ownership of land, etc.).

The main types of barriers mentioned were further subdivided and addressed in the questionnaire completed by the Focus Group experts, so as to explore the weight of key barriers and issues concerning deployment of renewable energy in the agricultural sector.

Table 4.1 provides a crude score on the role of different obstacles in hampering the use of renewable energy technologies on farms. Clearly, the economic performance stands out as a key issue. At the same time, all other obstacles listed (landscape impacts, access to technologies, implications for farm management and lack of synergy (or conflict) with core functions with respect to food production) are also mentioned. This illustrates that effective implementation of renewable energy on farms should address these obstacles simultaneously. And although financial performance is a key issue, which can be improved by more competitive technologies and (financial) policy instruments, these improvements alone will not be enough.

Table 4.1: Results of the questionnaire on the question: What are in your view the main obstacles for renewable energy on farms? – number of mentions by the Focus Group experts.

	Landscape impacts	Access to technology	Financial (higher costs and risks for farmers?)	More complex farm management (technology & maintenance, information management, interdependencies).	Competition with core functions on food production (in terms of land use and business model).	Other
Essential	1	2	10	4	0	5
Important	5	8	6	7	8	2
Supportive	4	4	1	2	5	2
Lesser importance	5	2	0	4	4	2
Not important	2	1	0	0	0	6

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In figure 4.5 a more detailed overview of the scored perceptions of the focus group experts is given concerning key barriers (economic, infrastructural, legislation, policy, other) focusing on different key renewable energy options on farms.

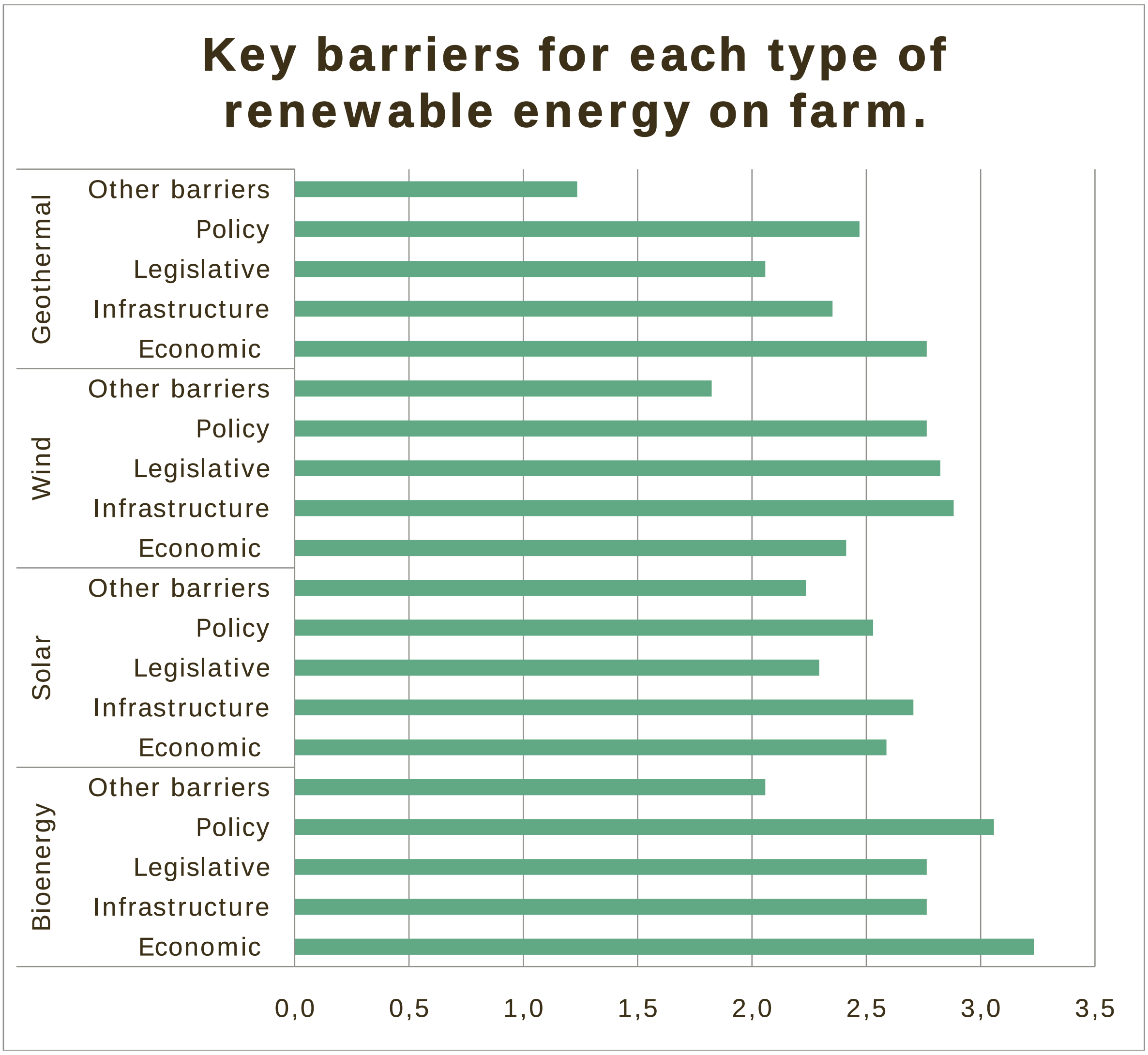

Figure 4.5: results of the questionnaire among Focus Group Experts with respect to key barriers (economic, infrastructural, legislation, policy, other) for the use of different key renewable energy options on farms. The graph shows the average rating (between 1 "not important" and 4 "essential") experts provided to each barrier.

The overall picture obtained does not provide sharp distinctions between renewable energy options, although bioenergy scores the highest overall with respect to key barriers on all dimensions covered. This is not surprising, given the complex character of bioenergy, relying on different biomass feedstocks, the use of which can result in widely variable environmental and other impacts (strongly depending on the resource and how it is managed and supplied). But also the other options are related to all the barriers mentioned. For wind energy, landscape impacts are clearly important, which is also the case for large solar parks. The questionnaire however only provides a very crude picture and a distinction between all the possible technologies (see section 3) was not made due to time constraints.

This confirms that effective implementation of renewable energy on farms will require addressing these barriers simultaneously.

5. Key priorities for Research Development, Demonstration, policy and dissemination

Considering the various barriers discussed in section 4 and the main objective of the Focus Group, It is suggested to discuss how to identify key strategies to enhance the use of (sustainable) RET options in agricultural settings. This will include technical, financial, policy dimensions a.o. This section explores which actors and factors should be considered for such strategies. Ideally, the Focus Group report should highlight clear success stories of RET deployment for different settings that can serve as inspiring examples (see also previous sections).

To structure and prioritise factors to support the use of renewable energy technologies on farms, the questionnaire also covered these elements. Figure 5.1 depicts which actors, according to the Focus Group experts, are important to support and realise the adoption of renewable energy options by farmers. The figure confirms that the various actor groups mentioned (cooperatives, advisers, technology suppliers, industrial partners, the research sector, the energy sector and the government all have their role to play in developing renewable energy in the agricultural sector. The overall picture is nuanced with relevant roles for each actor group, but the role of the government stands out in relation to providing clear targets and incentives or other regulations that support renewable energy deployment. Furthermore, cooperatives and technology suppliers score high.

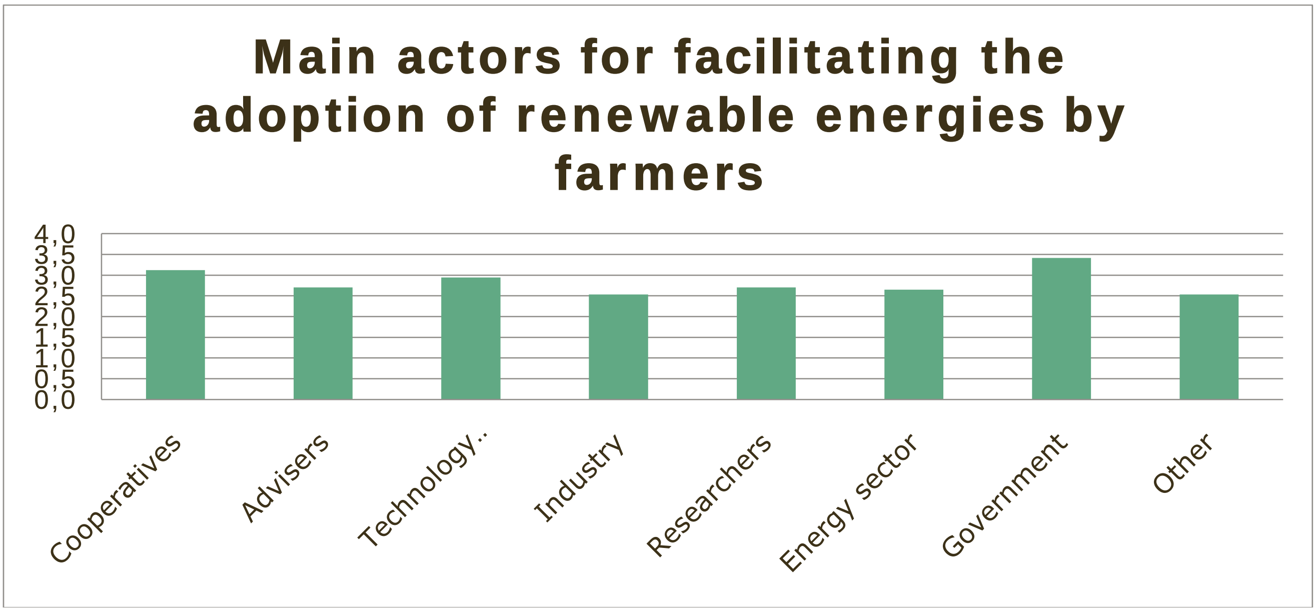

Figure 5.1: Outcome of the questionnaire with respect to the importance of main actors and players for facilitating the adoption of renewable energy options by farmers. The graph shows the average rating (between 1 and 4) that experts provided to each actor according to their importance.

Figures 5.2a+b present results of the questionnaire on the most important factors in facilitating renewable energy generation in the agricultural sector, covering: 1) R&D; 2) policy incentives; 3) capacity building among farmers (and key supplying sectors; e.g. installation technology); 4) innovation in farm technology integrated with energy efficiency and RET's; 5) collaboration of the agricultural sector with energy sector a.o.; 6) societal perception and support (and avoiding resistance); 7) infrastructure (energy infrastructure and logistics).
Policy incentives stand out as essential. Furthermore, it is confirmed that all factors mentioned are important, with high scores for integrated solutions (e.g. systems combining renewable energy options with energy efficiency measures) on farms and collaboration between the agricultural and the energy sector. Basically, no

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factor is identified that is not or even of lesser importance to facilitate the use of renewable energy technologies on farms.

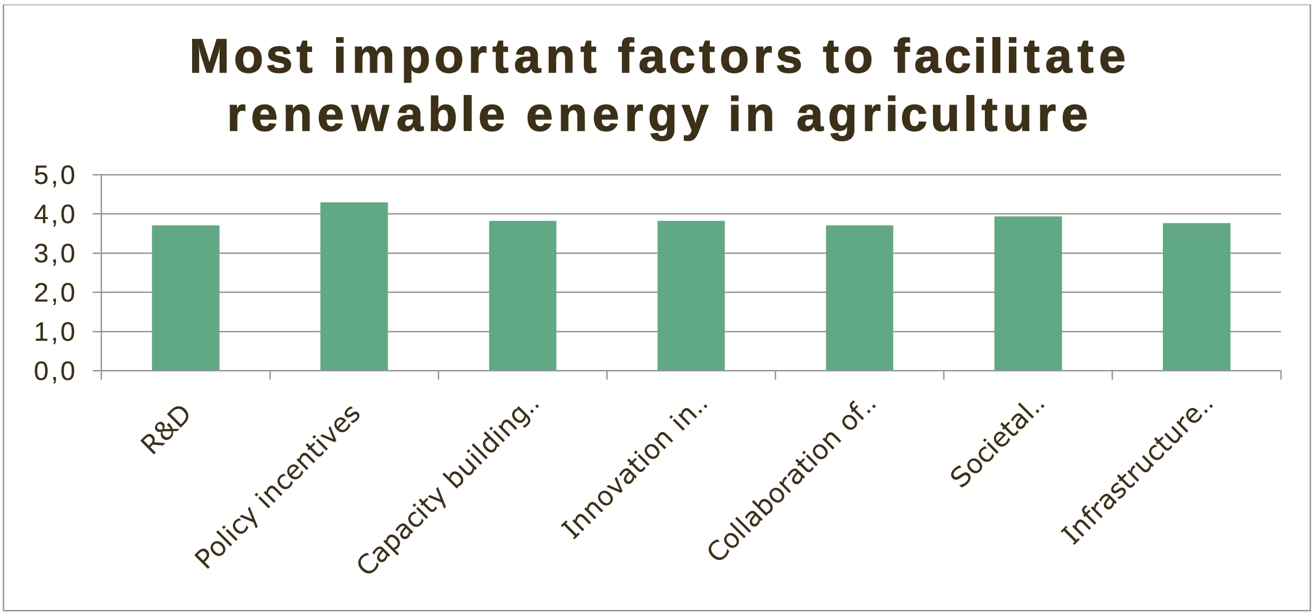

Figure 5.2: results of the questionnaire on the most important factors in facilitating renewable energy generation in the agricultural sector, covering: R&D, policy incentives. Capacity building among farmers (and key supplying sectors; e.g. installation technology). Innovation in farm technology integrated with energy efficiency and RET's. Collaboration of the agricultural sector with energy sector a.o. Societal perception and support (and avoiding resistance). Infrastructure (energy infrastructure and logistics). The graph shows the average ranking (between 1 and 4) that the Focus Group experts provided for each of the factors according to their importance.

Figure 5.2b: results of the questionnaire with scores of the factors mentioned ranging from essential to not important. Numbers indicate the number of mentions by expert group members.

The overall view of the factors and actors which were identified and ranked gives hints for Key priorities for research, policy and dissemination. Policies and incentives are needed to accelerate the use of renewable energy on farms in combination with good collaboration between actors mentioned and addressing various barriers identified (such as spatial planning, integration in the overall farm operations and reliable and integrated technical solutions).

Given the large number of technical options and system solutions for renewable energy use on farms in combination with the different farm types (livestock, arable, different scales) settings (climatic, soil, infrastructure) and regions (policy, innovation system, culture), it is obvious that further growth of renewable energy use on farms will have many forms and pathways. Generic (and positive) trends such as continuing cost decrease of renewable energy technologies, more experience and capacities with respect to renewable energy in the agriculture and the energy sectors, but also others such as the financial sector will accelerate further growth. However, increased deployment of larger scale use of bioenergy, wind energy and solar parks, also increasingly requires adjacent measures with respect to spatial planning, infrastructure, different business models and market organisation, trends that are not all under control from a farmer`s perspective. Integrated approaches and good practices will be very important to identify, develop and implement. For the further work of the Focus Group a wide variety of cross-cutting topics and themes could be considered:

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- Electromobility, as a means to lower energy use of transport and to use more (self-produced) renewable electricity on farms.
- Combinations of intermittent energy sources with energy storage and smart grids. Such integrated systems, also including energy efficiency measures provide (farm-specific) opportunities and pose specific technical challenges.
- Agro-forest management and use of residual biomass flows for renewable energy production; such systems can deliver multiple services and products. Optimisation involves the entire land and crop and forest management.
- Business models and funding; which is core to the financial viability of renewable energy on farms, connected to the financial possibilities and constraints of different farms and farmers.
- Societal aspects of renewable energy production and use on farms, covering amongst others how local stakeholders can accept implementation and how policy actors can be activated.
- Integrated approaches for energy, food, feed and biobased products, including more efficient and environmentally-friendly farming, closing nutrient cycles, improved soil and water management, etc.
- Biofuels; with a wide range of technical options and value chains and relying on land-based biomass for feedstock.
- Advising and equipping famers; with attention for accessibility of good-quality information on best practices, good implementation and effective dissemination reaching the critical target groups.

These themes will be further addressed in the final report of the Focus Group.

6. Proposed questions for discussion during the Focus Group meetings.

The discussions and work of the Focus Group aims to answer the tasks described in the Focus Group call. The proposed topics and questions described below as well as other suggestions from the Focus Group experts could help in that regard:

Discussion question 1: Following the overview of RET options (section 3), besides general sources on renewable energy options such as the IEA, IPCC, IRENA and other, which information sources provide the best information on renewable energy use in the agricultural sector, also highlighting priorities for future development and use?

Such information sources include specific EC-funded research projects as well as databases of national bodies supporting renewable energy (in agriculture).

Discussion question 2: What are best practices and good, representative, illustrations of the use of renewable energy at farm level and what are the key factors that made and make those cases a success?
This question requires collection of and good access to information. This paper illustrates which aspects are relevant and how and which specific data (e.g. on business models, but also on environmental impacts or on the operations of the farm) are desired to understand and describe cases in a meaningful way.

Discussion question 3: Will these best practices and options change over time due to the ongoing energy transition, technology developments and developments in the agricultural sector itself?
The ongoing changes in the larger energy system considerably affect renewable energy generation and use in the agricultural sector. The developing markets and increasing competitiveness of RET's allow farmers to contribute to centralised schemes (e.g. lease their land for wind farms of solar parks developed by larger companies), but these can also increasingly compete with smaller-scale technologies. Furthermore, market design and regulations are subject to change (e.g. sustainability criteria for bioenergy and pricing mechanisms for renewable electricity). It is therefore important to consider future development of renewable energy in agriculture as part of the larger context of energy system transitions. Addressing potential societal resistance via participatory or social innovation techniques to eliminate the resistance or uncertainty of planned RES projects are also important.

Discussion question 4: What are the major areas for growth and promising developments for renewable energy generation on farms in the coming 10-20 years? The discussion can on the one hand cover results of analyses on the potentials for renewable energy in the agricultural sector (e.g. scenario studies, technology assessments) but also cover implementation aspects that may either accelerate or slow down RET use on farms over time.

Clearly, all the factors mentioned matter. Technical potentials for all major renewable energy options are large, but their viability and attractiveness at farm level will depend strongly on location, farm type and natural conditions as well as policy environment.

Discussion question 5: What are the trade-offs between all types of on-farm bioenergy production options and alternative uses of biomass for food, feed and other non-food applications?
This question touches upon the competing demands for biomass resources and market, as well as environmental implications of shifts in biomass use. From a farmer's perspective, the question is which use of crops and biomass resources provides most benefits from an economic and environmental perspective.

Discussion question 6: What are the possible synergies between the use of various energy sources and demand on farm level?
Besides possibilities for the use of individual renewable energy technologies on farms, the combination of technologies (including energy efficiency measures) can provide further synergies and solutions for farmers to minimise costs and increase the share of renewable energy. At the same time this results in more complex systems and integration issues that need to be addressed.

Discussion question 7: What are the key opportunities overall for the agricultural sector to benefit from RET's on farm and as part of the larger energy transition and GHG mitigation policies and strategies?
The net impact of biomass production and use for energy (and renewable materials) strongly depends on sustainability requirements and their enforcement. Agriculture and forestry in Europe can mobilise substantially larger amounts of biomass resources in a sustainable way once productivity is increased.

Discussion question 8: Specifically, what are the main opportunities and barriers for combining increased biomass production for energy and materials with more efficient agricultural production?
This issue involves the combined improvements in agricultural practices with increased biomass production and harvest and good land use management in general. Given the very large diversity in agricultural production systems, regional economies and natural conditions, the actual choice of bioenergy systems and changes in land use and (adjacent) agriculture will also be regionally specific. This creates a demand for concrete examples, underpinning research and case studies, and experience with implementation as well as monitoring.

Discussion question 9: Based on the list of barriers in section 5, can these barriers be further specified in relation to specific RET's, farm types and rural setting? Are there overarching issues?
This question and the more generic barriers listed will translate into many specific matters per technology and farm type. On the other side, a range of barriers (e.g. financial, technical) will be quite universal. One of the facilitating measures could be making information about practical experiences and proven solutions widely available for farmers, and for technology suppliers and government bodies. Addressing financial risks (or profitability) is very important for farmers, and therefore this deserves special attention. Part of this question is which options and organisational models work best, e.g. including collective selling approaches.

Discussion question 10: what are the key priorities for future research to facilitate renewable energy use in the agricultural sector considering the aspects covered above ? Research can cover technical, environmental, social, policy and economic (etc.) issues.

This question connects to all preceding questions. Research & Development & Demonstration efforts are needed to improve the performance (in particular in economic terms) of renewable energy technologies. In some cases (e.g. biorefining, geothermal) this is a precondition for commercial application. However, given the number of factors relevant for implementation listed in this document, research that analyses real experiences in practice, implementation strategies and potentials (also in relation to the major changes in the overall energy system) and impacts in relation to specific regional conditions, is very important. Effective dissemination among key stakeholders poses specific challenges, again because of the wide diversity of setting, type of farmers, and policy actors.

Discussion question 11: Which actions could be taken to stimulate the knowledge and use of management practices that improve and accelerate the uptake of renewable energy on farms and how do such actions provide examples and inspiration for EIP-AGRI Operational Groups?

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