AGRI-2010-EVAL-03

IMPACTS OF RENEWABLE ENERGY ON EUROPEAN FARMERS

CREATING BENEFITS FOR FARMERS AND SOCIETY

Final Report

for the European Commission
Directorate-General Agriculture and Rural Development

5 December 2011

Lead Contractor: Alterra Wageningen UR, in cooperation with
Ecologic Institute, EC BREC IEO, SoriActiva, ECN and Wageningen University

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Bas Pedroli & Hans Langeveld (Eds.)

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Executive Summary

This report presents results of the project ***Impacts of Renewable Energy on European Farmers***. It focuses on the (potential) role that on-farm generation of Renewable Energy in the EU-27 may play both in realisation of national and EU environmental targets as in (re)vitalising agriculture and rural economy in different regions of the Union. Renewable Energy (RE) in this respect includes the energy generated on farms by using wind, PV, solar thermal, hydro, geothermal or biomass resources. Activities executed in the project include

- an assessment of current and possible future production of RE on farms,
- the analysis of national and EU RE policies and markets,
- construction of national and EU balances for 2008 and 2020,
- a survey held among 800 farmers in eight case regions located in Germany, Poland, Spain and Austria,
- an analysis of perspectives and implications of RE development for farm incomes and non-RE farm production,
- identification of existing barriers for further RE development and the role (Rural Development) policies can play in overcoming them, and
- focus group meetings held with stakeholders in the case regions.

Results from project activities are listed here in an organised and thematic way. Details of the findings are reported in the final report and its background documents.

In this report Renewable Energy (RE) is defined as energy derived from natural resources which are renewable (being naturally replenished, e.g. sunlight, wind, rain, tides, geothermal heat, biomass). ***On-farm Renewable Energy*** is produced on farms. Farms are economic enterprises basically relying on biological processes to generate agricultural products – food, feed, fibres, other natural materials, fuels – from natural resources such as land and/or non-saline water. On-farm RE covers energy generated by installations paid and/or operated by farms as well as by installations paid and/or operated by other legal entities (whether owned and/or managed by the farmer or not), and includes:

- primary, intermediate and final RE that is both produced and consumed on the same farm,
- final or intermediate RE that is consumed on one farm but produced on other farms,
- final energy that is produced on the farm and that is exported,
- final or intermediate RE produced on farms from biomass or waste from non-farming activities,
- intermediate and final RE produced not on farms but using biomass or waste produced on farms.

In this report, six ***key questions*** are used to elaborate crucial issues for on-farm RE production in the EU-27. Summarised, these are: (i) how much RE is produced (‘*how much?*’), (ii) why do farmers (not) get involved in RE production (‘*why?*’), (iii) and (iv): what impact does their involvement have on farming and farm income (‘*what impacts*’), (v) what barriers can be identified that limit further on-farm RE development (‘*what barriers*’), and (vi) what role can Rural Development policies play in overcoming these barriers (‘*role for RD policies*’).

I How much on-farm RE is produced?

1. Present (2008) and future (2020) levels of on-farm RE production at the level of Member States (MS) as well as an aggregated overview for the EU-27 level has been assessed by means of compiling ***RE balances*** for the agriculture sector. These balances include primary (biomass including energy crops, wood, waste, manure, etc.), intermediate (biogas produced on the farm) and final energy (mostly electricity and heat generated on the farm). Present RE production was calculated using national, international RE statistics and National Renewable Energy Action

Plans (NREAPs). Future production was based on a combination of estimations provided by MS´s in their NREAPs and own assumptions on possible development of RE on farms.

2. In creating the 2020 balances, it is assumed that all RES activities that can be employed at farm level will develop according to the average ***growth figures for renewables*** needed to reach the NREAP 2020 targets (as compared to 2008 baseline). Since no specific incentives are given under this scenario to stimulate RES on farms there is no reason to assume that growth rates for the farm sector will be higher than in other sectors. Although this may be considered a simplification, it is felt that, especially for the main types of final energy production, like wind, solar and biogas electricity, which in most cases benefit from the same support schemes regardless of installation ownership, this is a reasonable assumption.
3. A second, ***"NREAP+" scenario*** also takes the NREAPs as a starting point, but in addition it is assumed that region-specific dedicated stimulation measures lead to a higher than average increase in on-farm RE production, allowing farms to contribute more to the renewable energy targets set in the NREAPs. The NREAP and NREAP+ scenarios should be considered as trend extrapolations based on the NREAPs, as is described in more detail in Annex II.
4. Calculation of ***GHG emission saved or avoided*** by on-farm RE production is based on two methodologies. For solar, wind and geothermal energy and energy from solid biomass, GHG savings were calculated using the so-called ´RE monitoring protocol´. For energy crops and biogas the GHG emission savings were assessed with the MITERRA-Europe model. As part of this project the (co)-digestion sustainability tool was included in the MITERRA-Europe model to assess the saved and avoided GHG emissions from digestion for biogas production. System boundaries for the calculations were in line with the EU Renewable Energy Directive (RED). Several emission and conversion factors were country specific. When no country specific values were available, standard values were used from the BIOGRACE project.
5. Total ***on-farm production*** of final energy from renewable sources in the EU-27 in 2008 amounts to 11.8 Mtoe: 8.0 Mtoe of electricity and 3.8 Mtoe of heat. Most of this is exported as electricity, the lion's share of which is derived from wind energy. Heat production is mostly used for own consumption on the farm. Primary energy production (energy crops, forest wood, waste and manure) exceeds 23.4 Mtoe. Part of this is implied in the production of biogas used for generation of final energy (heat, electricity).
6. Projected on-farm ***RE production in 2020*** in the EU-27 under the NREAP scenario could reach 35.9 Mtoe electricity generation, a four to five-fold increase compared to 2008. Production of heat (6.1 Mtoe in 2020) is showing a more modest increase. These figures all refer to a scenario where RE production increase rates in agriculture are set at average NREAP levels. In terms of primary energy, energy crop production is expected to double compared to 2008 levels, mainly due to an increased cultivation of woody crops. In terms of energy value, energy crops could fall behind agricultural waste, production of which is projected to increase four times and reach 21 Mtoe. Assuming higher than average increases in agriculture in the more ambitious NREAP+ scenario, final energy generation could show even stronger increases, with electricity production possibly reaching a staggering 62.5 Mtoe (almost eight times the 2008 levels). Differences for heat (7.9 Mtoe or +1.7 for the NREAP+ scenario, as compared to the NREAP scenario) and primary energy production (+10 Mtoe) are considerably smaller.
7. A large number of data sources were consulted during the ***data collection process*** and a number of issues arose. Very few centralised data sources exist which collect relevant data following the same methodology and format for all countries; most have incomplete or inaccurate datasets. Since most necessary data were not directly obtainable, proxies were used to calculate estimates. As different data were available in different countries, a single accounting rule for all countries could not be established, which introduced some inconsistencies in the RE balances. Because of discrepancies between different sources total figures are not always the sum of sub-categories.
8. ***GHG reduction*** through on-farm RE production in 2008 amounts to 86 Mton CO_2-eq. According to UNFCCC accounting rules, most of these savings are realised in sectors other than agriculture (energy, transport) but to put the amount into perspective: It corresponds to 18% of the reported GHG emissions from the UNFCCC sector agriculture in the EU. Wind energy is responsible for more than half of the savings (53 Mton CO_2-eq), followed by solid

biomass for heating (17 Mton CO_2-eq), biofuels (8.7 Mton CO_2-eq) and biogas (5.0 Mton CO_2-eq). Other RE types have a marginal effect. Germany contributes 33% of total GHG savings, mainly through wind energy and biogas, followed by Spain with 12%, mainly from wind energy.

9. In terms of ***GHG emission reduction performance***, wind electricity is the most efficient way to reduce GHG emissions reducing emissions by more than 7 ton CO_2-eq/toe in 2008. GHG reduction efficiencies of biogas, PV/solar thermal energy and solid biomass for electricity are almost equal to wind, as are second generation biofuel crops. Alternatives like heating from solar, from solid biomass or geothermal and show GHG reduction efficiencies that are considerably lower (generally 3 to 4 ton CO_2-eq/toe) while first generation energy crops (around 1 ton CO_2-eq/toe) achieve very little GHG reduction per toe. For 2020, biogas is surpassing wind energy as its production increasingly can make use of agricultural waste and crop by-products.
10. Power generation contributes most to ***GHG emissions savings from biogas*** (5.2 Mton CO_2-eq), whereas the contribution from biogas-based heat is low (0.1 Mton CO_2-eq). The reason is that only very little (2.6%) of the heat generated in biogas installations is actually used. Net avoided emissions from manure storage are estimated at 1.5 Mton CO_2-eq in 2008. The net GHG savings are lower, since they are corrected for GHG emitted during biogas and feedstock production (mostly related to the cultivation of energy crops like maize). Net GHG reduction is relatively higher in countries where no energy crops are used (e.g. Denmark, Spain).
11. In ***2020, GHG emission reductions*** are expected to rise to 315 Mton CO_2-eq under the NREAP scenario, equivalent to 65% of the total reported GHG emissions from the UNFCCC sector agriculture in the EU in 2008. Savings under the more ambitious NREAP+ scenario amount to 512 Mton CO_2-eq (105% of the current reported emissions from the UNFCCC sector Agriculture). Most GHG savings are due to wind energy (about 73%), followed by biogas, solid biomass for heating and electricity from second generation energy crops. Germany remains the largest contributor under the NREAP scenario (27% of total GHG savings), but it is caught up by France under the NREAP+ scenario (both 25% of savings), mainly due to a very large increase of wind energy in the latter.

II Why do farmers (not) involve in RE production?

12. Issues related to farmer decision making to (not) involve in RE production were studied in detail using a ***farm level survey***. Eight case study regions from four Member States were selected to be included in the analysis. Selection of the regions included the following criteria (in descending order of importance): (i) dynamism of on-farm RE development, (ii) EU-wide distribution, (iii) climatic and ecological conditions representing different environmental zones, (iv) agricultural activities and main crop types, (v) farm types, (vi) types of RE used, (vii) availability of micro-economic, farm-level data, (viii) availability of or access to primary data, and (ix) difference in energy-related infrastructure endowment.
13. A dynamic region and a region with slower RE growth (or smaller near-term potential) were selected for each of the four MS's. The ***regions*** represented the diversity of farm types and agricultural activities, ecological zones and RE types in the MS and the EU. Availability of farm-level data also was an important criterion. The following regions were selected: North East Brandenburg and Saarland (Germany), Valencia and Soria (Spain), Mazowiecki and Warminsko-Mazurskie (Poland) and Upper Austria and Carinthia (Austria). The cases cover all major geographical regions, climatic conditions, farm types and bioenergy feedstock crops found in the EU. Table 1 provides details of the selected regions.
14. A survey was held among 100 farmers in each of the eight case regions in Austria, Germany, Poland and Spain. Using a ***questionnaire*** guaranteed that participating farmers in all case studies were asked exactly the same questions and provided with the same optional answers, thus allowing for a thorough comparison between countries and regions. The questionnaire included open questions as well as closed questions (multiple choice). Opinions held by farmers were collected using a 5-point Likert scale providing statements for which the farmers had to fill in to what level they (dis)agree with the statement.

15. A total of more than 800 questionnaires have been submitted by farmers. Out of this, 358 farmers indicated they ***invested in RE*** (total of 372 RE investments). Farmer in Poland and Soria sometimes did not specify which investments were made. If this would have been the case, the number of investments would have been higher. An additional 65 farmers indicated that investments were done on their farm by a third party on their behalf.
16. Total ***reported RE investments*** amount to 125 million Euro, representing an average investment of nearly 350,000 Euro per farmer. Average investments vary between 37,000 Euro in Warminsko-Mazurski and around one million Euro in Brandenburg and Valencia. Intermediate figures (around 300,000 Euro) were reported for Saarland, Soria and Upper Austria. Investments in Mazowiecki (77,000) and Carinthia (176,000) are on the lower end of the spectrum. Figures presented here do not include RE investments done by external parties (farmers leasing out land or roof area for a fee).
17. Most ***investments that were reported*** relate to biomass (37% of reported RE activities, not including biogas production). Most of this refers to solid (woody) biomass use for heating and electricity production Other important RE types include PV (26%), solar thermal (11%) and biogas (8%). Biomass related investments are most popular in Austria and Poland, PV in Germany and Upper Austria, whereas solar thermal is most often reported in Austria and Mazowiecki. Most reported biogas installations are found in Upper Austria and Brandenburg. The number of on-farm wind investments in most regions was rather low (generally 8-12% of the farmers where RE production is found (also) reporting wind energy), Soria (28%) being an exception to the rule. Possibly, a higher figure for wind in Brandenburg (reported by 9% of the farmers), where a large number of wind turbines are found, could be expected. Analysis of wind turbine ownership and location in this region suggest that turbines are often clustered, mostly on land that has been (recently) devoted solely to this use, thus taking it out of agricultural (farm) area. The following percentage of investments was for own use mainly: Saarland 30%, Brandenburg 20%, Mazowieckie 39%, Warminsko-Mazurskie 55%, Valencia 29%, Soria 19%, Carinthia 60%, Upper Austria 65%. However, many questionnaires were incompletely filled in for this question. Still, there is a clear picture of low shares in Germany and Spain (especially Brandenburg and Soria), and high shares in Austria.
18. ***Farmers who invested in RE*** more frequently have a successor than farmers who did not invest, while they often indicated to earn an income that is above the regional average. The income effect is strongest for farmers who invested in PV and biogas. There are no other major differences between farmers who did and farmers who did not invest in RE. Farmers who invested do not have larger farms, nor do they grow different crops or have higher solvability ratios.
19. Most investments have been done by ***individual farmers***, generally using personal or farm funds or bank loans provided to farmers as entrepreneurs or individuals. Investments by external institutions, companies or individuals are not common. On average, only one in seven (15%) of the investments involved (co-)investing by external parties. Higher involvement of external parties in Soria, Saarland and Brandenburg can be explained by specific local conditions (e.g. investments in expensive wind turbines by external parties in Soria and Brandenburg, or external involvement in energy crop investments in Soria, limited investment capacity especially in Soria and Saarland).
20. Active involvement of ***external companies*** can have considerable advantages (reducing the investment load for the farmer, often also taking care of communication with utilities or even arranging subsidies and permits). In some cases, however, farmers stated their reservation or even distrust with regard to external involvement. Reasons for this can be found in the (recent) past. Earlier experiences with large bioenergy initiatives in Brandenburg, for example, showed that investing companies tended to buy the *land* (and hire the farmers) rather than purchasing the *feedstock*. This was frowned upon by farmers. For different reasons, group investment initiatives are not met with enthusiasm in former communist states like Poland.
21. Our survey confirms that farmers tend to invest in RE mainly for ***economic reasons***. The investment represents an opportunity to diversify income sources and to make income and costs less volatile. Others reasons reported by farmers to invest in RE include (i) the wish to contribute to renewable energy sources, (ii) to become less dependent on rising energy prices in

the future, (iii) the wish to diversify sources of income, and (iv) the possibility to get a guaranteed price for a fixed period of time.

22. Out of the reasons mentioned by farmers to invest in on-farm RE, the role of ***feed-in tariffs*** appears to dominate. The impact of feed-in tariff has two elements: (i) feed-in tariffs ensure that farmers receive stable, guaranteed prices, and (ii) they are subsidies, thus increasing farm incomes. Farmers indicate that the first element (stabilising farm incomes especially where current incomes depend on highly fluctuating crop prices) is extremely important. While the absolute level of the prices (subsidies) is also relevant, some farmers prefer lower – but guaranteed – price levels as a way to reduce income fluctuations (e.g. by leasing out land or stable roofs to companies offering a fixed price rather than investing in farm-owned PV installations; it has to be noted that in the case of a biogas plant running mainly on silage maize with a changing price, the fixed feed-in tariff may actually destabilise farm income).

III What impact does RE production have on farming?

The impact of RE production on farming is assessed using a two-step approach. First, a number of answers of the survey were used to identify whether farmers indicate that RE production affects farming (e.g. time allocated to other farm activities, purchases of inputs, but also farm income or time spent on the farm as a whole). Next, specific relations are further specified using FSSIM modelling for representative farm types in the case study regions. Subsequently, results were used to assess more generic relations and impacts on farm economy.

23. If farms are considered as a unit for producing inputs for biomass or biogas installations, without having the installations on each farm, the ***income effect is positive***, with a small positive effect (1-10%) in German, Austrian and Spanish regions, and a large positive effect in Polish regions. For those farms investing in biogas and biomass installations, the situation is more complex given the considerable investment costs required for such installations.
24. Our analysis shows a general ***positive labour effect*** of introducing RE production on farms, implying that more labour is required on the farm. These effects are most pronounced on the Polish farms surveyed, with large increases in labour required on farm, due to changes in RE activities. The effects are smaller, and still mostly positive for other regions. For some farm types, reductions are observed due to changes in the cropping pattern, moving away from more intensive crops towards less intensive RE activities, if these are profitable enough.
25. Farmers indicated that RE investments lead to an increase of ***farm income*** (Germany, Poland, Valencia).
26. As a consequence of RE production, farmers indicate that the amount of ***work on the farm*** has increased (in Upper Austria and Brandenburg). Labour requirements generally are associated with solid biomass and biogas production, and do not refer to PV and wind energy installations. Farmers indicate that other farm activities are generally not affected.
27. The impact of energy crop use in biogas installations has been modelled using FSSIM farm level model for representative farm types in Brandenburg, Saarland and Upper Austria. Results suggest that an expansion of silage maize area because of high feed-in tariffs for electricity from biogas would go mainly at the expense of other cereal crops rather than at the expense of grassland. This would lead to a slight ***increase in nitrogen use***, in labour use and farm income.

IV How does RE affect the rural economy?

28. Results from RE impact on farming have further been specified and upscaled to regional levels. From the survey, it is confirmed that RE investments in ***less dynamic regions*** are generally not as high as those in more developed regions.
29. Farmers tend, however, to be more satisfied with returns on their investments in less dynamic regions, indicating that ***RE investments are most welcome***. Farmers also indicated that RE has contributed to an observable change in their regions (Germany and less dynamic regions of Carinthia and Warminsko-Mazurski).

30. Farmers in Brandenburg and Austria further feel that ***RE is accelerating innovation and modernisation***. It may also improve acceptance of agricultural activities. This confirms the understanding that RE can be part of a (re)vitalisation process in regions with slow economic performance. Farmers in Spain, however, are less optimistic about the impact of RE on perspectives for farming and rural development, probably because of lower investment capacity.

V What barriers limit on-farm RE production?

31. Barriers limiting on-farm investments and production have been assessed using answers to questions dedicated to this subject. Results have been presented to and discussed with focus groups consisting of representatives of farmer communities and national and local institutions related to farming and RE. It was found that farmers who invested in RE generally did not express clear, unambiguous views on ***unexpected problems*** that were encountered during investment and RE production. Farmers did however clearly indicate that availability of assistance for RE technology (e.g. for installation, advise or maintenance) was definitely *not* a problem. PV and solar thermal investors reported no problems at all. Some owners of biogas installations (especially in Upper Austria and Soria) were surprised by unexpectedly high investment costs, relatively low profitability, and difficulties with obtaining permits while reliability of the biogas technology was lower than expected.
32. ***Obtaining permits or subsidies*** was reported to be problematic in Upper-Austria, which coincides with a high number of biogas plants in this region. By contrast, RE farmers in Saarland reported smooth procedures, since they mostly invested in PV installations. More barriers have been reported for southern and eastern countries.
33. In some regions, ***resistance*** has been reported against further development of (large scale) RE installations, especially wind and biogas in Spain and Brandenburg. This is linked with landscape perception and topography – hilly regions (Saarland, Carinthia) generally showing less suitability for wind turbines and thus also less resistance.
34. In many countries, ***connection to the grid*** is not well organised and potentially forming a barrier towards RE development in rural areas. Germany is an exception.
35. Availability of ***(investment) subsidies*** does play a role in decision making for RE investments. One quarter of all farmers that did invest have used some kind of subsidy in the process of purchasing and installing the RE equipment. Subsidies are most important in biogas and wind turbines. There are large differences between countries (Spain showing the lowest subsidy use, Austria the largest) and among regions (weaker regions in Germany and Poland showing more use of subsidies, while the opposite was the case in Austria). Notwithstanding the relevance of initial subsidies, the role of feed-in tariffs seems to be more important. In many cases, farmers indicated that they prefer guaranteed feed-in tariffs over investment subsidies. Availability of proven technology or technical advice does not play a role, with the exception of Poland.

VI What role can rural development (RD) policies play in stimulating RE production?

36. ***Dedicated policies*** could increase on-farm RE contributions. A comparison of two trend projections for 2020 (the NREAP and NREAP+ scenarios) assumes that policies dedicated to on-farm RE development may lead to considerable extra RE production on farms. Analysis of investment subsidies suggest that subsidies may play a more important role in regions with weaker economic conditions. This was shown for RE investments in Saarland and Warminsko-Mazurski.
37. Stimulating policies for farm-related RE production should include ***combinations of various elements***: price guarantees for a fixed period of time, investments in grid infrastructure to ensure that production is effectively transported to users, and streamlining of procedures to obtain (subsidies and) RE production permits and grid connection.
38. Although this has not been studied as such, ***agri-environmental measures*** may well be useful in enhancing RE. The support of the maintenance of hedgerows and tree lines on farms may

stimulate the use of woody material for RE production. Also RD investment subsidies for constructing e.g. environmentally friendly wood stoves for collective use, or for pelletising farm waste, may stimulate the production of RE on farms.

General conclusions

- Current ***on-farm production of final energy*** from renewable sources is mainly related to the production of electricity. The much smaller amount of renewable heat produced is generally used directly on the farm; electricity is mainly exported. Most energy is produced by wind turbines, plus solid biomass for heating.
- Following projections defined in NREAPs, ***RE production in 2020*** will grow considerably. Electricity production could show a four to five-fold increase by 2020. Production of heat will be modest. Primary energy crop production is expected to double. Energy from agricultural waste will increase five-fold. Under the more ambitious NREAP+ scenario, electricity production could reach 62.5 Mtoe (eight times the 2008 levels); but differences for heat and energy crops are considerably smaller. Agricultural waste will surpass first generation energy crops as supplier of primary energy.
- Reductions in GHG emissions by 2020, mostly in non-agricultural sectors (energy, transport) are expected to quadruple to 315 Mton CO_2-eq (NREAP scenario), equivalent to two thirds of total GHG emissions from the sector Agriculture. Under the more ambitious ***NREAP+*** scenario, GHG savings amount to 512 Mton CO_2-eq. The dominance of wind is increasing. Other major contributors are biogas, solid biomass for heating and electricity and second generation energy crops. Germany remains the largest contributor under the NREAP scenario (27% of total savings), but it is caught up by France in the NREAP+ scenario (both 25% of savings).
- Wind is the most ***efficient way to reduce GHG emissions*** (reducing emissions by more than 7 ton CO_2-eq/toe in 2008), but efficiencies of biogas, PV/solar thermal energy and solid biomass for electricity are almost as high as the one of wind energy, as are second generation biofuel crops. Heating options (solar, solid biomass, geothermal) are about half as efficient as wind energy in reducing GHG emissions. First generation energy crops achieve very little reduction per toe. Biogas efficiency in reducing GHG emissions will increase in 2020 due to the reduced use of energy crops.
- Notwithstanding a projected increase of ***dedicated cropping***, especially woody crops, their contribution to RE generation in 2020 will remain modest (6 to 7% of total primary energy).
- ***Biogas has huge potential*** for energy production but under present conditions application of energy crops is reducing its potential for GHG emission reduction. Also, farmers are often facing low returns on investment (with the exception of Germany), limiting their willingness to invest.
- Main ***reason for farmers to invest*** in RE is that it represents an additional and stable income source, often guaranteed for longer periods of time. Farmers also appreciate not being subject to future energy price increases, while they wish to contribute to environmentally friendly energy production.
- The main impact of RE production is its contribution to ***farm income***. In some regions, depending on the RE mix it can generate on-farm jobs, most increase being related to biogas and solid biomass. PV, solar thermal and wind do not generate more job opportunities, but may have an impact on regional development via indirect effects of enhanced and stabilised farm incomes (multiplier effects) and on regional technical infrastructure development.
- Biogas based on dedicated crops, stimulated by high feed-in tariffs, may in some regions lead to ***increased pressure to convert permanent grasslands***, although this is gradually being discouraged by EU policies.
- ***External investors*** can provide capital and bear risks for large investments, e.g. for wind turbines. Involvement of large non-agricultural investors or electricity companies may lead, however, to less economic returns for the agricultural sector and the rural economy, since these investors tend to be non-local companies.

- ***Competitive potential*** for RE including biogas and dedicated crops at price levels expected in 2020 is showing large variations by region and farm types.
- Entrepreneurship by farmers is challenged by the ***need to cooperate*** beyond present levels. Especially substantial investments in large-scale biogas plants and wind farms will not be possible without extended co-operation.

Contents

1 Methodology followed

1.1 Objectives and outline

1.1.1 Renewable energy on farms: creating benefits for farmers and society

The European Union energy policy is focused on a transformation of a fossil-fuel based energy production to the use of Renewable Energy (RE). In December 2008 the EU Directive on the promotion of the use of energy from renewable sources (RED) was approved by the European Parliament and the Council (2009/28/EC). It sets an overall target of 20% renewable energy consumption to be reached by 2020 and a 10% target for renewable energy sources including biofuels in total final energy consumption for transport.

It is evident that this policy substantially affects the agricultural sector in two ways:

1. the agricultural sector is challenged to contribute to the production of Renewable Energy, and
2. agriculture is challenged to reduce its own use of fossil energy and its emission of Greenhouse Gas.

Depending on how these challenges will be answered, the impacts of such energy policy on European farmers can be very significant.

Since the current production and use of renewable energy on farms has not been studied in great detail for the EU, this study has been set up to give a first overview of the impacts of Renewable Energy on European farmers, both at present and for the target year of 2020.

On-farm RE production has the potential to play a crucial role in the transition of European agriculture, as:

- it provides a new, additional, source of farm income and reduces farmers' expenses on energy;
- it supports the rural economy by creating new jobs and added value;
- it reduces CO_2 and other GHG emissions in different economic sectors (agriculture, energy, transportation), thereby delivering a public good;
- it saves energy from the grid (reduction of transmission losses), improves security of energy supply for farmers and reduces dependence on oil-exporting countries;
- it supports the development of innovative new industries in member states, with the potential of making Europe a front-runner in farm-based energy production.

If well organised, RE production on farms may thus bring a substantial benefit to farmers and society on a European level.

1.1.2 EU policy agenda relevant to renewable energy on farms in global perspective

Trends that can be foreseen for the period until 2020 (the time-frame for our study) relate to a reorientation of EU rural and agricultural policies, rural economic development, and evolvement of RE technology. They are discussed briefly below.

Developments in agricultural and rural development policies

The EU Rural Development Policy aims to establish a coherent and sustainable framework for the future of rural areas in Europe. In its early days, it was essentially sectoral (dealing mainly with agricultural structures) with limited territorial aspects. This was changed under Agenda 2000 which established Rural Development Policy as the second pillar of the EU Common Agricultural Policy (CAP) and brought rural development under one regulation (2000-2006). In addition to agricultural restructuring, it also addressed environmental concerns and the general needs of rural areas.

The mid-term review of the CAP in 2003 led to a strengthening of Rural Development Policy, allocating more funds. In September 2005, a rural development regulation was adopted for the period of 2007-2013. Rural development presently is implemented through one fund and one type of programming while reformulating the aims of the policy around clearly defined economic, environmental and territorial objectives:

- Improving the competitiveness of agriculture and forestry;
- Improving the environment and the countryside;
- Improving the quality of life in rural areas and encouraging diversification of economic activity.

Meanwhile, under the 2008 CAP Health Check additional funds of around 1 billion Euro were made available for projects in renewable energy and climate change (alongside with themes like water management and biodiversity). In addition to this, Member States (and regions) have drawn up national and regional support schemes, state aid programmes, regional development policies, etc., all of which can include measures to stimulate RE production. This means that farmers may have different opportunities to obtain support for RE development including investment subsidies.

Rural development programmes in most EU member States (RDP programmes 2007-2013) offer a range of possibilities to support farming practices and investments that can contribute to climate change mitigation including the increase of the use of Renewable Energy resources. As a consequence, the operations related to these Community priorities have been further strengthened in the RDPs of most MS.

Renewable Energy: Europe's position

Before we analyse the position and perspectives of on-farm RE, as well as their (potential) impact on Rural Development, we provide a brief overview of the present position of major RE types (wind, PV, biomass) in the EU. This overview is mostly taken from the 2011 Renewables Global Status Report (REN21 2011).

Seen in a global perspective, the EU is in a relatively good position with respect to RE development. In 2010 renewables accounted for 41% of newly installed electric capacity in the EU, with PV accounting for more than half of the total. Although the share was lower than the 60% RE share of capacity added in 2009, more renewable power capacity was added last year in Europe than ever before (22.6 GW) according to the 2011 Renewables Global Status Report (REN21 2011). Renewable Energy's share in electricity generation in the EU in 2009 approached 20%; its share of total energy consumption increasing from 5.4% in 1999 to 9% in 2009.

There are, however, large differences between regions and RE types. Europe has a relatively strong position in wind energy, Germany and Spain being the third and fourth nations in wind capacity (after China and the USA). They are followed by India, Italy, France and the UK. Existing EU capacity installed by the end of 2011 could meet 5.3% of the EU's electricity consumption in a normal wind year (up from 4.8% in 2009). According to the 2011 Renewables Global Status Report (REN21 2011), several Member States are realising higher shares of their electricity demand with wind power in 2010, including Denmark (22%), Portugal (21%), Spain (15.4%), Ireland (10.1 %), and Germany (6%; but four regions covering 40% of their electricity needs with wind in 2010).

Wind is expected to show continuous growth in the EU as well as outside Europe. This will have positive effects on investment costs (expressed as € per kW capacity installed).

Also for PV, together with CSP currently among the most dynamic RE sectors, large capacity increases were reported in 2010. The EU accounted for 80% of the world total investments, with about 13.2 GW newly installed capacity (enough to cover energy needs of 10 million households). Germany and Spain host more than half of all PV capacity in the world (REN21 2011). Beyond Europe, the largest PV markets are found in Japan (nearly 1 GW), the United States (0.9 GW), and China (0.6 GW). Production of PV panels, however, is mostly concentrated outside the EU, Asia now harbours 10 out of 15 largest PV manufacturers.

Following a further expected capacity increase around the world, large price declines are expected for PV. According to EPIA (the European Photovoltaic Industry Association), prices could decline with 36-51% over the next decade while commercial production at competitive prices may be expected to emerge before 2020. The industry still depends on government support, but feed-in tariffs are being scaled back to enforce quick reduction of investment costs. According to EPIA, the cost of PV electricity generation in Europe could decrease from a range of 0.16-0.35 € per kilowatt hour (kWh) in 2010 to 0.08-0.18 € per kWh in 2020 [1].

Worldwide use of biomass for heat production totalled 11,600 petajoules (PJ) in 2008, the most recent year for which global data are available. Significant increases in biomass use for power generation were seen during 2010 in the EU as well as in the United States, China, India, and several other developing countries. The United States is leading the world for biomass power generation, other significant producers including EU Member States Germany, Sweden and the United Kingdom, plus Brazil, China, and Japan (REN21 2011).

The European Union's gross electricity production from biomass increased nearly 10.2% between 2008 and 2009, from 79.3 TWh to 87.4 TWh (657 Mtoe). Solid biomass accounted for 62.2 TWh – about 71% – and biogas accounted for the remainder. About half of Europe's biomass power production came from electric-only facilities and half came from combined heat and power (CHP) plants, the breakdown varying by country.

Biomass pellets are becoming an increasingly common fuel in the EU. Whereas they are used primarily for electricity generation in Belgium and the Netherlands, in Sweden and Denmark pellets are burned mainly in CHP plants; elsewhere, they are used widely to heat residential and commercial buildings. The EU consumed more than 11 million tonnes of wood pellets in 2010, an increase of 7% over 2009. Sweden was the largest consumer in 2010 at 2 million tonnes, and Germany consumed almost 1 million tonnes.

Although biogas experienced the most significant increase in the EU in 2009 (up almost 18%), generation from all biomass sources has increased rapidly. EU electricity production from solid biomass tripled between 2001 and 2009, and by early 2010 some 800 solid biomass power plants (an estimated 7.1 GW) were operating in Europe. Growth of biomass for power and heat in the EU has been driven greatly by supportive policies, which in many countries are coupled with taxes on fossil fuels or carbon dioxide emissions, as well as EU regulations that require reductions in landfilling of organic waste.

The top three biomass energy countries in Europe – Germany, Sweden, and the United Kingdom – accounted for nearly 50% of the EU's electricity production from biomass in 2009. According to the 2011 Status Report (REN21 2011), Germany alone accounted for about 50% of the EU's biogas generation and almost 30% of total EU electricity generation from biomass. Germany's total power output from biomass increased by an annual average of more than 22% during the past decade, to an estimated 28.7 TWh (71 Mtoe) with a total of 4.9 GW capacity in 2010. By the end of 2010, bioenergy accounted for 5.5% of Germany's total electricity consumption, making it the country's second largest renewable energy source after wind power. Most biomass power in this

[1] http://www.euractiv.com/climate-environment/european-solar-power-competitive-2020-lobby-news-507311?utm_source=EurActiv+Newsletter&utm_campaign=c12c0e216f-my_google_analytics_key&utm_medium=email. Accessed 110910.

country comes from biogas, with capacity increasing more than 20% during 2010, and generating enough electricity for 4.3 million households. Germany generated about 13.8 TWh (16 Mtoe) with biogas in 2010, followed by the U.K. (6.8 TWh or 4 Mtoe) and Italy (2.1 TWh, 0,4 Mtoe).

1.1.3 Definition of On-Farm Renewable Energy

Renewable Energy (RE) is defined here as energy derived from natural resources which are renewable (being naturally replenished, e.g. sunlight, wind, rain, tides, geothermal heat, biomass). On-farm Renewable Energy is produced on farms; farms are economic enterprises basically relying on biological processes to generate agricultural products – food, feed, fibres, other natural materials, fuels – from natural resources such as land and/or non-saline water. On-farm RE covers energy generated by installations paid and/or operated by farms as well as by installations paid and/or operated by other legal entities (whether owned and/or managed by the farmer or not), and includes:

- primary, intermediate and final RE that is both produced and consumed on the same farm,
- final or intermediate RE that is consumed on one farm but produced on other farms,
- final energy that is produced on the farm and that is exported,
- final or intermediate RE produced on farms from biomass or waste from non-farming activities,
- intermediate and final RE produced not on farms but using biomass or waste produced on farms.

The flows of on-farm RE considered in this project are summarised in the diagrams of Figure 1.

1.1.4 Main questions addressed

This report answers six key questions as posed by the European Commission.

1) How much Renewable Energy (RE) does agriculture produce in the EU at present, and how much can be expected in the medium term (by 2020), in total and by type of RE? What consequences has this for Greenhouse Gas (GHG) emissions?

This question is answered by an EU-27 wide inventory making use of a range of data sources including policy documents, statistics at EU and national and regional levels, but also key informants working in policy, farmers organisations, energy companies, etc. Actual RE production is presented at national level for all EU-27 countries and a distinction is made in the following types of RE:

- Biomass based RE: Biogas, bioethanol, biodiesel, (forest-based) heat and power
- PV and thermal solar energy
- Wind

A RE-balance is constructed for the member states and the EU as whole (Section 3.1).
An estimate is made of the GHG emissions that can be avoided by 2020 through RE produced by the Agricultural Sector, using the model MITERRA. This is described in Section 0.

2) Why do farmers engage in the production of RE, and if they do not, what are the main obstacles?

Through 8 case studies in 4 countries with 'stronger' and 'weaker' development of RE production, the differences between regions and the obstacles for RE development (e.g. investment costs, policy support, local capacity) are assessed. A farm survey was held with a large sample of farms, analysed statistically to identify the main obstacles. This is described in Section 3.3.

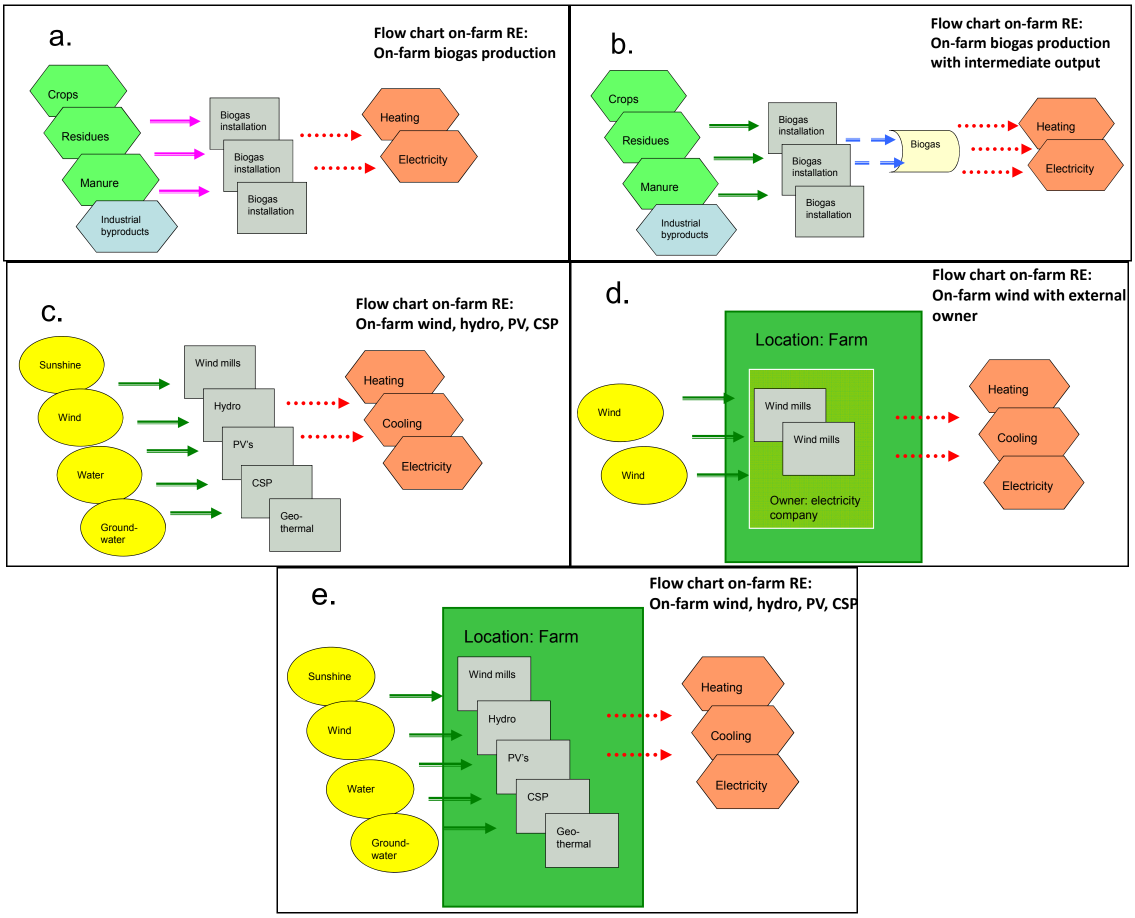

Figure 1 Flow diagrams of the various roles of RE on farms

3) What are the organisational, economic and technical impacts of the introduction of RE production on the conventional farming activities, at whole farm level and on the surrounding rural economy?

A farm level model, simulating farm types at a low level of detail, was used to additionally investigate the organisational, economic and technical impacts of introduction of RE on farms. Through the model simulations, RE innovations are either taken up or not by the farm, depending on the economic feasibility, and main changes in labour demand, farm income, investments and production activities are identified (Section 3.4).

Impacts assessed include additional income and farm employment generated as well as impact on GHG emissions and general farm (non-RE) productivity. The effect on rural economy is captured by estimating labour required from the non-farming community to establish the RE activities on the farms. This non-farm labour is matched to the local capacity available as identified in the case studies.

4) What role does RE play in the economy of different types of farms? Under which conditions does RE production bring the highest contribution to farm and rural economies?

With the farm level model different types of farms have been studied. Not only potential, but also optimal RE activities on farms are selected, that fit best with the farm planning and maximise the returns to the farmer. These results in terms of 'best-RE-activities' are confronted with the conditions in the case study regions and assessed on feasibility. Through a focus on investment, the continuity of RE production on farms is assessed, and conditions required to provide this continuity can be identified. This is described in section 3.5.

5) What are the main barriers to further development and the problems posed by the current regulatory framework? How could this framework be improved to favour the expansion of farmers' involvement in RE production?

Through an inventory of the current regulatory framework, markets and RE production, strengths and weaknesses are identified EU-wide. By detailed assessments in the case studies, the impact and implications of the regulatory framework on farmers are assessed, and barriers identified. Regulatory frameworks that favour RE production and take account of barriers are formulated, either based on success stories of the EU wide inventory or through the insights obtained in the case studies. Main barriers (i.e. economic, institutional, social) are identified in all research activities, either the EU wide inventory, the case studies, the farm level modelling and the statistical analysis. This is described in section 3.6.

6) What role does Rural Development (RD) policy play and how can this role be strengthened?

The role of RD policy is investigated in the case studies and through the EU wide inventory. The contribution of RD policy to local capacity building and lowering RE investment costs is analysed, just as limitations RD policy poses to farm development. This is described in section 3.6. as well.

1.2 RE Balance

1.2.1 Methodology used

The main underlying goal of constructing and analysing Renewable Energy (RE) balances for the agriculture sector is to quantify the production and consumption of renewables on European farms now and in the near future, which offers the dual insight into (i) the contribution of the agricultural sector to the energy transition of Europe as mandated by the 2009 RES Directive as well as (ii) the transformation of European farms to multi-functional production units, broadening their purpose and income opportunities beyond the traditional role of food and feed producers.

The renewable energy balance aims to capture all the flows of renewable energy produced and consumed by, as well as imported to and exported from the agricultural sector, as shown in Figure 2.

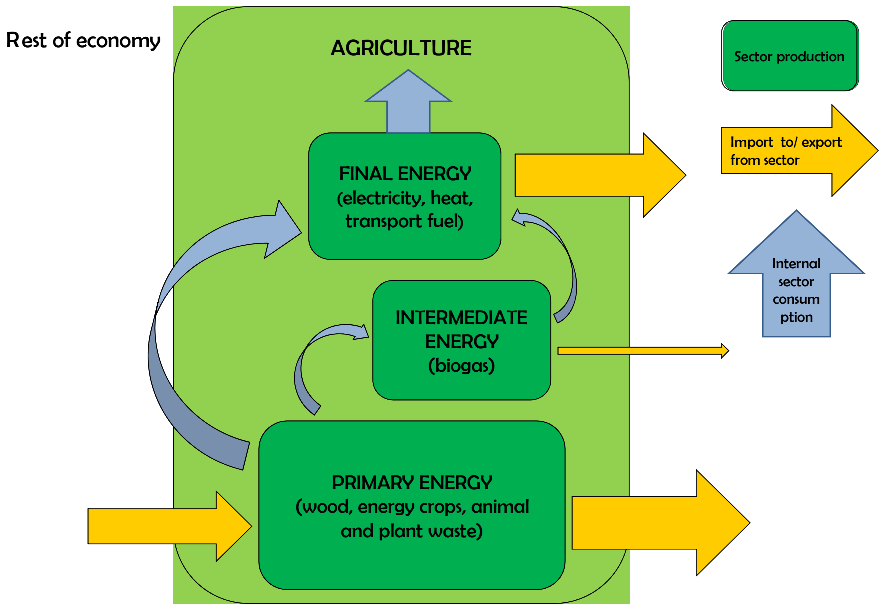

Figure 2. RE flows in the agriculture sector

Initially, the RE balances were planned to be set-up following Eurostat structure and statistics for renewables and wastes. However, it soon became clear that this approach does not offer enough detail for a satisfactory picture of the flows of renewable energy to and from farms, so an own approach was developed, in which final, intermediate and primary energy flows, each subdivided into a relevant number of sources, can be accounted for when imported to farms from other sectors, produced and consumed on farms or exported from them to other sectors.

The final set-up of the balance is presented in Figure 3 and is accompanied with a colour legend of some basic underlying assumptions on flows that cannot be further disaggregated, are a summation of different sources or are simply unrealistic.

	Import on farm	Production on farm	Export from farm	Consumption on farm	
Final energy				**Total**	**by households**
Electricity					
Heating					
Cooling					
Biofuels for transport					
Biofuels for machinery					
Intermediate fuels					
Biogas					
Primary fuels					
Total energy crops					
Forest wood					
Agro waste					
….					

Input
Unrealistic input
Calculation
No disaggregation possible
Assumption
"-" = Not Known

Figure 3 RE balance set-up (simplified)

The following paragraphs explain the basic assumptions related to the energy flows captured in the RE balance and its relationship to and deviation from the Eurostat definitions and accounting rules. All the figures presented in the RE balance are given in ktoe.

Final energy

- Renewable electricity and heat, which are imported to the farm from national grids cannot be disaggregated by source and are calculated as follows:

  electricity use by agriculture sector * fraction of electricity produced by renewable sources on a national level.

- The category "biofuels" covers all types of biofuels and was in certain cases calculated according to the following rule:

  on-farm import of biofuels = fuel consumption agriculture sector * fraction of biofuels in national transport fuel mix.

- Transmission losses (related to imports and exports of final energy) and consumption losses are not explicitly accounted for; "on-farm consumption" values thus refer to input of final energy to a productive or household use and can be the same value as final energy import or production.

Intermediate fuels

- Biogas in its basic form (as produced in methanisation plants) is currently not transported, hence its import to farms is described as "unrealistic".
- Production corresponds to the heat content (Net Calorific Value, NCV) of the biogas produced, including the gases consumed during the fermentation processes but excluding flared gases.
- On farm consumption of biogas refers to biogas use for production of electricity and heat.

Primary fuels

- Although the flow of energy crops and agro waste would be a closed cycle from the sector's perspective (they can only be produced on farm and so would only move within the agricultural sector), the possibility of their import on farm was left open to account for any international trade between farmers, and for eventual forest biomass and biowaste from other sectors.
- The wood and wood waste consumed on farms (mainly for heating purposes), can be produced on farms or imported from the forestry sector.
- Production represents the heat content (NCV) of the biomass used as primary fuel.
- On farm consumption of primary fuels refers to their use for production of intermediate or final energy.

A more detailed overview of definitions, accounting rules and its relationship to and deviation from the Eurostat definitions can be found in Annex II.1. As mentioned in the introduction, the RE balances aim to provide a picture of renewable energy flows between the agriculture sector and the rest of the economy at present and in the future. For this purpose the same balances were prepared for the year 2020, where two possible development paths of on-farm renewables were considered through two scenarios, which are explained next.

1.2.2 Scenarios for 2020

To derive a picture of the most likely mid-term developments on production and use of RE in agriculture the following two scenarios[2] were considered:

1. A "pure NREAP" scenario in which the growth factors for production of different renewable sources on farms were calculated based on the NREAP projections of development trajectories[3] for the various renewable sources, with **no additional incentives** specific to the agriculture sector. These growth factors are applied to each data category in the RE balance to derive estimates for 2020.

In this storyline the NREAP targets are reached based only on the existing support schemes for RES, without any additional specific stimulation measures for development of RES activities on farms. Thus the assumption is that all RES activities that can be employed at farm level will develop according to the average growth figures for renewables needed to reach the NREAP 2020 targets (as compared to 2008 baseline). Since no specific incentives are given under this scenario to stimulate RES on farms, e.g. no stimulation of RES through the Rural Development Programme, there is no reason to assume that growth levels for the farm sector will be higher than for RES in other sectors.

This approach thus disregards the relative contribution of different sectors to achieving the NREAP targets. The NREAPs themselves do not offer any clues on this, and the role of agriculture as contributor of renewable energy is only explicitly mentioned by the projected supply of primary energy sources coming from agriculture[4]. In this respect, the assumption of equal growth rates of renewables across economic sectors may be an oversimplification, but at this moment there is no country specific information available providing an estimate of the relative contribution of the farming sector to the NREAP targets. If no additional farm-specific incentives for the development of on-farm renewables are in place, there is no reason to assume the renewables growth rates should be higher or lower in agriculture compared to other sectors, especially for the main types of final energy production, like wind and biogas, which in most cases benefit from the same support schemes regardless of the sector holding the installation.

[2] The term Scenario in this study is to be understood as a trend projection.
[3] A complete overview of NREAP projections is available in Beurskens and Hekkenberg (2011) and is available on http://www.ecn.nl/units/ps/themes/renewable-energy/projects/nreap/
[4] Summarised in Tables 7a in the NREAPs.

2. A second, "NREAP+" scenario on the other hand also takes the NREAPs as a starting point (same as above), but in addition takes into consideration region-specific data on important biophysical and farm-structural parameters, which could, under correct **stimulation schemes**, result in a higher contribution of renewable energy from farms.

In this scenario it is assumed that the contribution from farming to reaching renewable energy targets from NREAPs will be larger than in the other scenario because of additional stimulation measures for RE-development on farms. Without specifying those measures[5], it will be assumed that in regions where certain circumstances are more optimal to develop certain on-farm RE-activities, the right incentive schemes (most probably through RDP stimulation measures) would indeed lead to their optimal deployment, resulting in an above average growth. Above average implies above the average growth rate needed to reach the NREAP targets by 2020. The latter however only applies to those RE-activities that are particularly suitable to develop on farms given specific regional circumstances and farm structural characteristics in different EU regions.

The analytical sequence and a calculation example of the scenario implementation steps to derive the final energy part of the RE balances in 2020 is described in Annex II.2.

1.3 GHG Balance

The approach for the calculation of saved or avoided GHG emissions is based on two methodologies that differ for the type of RE sources. For solar, wind and geothermal energy and energy from solid biomass, the GHG savings were calculated using the RE monitoring protocol (Te Buck et al. 2010). For energy crops and biogas the GHG emission savings were assessed with the MITERRA-Europe model (Velthof et al. 2009). As part of this project the (co)-digestion sustainability tool (Zwart et al. 2006) was included in the MITERRA-Europe model to assess the saved and avoided GHG emissions from digestion for biogas production. The system boundaries for the calculation of the saved and avoided GHG emissions were in line with the EU Renewable Energy Directive (RED). The proposed methodology for sustainability criteria, including GHG balance, for solid biomass (SEC(2010) 65-66) is in line with the current RED sustainability criteria. Several emissions factors, conversion factors and other parameters were country specific. When no country specific values were available, we used the standard values from the BIOGRACE project[6], which deals with the harmonisation of greenhouse gas emission calculations of biofuels throughout the European Union.

1.3.1 GHG emission factors for fossil fuel reference

GHG emission factors for fossil fuel combustion are needed to calculate the amount of saved GHG emissions from RE due to reduced fossil fuel use. The Renewable Energy Directive provides default values; however, due to differences in fossil fuel mix, these values should be country specific. The coal-to-electricity fuel cycles vary to a large extent between EU Member States according to their coal extraction, transport distances, power plant efficiencies, and emission control technologies. In contrast, lesser differences can be observed in the case of gas or oil based systems, either for electricity generation or heating (Fritsche et al. 2006). Several sources of CO_2 and GHG emission factors were found (EEA 2008; IAE 2010), but these data were not always consistent, due to differences related to the inclusion of renewable and nuclear energy. Finally, we decided to use GHG emission factors based on GEMIS, which are based on **full life-cycle**

[5] Some countries do in fact include some agriculture-specific measures in their NREAPs. While their effect is not explicitly quantified, if effectively implemented, they could provide additional stimulation for farmers to develop renewable energy installations. Hence we consider their effect only implicitly, through the overall higher share of RES projected to be achieved and the related higher growth rates in those countries. An overview of those measures is presented in Annex I.
[6] http://www.biograce.net/

emissions, and not the GHG emission from fossil fuel combustion only (Table 1). GEMIS[7] is a life-cycle analysis program and database for energy, material, and transport systems, and comprises a database on 1) fossil fuels, renewables, nuclear, biomass and hydrogen, 2) processes for electricity and heat, 3) materials and 4) transports.

Table 1. GHG emission factors per country for fossil fuel reference (in g CO_2-eq / MJ)

Country	***Electricity***		***Heat***	
	2008	***2020***	***2008***	***2020***
Austria	156	158	108	94
Bulgaria	221	249	126	170
Belgium	134	146	103	92
Cyprus	88	101	110	107
Czech Republic	227	261	126	100
Germany	195	200	100	85
Denmark	198	170	102	85
Estonia	230	267	112	87
Greece	184	215	110	105
Spain	164	166	98	92
Finland	196	187	107	90
France	164	140	98	88
Hungary	150	167	102	94
Ireland	144	161	104	109
Italy	131	141	101	86
Lithuania	109	111	118	105
Luxembourg	111	111	102	92
Latvia	111	173	111	98
Netherlands	142	158	95	73
Poland	229	249	142	154
Portugal	164	168	98	92
Romania	159	180	109	86
Sweden	125	119	110	93
Slovenia	226	260	114	111
Slovakia	189	184	133	103
United Kingdom	154	153	94	76

The GHG emission factors are based on fossil fuels only (coal, lignite, oil and natural gas), since we assume that RE will replace fossil fuels and not other RE sources or nuclear energy. For the fossil fuel mix in 2008 we used statistics from DG TREN (Energy Pocket, 2010)[8]. The fossil fuel mix for 2020 for both electricity and heat is based on the PRIMES reference scenario for 2020 (Capros et al. 2009). For biofuels the default value of 83.8 gCO2eq/MJ, as stated in the RED, was used as the fossil fuel comparator emission factor.

1.3.2 RE monitoring protocol

To calculate emission reductions from various RE technologies the 'Renewable energy monitoring protocol' (Te Buck et al. 2010) was used. This protocol is used in the Netherlands to calculate and record the amounts of energy produced from renewable sources. The protocol describes the methodology to calculate the contribution of RE and the avoided GHG emissions for many sources of renewable energy. The following sources of renewable energy were included: wind energy, thermal use of solar energy, photovoltaic use of solar energy, geothermal energy, and small scale burning of solid biomass. For each of these RE sources a factsheet is included in the protocol, which describes the calculation of the amount of renewable energy and saved GHG emissions.

[7] http://www.oeko.de/service/gemis/en/
[8] http://ec.europa.eu/energy/publications/doc/statistics/part_2_energy_pocket_book_2010.pdf

The resulting RE balances from Theme 1 refer to the net energy produced. Since full life cycle emission factors are used for the fossil fuel reference, also the full life cycle emissions of RE have to be accounted for. For biogas and biofuels from energy crops detailed methodologies were applied, which account for all related GHG emissions. For the RE types assess with the RE monitoring protocol the amount of avoided GHG emissions was reduced with a default life cycle GHG emission per MJ produced. These life cycle emission factors for RE types derived from Pehnt (2006).

1.3.3 MITERRA-Europe

MITERRA-Europe is an environmental impact assessment model, which can assess the impact of measures, policies and land use changes on environmental indicators on a NUTS-2 and MS level in the EU-27 (Lesschen et al. 2011; Velthof et al. 2009). MITERRA-Europe is partly based on the existing models CAPRI and GAINS, and was supplemented with an N leaching module, a soil carbon module and a measures module. The model comprises the same 35 crops as in CAPRI. In addition six second generation energy crops (*Miscanthus*, switchgrass, canary reed, poplar, willow and eucalyptus) are included.

In Annex V of the Renewable Energy Directive (RED) the calculation rules for the GHG impact of the production of biofuels and bioliquids are stated. In most cases emissions from cultivation, e_{ec}, are the most important ones, which were assessed in more detail with MITERRA-Europe. The emissions from carbon stock changes due to direct land use change (e_l) and saved emissions from soil carbon accumulation via improved agricultural management (e_{sca}) can also be assessed by MITERRA-Europe. However, data on direct land use changes and changes in soil management is not available at a regional or national scale, and therefore these emissions were not included in the assessment. For the emissions from processing and transport the default values from the RED were used. For electricity from second generation energy crops – see paragraph above – these values were not available and an average emission of 5 g CO_2-eq/MJ was assumed for processing and transport. Emissions from indirect land use change (ILUC) were not included, since this was out of the scope of this study.

The following sources of GHG emissions were included in the calculation for the GHG emissions from energy crops: direct N_2O soil emissions (from fertiliser and manure application and crop residues), indirect N_2O soil emissions (from N deposition and N leaching), GHG emissions from fertiliser production, CO_2 emissions from fuel consumption and CO_2 emissions from organic soils, liming and urea application. The calculations follow the methodology of the IPCC 2006 guidelines and are described in more detail in Lesschen et al. (2011).

1.3.4 Co-digestion sustainability tool

Co-digestion is the simultaneous digestion of manure and a co-substrate and its conversion into biogas. Zwart et al. (2006) report on a methodology to assess the sustainability of bio-energy from co-digestion with emphasis on energy and greenhouse gasses. This includes both the saved CO_2 emissions from fossil fuels and the avoided emissions of CH_4 and N_2O from manure storage. This methodology has already been implemented and applied for the Netherlands. The calculation rules of the tool were implemented in MITERRA-Europe in order to calculate the saved and avoided GHG emissions from (co)digestion for all MSs. Some of the parameters are general and can be applied for all EU countries, whereas for others (e.g. maize yield and related N_2O emissions) country specific values have to be collected or calculated. In most cases these country specific data are already included in MITERRA-Europe. Based on the data collection six different substrate types were distinguished (see Section 2.2). The properties of these substrates are shown in Table 2.

Table 2. Assigned properties of substrates (mainly based on (Zwart et al. 2006))

Substrate	*Energy yield*	*CH_4 yield*	*Transport distance*	*NH_3 emission factor stored N*	*N content*	*OM*	*DM*
	MJ/ton	*m^3 CH_4/ton*	*km*	*%*	*kg/ton*	*kg/ton*	*%*
Pig manure	421	11	10	1	7.7	55	5
Cattle manure	493	12	10	1	4.3	75	5
Silage maize	4872	122	20	2	4.3	250	33
Grass	2706	68	20	2	2.5	350	20
Slaughterhouse waste	4776	120	100	0	8	200	20
Organic residues	5174	130	75	2	4	150	25

For most countries no information was available about the type of manure that is used for anaerobic digestion. We distinguished two types of manure, i.e. pig and cattle manure, and based the ratio on the total amount available in a country. Based on the country and livestock type specific N excretion data in MITERRA -Europe, we calculated the total amount of pig and cattle manure that is produced in stables, thus potentially available for anaerobic digestion. We assumed that only liquid manure is used for anaerobic digestion. For pig slurry an N content of 8 kg N/m^3 manure was used and for cattle slurry 5 kg N/m^3.

1.4 Selection of case study regions

Eight case study regions were selected in four Member States to be included in the analysis. Selection of the regions included the following criteria (in descending order of importance): (i) dynamism of on-farm RES development;, (ii) EU-wide distribution, (iii) climatic and ecological conditions representing different environmental zones, (iv) agricultural activities and main crop types, (v) farm types, (vi) types of RE used, (vii) availability of micro-economic, farm-level data, (viii) availability of or access to primary data, and (ix) difference in energy-related infrastructure endowment.

In order to assess the dynamism of RES production in a consistent manner, the project team defined the following indicators:

- RES capacity installed at present and trend over time (starting from 2000), taking into account what share is estimated to come from on-farm production;
- Existence of regulation for supporting small-scale installations;
- Existence of dedicated subsidies for RES production on farms;
- Investment capacity of farmers/ farmers' access to financial resources;
- Existence of 100%-RES villages which aim to cover their total energy demand from RES;
- Trend in energy consumption per ha or any other production unit.

The importance of each of these indicators varies by country. While the first indicator, the level of RES capacity installed, can be applied in countries that have already reached a considerable share of RES in total energy production, the following indicators are more appropriate in countries where the development of RES is still in the start-up period. In these cases, the indicators help to identify the regions with most potential for a dynamic build-up of on-farm RES capacity in the near future.

A first screening of potential case study regions showed that most regions represent a mix of unique characteristics. As a consequence, the original idea of finding two regions with similar factor endowment and a comparable policy environment for RE promotion, but with differing levels of activity proved hard to realise in practice.

In the selection, the aim was to select case studies that, across all criteria, represent the diversity of the EU to the extent possible. Thus, for each country a dynamic region and a region with slower RES growth (or smaller near-term potential) were selected. The regions did not necessarily share the same factor endowment. Rather they represent the diversity of farm types and agricultural activities in the MS and in the EU as whole, as well as representing different ecological zones and different types of RES. Availability of existing micro-economic, farm-level data and access to primary are also were important selection criteria in order to ensure the successful implementation of the case studies. Case regions had to be big enough to allow collection of 100 completed questionnaires. Thus, all case study regions have been defined at a size corresponding to NUTS 2-level.

Following the reflections presented above, the following regions have been selected (Figure 4): North East Brandenburg and Saarland (Germany), Valencia and Soria (Spain), Mazowieckie and Warminsko-Mazurskie (Poland) and Northern Upper Austria and Carinthia (Austria). Of these, the first mentioned for each country can be classified as the more dynamic region while the second is less dynamic. This is always on a relative scale, comparing RE activities within the national context. Exceptions to this rule are PV in Germany (being more important in Saarland) and forest-based bioenergy in Austria (being mostly located in forested regions like Carinthia).

Figure 4 Location of the case study regions

The cases cover all major geographical regions of the European Communion plus major climatic conditions: humid oceanic (Saarland), humid (North East Brandenburg), dry (Soria) and temperate continental (Northern Upper Austria; Mazowiecki, Waminsko-Mazurski), coastal Mediterranean (Valencia) and alpine (Carinthia). The cases also represent major EU farm types (small and large scale, livestock, arable and mixed), plus main bioenergy feedstock crops (maize, wheat, rape, sunflower but also fruit/horticulture and on-farm forestry).

Cases further cover different EU countries in western, central-eastern and southern Europe and all major environmental zones: Atlantic central (Saarland), continental (North East Brandenburg Mazowieckie, Waminsko-Mazurskie), Mediterranean North and mountains (Soria), Mediterranean South (Valencia) and Alpine (Northern Upper Austria and Carinthia) while representing major EU farm types (small and large scale, livestock, arable and mixed), plus main bioenergy feedstock crops (maize, wheat, rape, sunflower but also fruit/horticulture and on-farm forestry).

RE activities in the case regions include wind, PV, solar, small hydro, biogas, biofuels and forestry-based. Table 3 presents an overview of the regions. It also includes issues of data availability and energy infrastructure availability. Details on the proposed case regions as well as their perspectives and representativeness for other regions in the Union are provided below.

Table 3 Overview of the main characteristics of the case study regions

Region	*Dynamism*	*Geographic zone*	*Environmental zone*	*Climate zone*	*Main farm type (cropping, animal husbandry, mixed)*	*Main feedstocks*	*Types of RES used*	*Energy-related Infrastructure*
North East Brandenburg, DE	High (except for PV)	Central Europe	Continental	Humid continental	Large-scale, mixed	Maize, wheat, rape	Wind, biogas, biofuel	German average
Saarland, DE	Low (except for PV)	Central Europe	Atlantic	Humid oceanic	Small-scale farms		PV, biomass	German average
Soria, ES	Medium-high	Southern Europe	Mediterranean North & mountains	Dry Continental-Mediterranean	Large-scale, mixed	Maize, wheat, rape, sunflower, legumes, forage crops	Biomass, wind, Small Hydro, PV	Spanish average (high quality)
Valencia, ES	Medium-low	Southern Europe	Mediterranean South	Coast-Mediterranean	Small-scale mixed	Fruits, citrus, horticulture, olives, vineyards and winter cereals	Wind, biomass bio-ethanol, Hydro, Solar	Spanish average (high quality)
Mazowieckie, PO	High economic dynamism, but lower RES development potential	Central-eastern Europe	Continental	Temperate-Continental	Small scale, mixed	Cereals, potatoes, silage maize, horticulture, forage crops - meadow	Small scale wind, biomass, biogas, solar	Polish average
Warminsko-Mazurskie, PO	Low economic dynamism, but high RES development potential	Central-eastern Europe	Continental	Temperate - Continental	Large scale, animal husbandry	Cereals, rape, forage crops	Large scale wind, biomass, biogas, solar	Below Polish average
Upper Austria, AT	High	Central Europe	Alpine-continental	Continental	Livestock farming, arable crops	Maize, cereals	Biogas, biofuels	Austrian average
Carinthia, AT	Low	Central Europe	Alpine	Alpine	Forestry, livestock farming	Maize, cereals, livestock feed, fodder from grassland	Forest-based biomass biogas	Austrian average

1.5 Farm based analysis

To get insight in the characteristics, reasons and barriers for RE investments on farms a questionnaire was designed which had to be filled in by 800 farmers. The design of the questionnaire, the selection of farmers and the analysis of the questionnaire is described below.

1.5.1 Design of questionnaire

The main objective of the questionnaire was to get a better understanding of the effects of Renewable Energy on farming and the barriers en opportunities RE provides to farming and the wider rural development. Detailed results of the questionnaire were also used as input to farm level modelling to assess the environmental and economic impacts of RE on groups of farms in the case regions. By gathering information through a questionnaire, it was guaranteed that all participating farmers in the four countries got exactly the same questions with the same answer options, which made comparison between countries and regions possible. The questionnaire was designed in collaboration with the case partners. A 30 minutes questionnaire was the result, which was expected to be the maximum length a farmer was willing to invest. The partners also indicated that most farmers do not want to give detailed personal information, like exact economic values (e.g., solvability and farm income). Also detailed questions on for instance energy use were expected to be complicated for most of the farmers to answer correctly and were therefore limited but could not be completely avoided.

As it was very important that complete questionnaires were returned (for enough statistical power and reliable results), the above points were taken very seriously when designing the questionnaire. Open questions were included as little as possible although were still needed to answer the objectives on getting insight in some economic parameters of the farm, energy use and RE production capacities. Therefore, ranges (e.g. classes) as answer options were given as much as possible. To get insights in the opinion of farmers (e.g., about consequences of RE investments for the farm) questions were designed with a 5-point Likert scale. These questions consisted of statements for which the farmers had to indicate to what degree they agreed with the statement (I fully agree, I agree, I neither agree nor disagree, I disagree, I fully disagree).

The questionnaire used consists of three parts (see Annex IV Part 5). The first part (questions 1-17) contains questions on general information, and can be divided into farmer information (e.g. age, education level, availability of successor), farm information (e.g., area, type of farm, employees) and economic information (e.g. farm income and solvability). Answers from this part of the questionnaire allowed us to identify possible relations between specific farm and farmer characteristics and presence, type and scale of investments in RE. The second part of the questionnaire consists of nine statements (question 18) about social conditions, price levels of agricultural products and energy price levels. The farmers were asked to indicate to what extent they agreed with these statements. With the answers to this part of the questionnaire it was possible to relate for instance the social conditions of the farmers to the willingness to invest in RE. The last part of the questionnaire (questions 19-34) consists of questions specifically for farmers with and without RE investments. These questions were used to find out which factors favoured RE investments and which barriers limited the RE investments on farms. Additionally, there are questions on the impact of RE investment on the farm business. Farmers who invested in RE had to answer 30 questions; farmers without RE investments answered 24 questions.

1.5.2 Farmer selection and survey response

The questionnaires had to be completed by 100 farmers in each case study region. It was crucial that questionnaires were filled out by farmers with similar characteristics to that of the total farming population of a region (e.g. farm type and size distribution). Therefore, the farmers were selected at random in terms of main farming characteristics although it was ensured that enough farms with RE activities were included in the survey population to enable statistical analysis of the results. In all case study regions this dictated an overrepresentation of farmers with RE investments: if 10% of the farmers invested in RE, then a random sample will include only 10 RE-farmers (10% of 100) which is not enough to guarantee reliable statistical analyses. In regions where less than 50% of the farmers invested in RE, measures were taken to guarantee that half of the questionnaires were filled out by RE-investors. The remainder was filled by a random sample of farmers.

The selection of farmers was done by every regional partner (Ecologic Institute, IEO, SoriActiva, Environment Agency Austria), or with help of regional agencies such as the Energy Agency of Warminsko-Mazurskie Voivodship, the Austrian Biomass Organisation and the Organic Agriculture Austria Association. The method of collecting questionnaires was different in each region. In both Spanish regions direct interviews were conducted by employees of Soriactiva. In both Polish regions the questionnaires were collected via telephone interviews, e-mail and direct interviews. In Brandenburg, the questionnaires were collected via telephone interviews and e-mail. An online version of the questionnaire was created, so that the link could be sent to the farmers. A lot of efforts were made to contact farmers, but in general it was perceived that reaching farmers was very difficult. In Saarland, the questionnaires were collected via telephone interviews, e-mail, direct interviews conducted by students and farmers by contacting them directly and also by contacting them at a regional agricultural fair where the visiting farmers were asked to complete the questionnaire. The regional fair was visited with help of the union of beef farmers. At the fair 57 direct interviews were conducted, and later on two completed questionnaires were returned by mail. In addition, two students in agricultural science with roots in Saarland conducted 31 direct interviews. In Austria the most important way of reaching farmers was through the distribution of the internet based version of the questionnaire via agricultural organisations, and the dissemination of questionnaires via postal services – therefore a random sample of farm addresses was provided by the Federal Ministry of Agriculture. Another important means to fulfil the required response rate was the distribution of the questionnaires by well-known persons in the agricultural sector within the case study regions. Anyway, most questionnaires in Austria were filled in via internet or post. In addition, in Carinthia also 18 direct interviews were conducted and 20 prospective students of agricultural schools whose parents were farmers completed the questionnaire.

In six case study regions the collection of questionnaires took place between mid-February and the beginning of April 2011. In Saarland and Brandenburg it was especially hard to convince farmers to submit the questionnaires. Therefore it was decided to extend the period for collection of the questionnaires until the end of May 2011.

1.5.3 Representativeness of collected information

The case study partners provided information about the representativeness of the collected questionnaires. All partners indicated that both the sample of farms with RE investments and the sample of farms without RE investments were as random as possible. Efforts were made to select farms that were representative for the region (e.g. farm type, size, age and income), and represent the RE investments in the region. The partners indicated that the sample was as random as possible but that for interpretation of results some information about the method of collecting questionnaires has to be taken into account. For instance, in Carinthia and Upper Austria local organic farmer organisations were involved in reaching farmers. Therefore, the organic farms are overrepresented under the farms with RE. Due to difficulties in reaching farmers online and by phone, in Saarland a livestock market was visited, and farmers visiting this market completed the questionnaire. As a result, livestock farmers are overrepresented.

In the description of the case study selection (par. 1.4 on p. 12) the types of RE in the regions are described. The types of RE investments found in the regions are in accordance with the described RE types in the case study selection report. As mentioned in the report, RE investments in Carinthia were mostly forest based, in Upper Austria biogas installations were found, and farmers in Saarland have mainly invested in PV. There are however two striking observations. In the report it was described that Valencia has wind, biomass, hydro and solar energy. The partners in Valencia could however only find seven farms with RE investments (6 PV and 1 biogas). The partners ensured that no more on-farm RE investments are existing in Valencia. Like described in the case study selection report, Brandenburg is known as a region with a lot of wind energy (see Figure 5). From Brandenburg however only 5 questionnaires with on-farm wind investments are returned (out of 55 questionnaires from farms with RE (9%)). Possible reason for this relatively low number is that Brandenburg still has a lot of publically owned land (a heritage from the ex-GDR). The public company in charge of privatising these areas sold 4,5 million m2 to wind developers since the early 1990s and rents out land for wind energy development (Source: BVVG 2011, Annual Report 2010). Moreover, it is known that 1.5% of Brandenburg's land has been dedicated to wind development, and that wind turbines are highly concentrated in certain locations and thus very unequally distributed over the whole space. This would mean that most wind energy in Brandenburg are not based on on-farm investments, which explains the relatively low number of farm investments found in this survey. This seems in contradiction to the general picture of wind energy in Brandenburg as shown in Figure 5; the attribution of wind turbines to agricultural land in the NUTS3 region statistics apparently does not coincide with the situation in practice.

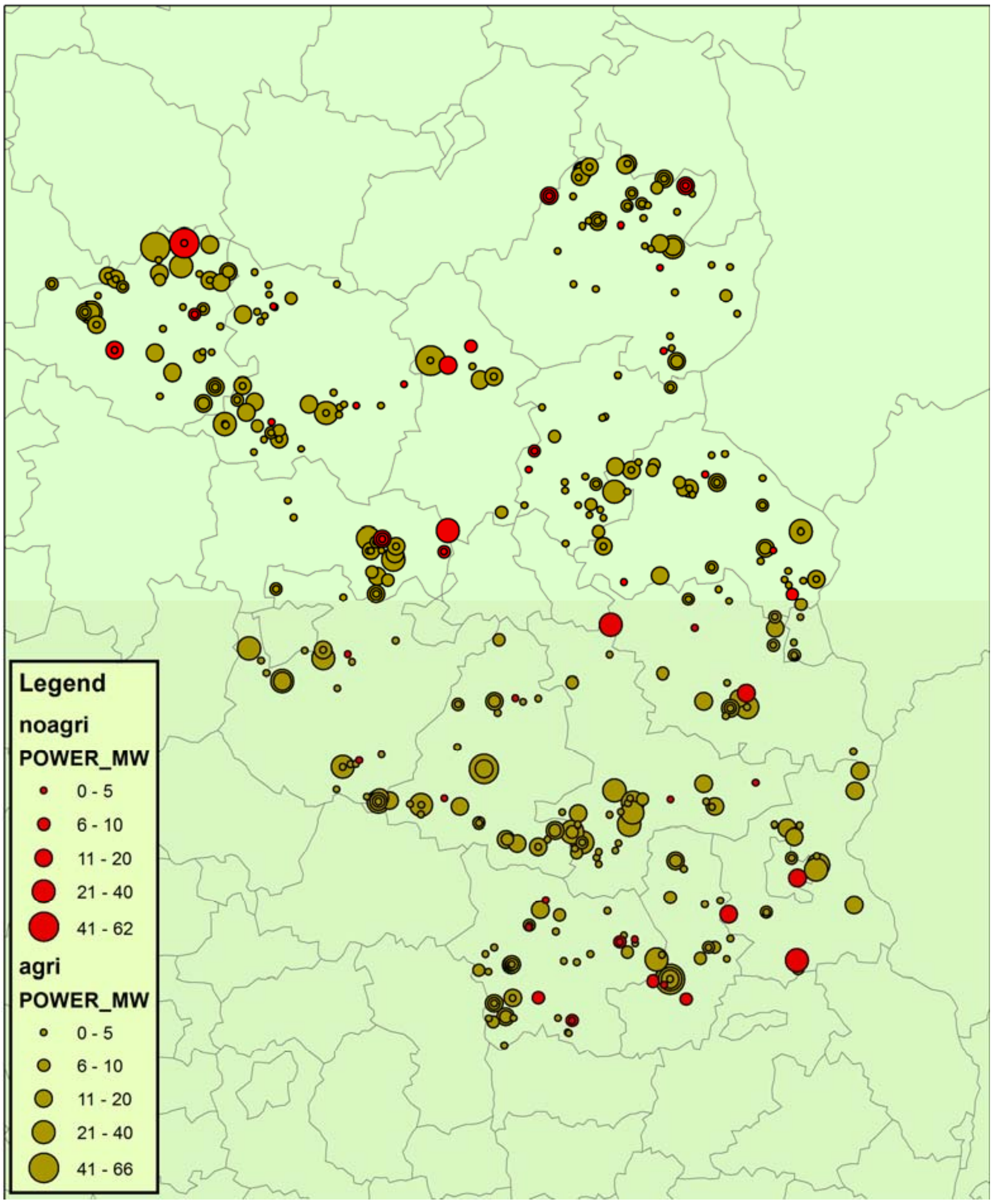

Figure 5 Distribution of wind turbines on agricultural and non-agricultural land in Brandenburg (delineated polygons are NUTS3 regions)

1.5.4 Analysis of the survey results

Statistical analysis of the survey results was carried out as follows. All answers are checked for outliers, and unreliable and unrealistic values deleted. For the first part of the questionnaire (questions 1-17) mean values and standard deviations (e.g., for age of the farmer and size of the farm) and frequency of answers (e.g., for having successor) are calculated for farms invested in RE and farms without RE investments. The mean values and frequency tables are compared between these two groups of farms (overall and within regions) with a t-test and a chi-square test. The significance level was set at 0.05 and 0.10. For the questions filled-in by farmers invested in RE (e.g. how was RE investment financed?) the number of answers are summed-up and presented in graphs for each case study region separately.

For all questions that included statements (answers possible between 1-5: I fully agree – I do not agree at all) the mean and median values are calculated. If both groups of farmers (invested in RE and not invested in RE) filled in the statements the median values are compared. If only one group of farmers (e.g., farmers invested in RE) filled in the statements the distribution of answers was used to determine whether there was a high level of agreement among the farmers about the statement. A significant p-value ($\leq$0.05) indicates that there was a high level of agreement among the farmers about the statement. A non-significant p-value (>0.05) indicates that the farmers disagreed with each other about the statement.

The responses to the questions in the questionnaire may be affected by several factors simultaneously. Therefore, a multivariate random-effects probit model was developed for each region to determine which joint effects influenced the decision to invest in RE or not. Also plausible interaction terms are tested.

1.5.5 Focus Group consultations

Additional to the questionnaire survey, specific meetings were organised to obtain feedback from local and national agriculture and RE experts on the survey results (see Annex IV Part 4). Objective of these meetings was to support the farm based analyses, thus to get a better view of impacts of RE production on other farming activities and to identify ways to overcome barriers in development of on-farm RE. In a special meeting, the so-called *Focus Groups* could take note of the outcomes and discuss among themselves plus representatives from the project partners whether the outcomes are in line with expectations, what explanations can be found for the on-farm RE development in the given regions and countries, what impacts on farming activities can be identified and how existing barriers might be overcome.

1.6 Farm based simulation of scenario situations 2020

1.6.1 Methodology applied

FSSIM is a bio-economic farm model for simulating the response of EU farming systems to agricultural and environmental policies, based on a constrained optimisation procedure (Janssen et al. 2009), in which it is assumed that a farm tries to maximise expected income incorporating a certain degree of risk aversion (see Annex V for details). To find the optimal expected income, FSSIM chooses between a large set of possible activities offered to the model (Louhichi et al. 2010). Each of these activities describe a production possibility on the farm as a comprehensive set of all inputs required (i.e. for crop type, rotation, seed, fertilisers, variable costs, labour, investment costs) to achieve a set of outputs (i.e. marketable product, side (environmental) effects such as GHG emissions). The set of activities selected by the model is restricted by farm resources, for example the area of land available, the family labour hours, on-farm produced feed for livestock, or the possibilities for investment. Policies and technological innovations influence the selection of the farm activities from the complete set in the optimisation procedure. Ultimately, the set of selected activities by FSSIM provide a farm plan. In different scenarios this set of selected activities will change. This will then demonstrate the substitutability of farm activities based on scenario settings, such as policy parameters, technological innovations and price developments. The FSSIM model been applied in 16 regions across Europe on multiple different farm types, which so far has not happened with other bio-economic farm models.

In this project, farmers response is simulated by FSSIM given specific farming conditions and a large set of possible activities offered to the farmer including different types of RE. The model optimises the choice for activities maximising expected income. Changes in farm activities and structure result and their effects in terms of environmental externalities (GHG-emissions) are assessed from it. While CAPRI models the market and farmers response of the whole EU farming sector, the FSSIM model simulates typical farms within regions providing insight in the most likely RE activities to be taken up and related implications for farm income, changes in activities and externalities. FSSIM results are not representative for the whole farming sector in a region but rather provide insight on the combination of farm and regional factors determining the adaptation RE activities.

FSSIM simulations encompass perspective modelling, or the assessment of on-farm RE implementation following economic, policy and technical conditions in 2020. The analysis focuses on on-farm impacts and understanding the impact on the farm economy and production, i.e. substitution between alternative on-farm activities. Potential regional supply or demand effects can be indicated from the FSSIM runs, if these are done for the most important (dominant) farm types representing a large part of the farm population. FSSIM runs simulate typical farms for a region. These farm types are represented in an EU wide farm typology (Andersen et al. 2007). For every farm type it is known how many of these are occurring, what share of the agricultural land they use, what their share in total regional farm economy is in every region. Through the farm type link, it is therefore known how many farms are represented. Finally it should also be emphasised that FSSIM runs focus on on-farm impacts and do not consider the whole chain and regional infrastructure required to achieve RE activities.

As a general principle, the farm simulation model FSSIM assumes that only a limited amount of change is allowed, as farms will not radically change their farm activities. To some extent, excessive change is penalised, leading to a more representative simulation of farm responses, taking into account transaction costs of change from one activity to another and risk aversion by farmers.

1.6.2 Regions and farm types analysed

The farm systems analysis started with the selection of 4 to 5 representative farm types for each of the case study regions, spanning two subsequent years (2005 and 2006) and representing the largest total utilised agricultural area. Valencia represents a specific case, as for this region not the most representative farm types but the farms with the largest citrus area were selected. The case study specific questions for this region focused on permanent crops and citrus crops, which induced the change in the selection criterion.

From this set of representative farms, the following set of farms was ultimately simulated with the bio-economic farm model FSSIM (see Table 4 and Annex V) and a few choices have been made:

1. A few regions have not been simulated.
    a. For Valencia, citrus cuttings are seen as a potential source of RE energy. Collecting the citrus cuttings or not were thought to be a small additional activity to the farmer, that does not significantly alter the farm as an enterprise and there were assumed to be no substitution effect with other farm activities. Depending on the price of the citrus cuttings and the general attitude of the farmer, the cuttings can generate some additional income, which can easily be calculated.
    b. For Carinthia, use of forest-based biomass is considered as a possible activity. The potential effect on income was calculated based on information on costs from the literature.
2. Mixed (livestock) farms have not been simulated with the FSSIM model, as this is outside the current capabilities of the model. Mixed farms have a combination of many different enterprises, which are usually interconnected through manure and feed cycles. These intricate connections between the different farm enterprises are difficult to capture correctly in a model, and the model would have to be extended to capture such representative farms. Contrary to what could have been expected, the analysis of the questionnaire survey results does not support the thesis that mixed or livestock farms react differently to RE implementation as do other (purely arable) farms (see Annex V for further details).
3. The FSSIM model used in this study is the most recent version of the model available (published in Janssen et al., 2010 and released through www.seamless-if.org[9]), in which for this project dedicated "CAP Health Check" policy measures and changes in set-aside policy have

[9] http://www.seamless-if.org/index.php?option=com_content&view=article&id=88:fssim-source-code-released&catid=43:fssim&Itemid=71

been incorporated. The farm simulation model uses the associated SEAMLESS database (Janssen et al. 2009). This database was released lastly in March 2009, but was updated as part of this project for changes in policy data with respect to "CAP Health Check" and changes in set aside policy; farm structure data used refer to the years 2005 and 2006 as available from FADN to the SEAMLESS Association (soon to be released on the website indicated in footnote 10). Furthermore, economic and market conditions are represented using the most recent CAPRI assessments incorporating the biofuel directive (see for the assessment Blanco Fonseca et al. 2010). As part of this project, crop and livestock management data have been updated for the case study regions (Section 2.4). After the abolishment of the set aside policy, fallow is not expected to completely disappear. Farmers will have transaction costs when taking fallow land back into production and some fallow areas might not be overly attractive to reintroduce production. Therefore, in the farm simulations, fallow area will only gradually and partially disappear.

4. Given the high investment costs for renewable energy, large investments in RE energy are not very likely to occur on small farms. In Brandenburg and Saarland, however, the mixed farms are large and have potential to invest in RE and would be of interest to analyse further. Unfortunately, the model does not allow to carry out this analysis.

For each region, specific investment and farmers responses are evaluated in relation to involvement in different RE activities. They include involvement in biogas production, and production of perennial biomass crops (both assessed as activities in FFSIM), and harvesting of solid biomass (not covered by FFSIM). The introduction of activities in a farm in the FSSIM model is modelled through feeding the model with different levels of return on investment and different price levels for solid and perennials biomass crops which may result from different levels of feed-in tariffs. The model then calculates the response of the farmer in terms of shifts in cropping and livestock patterns, related changes in income and externalities in terms of nitrogen and GHG emissions. The model results show at which crop price level RE activities become competitive with other agricultural activities at a farm.

1.7 Barriers and opportunities

Information on the main barriers (i.e. economic, institutional, social) for developing RE at farms was collected in several activities in the project. The main source of information is the survey and focus group discussions held in the 8 case study areas combined with information derived from the EU wide national specific inventory and literature review of stimulation policies and barriers and finally through farm level modelling to assess potential effects of RE on farms resulting from stimulation measures. The eventual overview of barriers and opportunities in this report results from an integration of outcomes of the analysis results of the different activities in this study. This is described in Section 3.6. Regulatory frameworks that favour RE production and take account of barriers are formulated, either based on success stories of the EU wide inventory or through the insights obtained in the case studies.

Table 4. Selection of representative farms for each of the case study regions and the price levels (farm gate prices) that have been varied

NUTS region	intensity	scale	farm type special-isation	year	number of farms repre-sented	utilised agricul-tural area (UAA, ha)	share of regional UAA	UAA (ha)	RE type	RE crop for price level changes	price levels for RE crop (€/ha)	current price level RE crop (2005/ 2006)	price levels other RE crops used for analysis
Brandenburg	Medium	Large	Arable/ Cereal	2005	249	128383	0.08	515.1	biogas	energy maize	0, 20, 40	20	*Miscanthus*: 0; willow: 0
									perennial biomass	*Miscanthus*	0, 80, 90	0	maize: 20, willow: 0
									perennial biomass	willow	0, 100, 110	0	maize: 20, *Miscanthus*: 0
Brandenburg	Medium	Large	Arable/ Fallow	2005	241	253581	0.16	1051.1	biogas	energy maize	0, 20, 40	20	*Miscanthus*: 0; willow: 0
									perennial biomass	*Miscanthus*	0, 80, 90	0	maize: 20, willow: 0
									perennial biomass	willow	0, 100, 110	0	maize: 20, *Miscanthus*: 0
Brandenburg	Medium	Large	Arable/ Cereal	2006	312	159073	0.1	510	biogas	energy maize	0, 20, 40	20	*Miscanthus*: 0; willow: 0
									perennial biomass	*Miscanthus*	0, 80, 90	0	maize: 20, willow: 0
									perennial biomass	willow	0, 100, 110	0	maize: 20, *Miscanthus*: 0
Brandenburg	Medium	Large	Dairy cattle/ Others	2005	153	54938	0.04	359.1	biogas	energy maize	0, 20, 40, 60, 80	20	
Mazowieckie	Medium	Large	Arable/ Cereal	2005	1192	487579	0.03	409	rape	rape	0, 225, 400, 500, 800	225	
Northern Upper Austria	Medium	Medium	Dairy cattle/ Perm. grass	2005	9454	325467	0.09	34.4	biogas	energy maize	0, 13, 40, 60, 80	13	
Northern Upper Austria	Medium	Large	Arable/ Cereal	2005	2101	186254	0.05	88.7	biogas	energy maize	0, 13, 40, 60, 80	13	
Northern Upper Austria	Medium	Medium	Dairy cattle/ Perm. grass	2006	7896	275545	0.07	34.9	biogas	energy maize	0, 13, 40, 60, 80	13	
Northern Upper Austria	Medium	Large	Arable/ Cereal	2006	1718	149240	0.04	86.9	biogas	energy maize	0, 13, 40, 60, 80	13	
Saarland	Medium	Large	Dairy cattle/ Perm. grass	2005	105	14543	0.31	138	biogas	energy maize	0, 20, 40, 60, 80	20	
Saarland	Medium	Large	Dairy cattle/ Perm. grass	2006	102	14453	0.31	141.1	biogas	energy maize	0, 20, 40, 60, 80	20	
Saarland	Medium	Large	Dairy cattle/ Others	2006	55	6995	0.15	128.2	biogas	energy maize	0, 20, 40, 60, 80	20	
Soria	Low	Medium	Arable/	2005	3874	400541	0.05	103.4	biogas	soft winter	0, 100,	190	

NUTS region	***intensity***	***scale***	***farm type special-isation***	***year***	***number of farms repre-sented***	***utilised agricul-tural area (UAA, ha)***	***share of regional UAA***	***UAA (ha)***	***RE type***	***RE crop for price level changes***	***price levels for RE crop (€/ha)***	***current price level RE crop (2005/ 2006)***	***price levels other RE crops used for analysis***
			Fallow							wheat	190, 250, 400		
Soria	Low	Large	Arable/ Cereal	2005	1487	423912	0.05	285.1	biogas	soft winter wheat	0, 100, 190, 250, 400	190	
Soria	Low	Small	Arable/ Fallow	2006	9596	329053	0.04	34.3	biogas	soft winter wheat	0, 100, 180, 250, 400	180	
Soria	Low	Medium	Arable/ Fallow	2006	3149	331921	0.04	105.4	biogas	soft winter wheat	0, 100, 180, 250, 400	180	
Warminsko-Mazurskie	Low	Large	Arable/ Cereal	2005	611	191550	0.04	313.5	perennial biomass	*Miscanthus*	0, 80, 90	0	willow: 0
									perennial biomass	willow	0, 100, 110	0	*Miscanthus*: 0
Warminsko-Mazurskie	Medium	Large	Arable/ Cereal	2005	737	312552	0.06	424	perennial biomass	*Miscanthus*	0, 80, 90	0	willow: 0
									perennial biomass	willow	0, 100, 110	0	*Miscanthus*: 0
Warminsko-Mazurskie	Medium	Small	Arable/ Cereal	2006	12206	227941	0.05	18.7	perennial biomass	*Miscanthus*	0, 80, 90	0	willow: 0
									perennial biomass	willow	0, 100, 110	0	*Miscanthus*: 0
Warminsko-Mazurskie	Medium	Large	Arable/ Cereal	2006	759	358271	0.07	471.8	perennial biomass	*Miscanthus*	0, 80, 90	0	willow: 0
									perennial biomass	willow	0, 100, 110	0	*Miscanthus*: 0

2 Information collected

2.1 RE Balances

The detailed overview of renewable energy flows to and from the agriculture sector provided by the RE balance set-up translates into very high data requirements. The limited statistical and scientific information available on the main features of rural areas, has been recognised as an issue in the Rural Development in the European Union report (DG AGRI, 2009) and has also represented a significant challenge in collecting the data for the construction of the RE balances.

A large number of data sources were consulted during the data collection process (see the Data Tracking Table in Annex I.1 for a detailed overview of sources consulted in each country) and a number of issues arose that complicated the process:

- Very few centralised data sources which collect relevant data following the same methodology and format for all countries exist; most of them have either incomplete or inaccurate datasets. A good example is the case of biogas. A category of biogas called "other" biogas is published by several relevant organisations and is presented as "agricultural" biogas by others. However, a closer look at this category reveals that it virtually always covers the following three categories of biogas: decentralised agricultural biogas plants, biogas from municipal solid waste and centralised digestion plants, data for which is rarely collected and never reported in a disaggregate manner. The relative importance of these three sources to the overall "other" biogas production varies across countries, and so those widely published figures could not be used here. Another example are tables 7 in the NREAPs which should be reporting the amount of primary energy contributed by the agricultural sector, but were unfortunately not filled by all MSs, hence other sources were used in some cases, reducing the comparability of this category across countries.
- Since most necessary data was not directly obtainable, proxies were often used to calculate estimates. However, because in different countries different data was available, we could not set-up a single accounting rule to follow across all countries, which may lead to some inconsistencies of estimates for certain categories in the RE balance. A case in point is consumption of renewable heat, which could sometimes be estimated by considering the share of agricultural households (or holdings, if number of households was not available) in total household consumption of solid biomass for heat, but other times it could only be calculated by starting with the contribution of solid biomass to final energy consumption in a country, assume that what the agriculture sector consumes of it is used mainly for heat production and calculate the total demand for it from agricultural households. For detailed calculations and assumptions related to individual estimates please refer to the RE balances presented in Annex II.
- Sometimes the only estimate that could be obtained came from an expert in the field and could not be verified. Nevertheless, these (few) estimates are reported as the experts providing them were judged to be sufficiently credible and no better figure could be obtained.
- Because of discrepancies between different sources total figures are not always the sum of sub-categories (i.e. information on energy use of agricultural sources from the NREAP might be different than the sum of individual agricultural streams from various sources).
- Not all data was available for 2008 (the base year for the RE balance), in such cases data for the closest available year was used.
- Conflicting estimates were found for a number of cases, often without a real possibility to evaluate the relative merits (reliability) of each conflicting estimate. The choice was then made on a case-by-case bases taking into the consideration the context information available and selecting the data that fitted best with the other figures in the balance. When

the choice had to be made between a smaller and a higher value, it was usually made in favour of the latter[10].

Because of the varying quality of data and different levels of data coverage, the RE balances are more suitable for evaluation of the current role of renewables in agriculture in individual MSs than for comparison across MSs. A more detailed overview of the major data categories and their quality assessment is presented in Annex I.

2.2 GHG Balances

Theme 1 provides the input regarding the amount of produced biogas and produced electricity and heat from biogas per country in terms of energy. However, for the calculation of the GHG performance of biogas production more specific information is needed. The parameter values used in the sustainability tool on (co)-digestion (Zwart et al. 2006) were mainly based on Dutch data. For some of these parameters default values were used, but for others country specific values were preferred. During the data collection we looked for country specific data on especially the following parameters: typical ratio of manure and co-products in digester, type of co-products, typical dimensions and type of digester, annual full operational hours, overall efficiency of digester and fraction of CH_4 leakage from digester. Details of data collection activity are reported in Annex III.

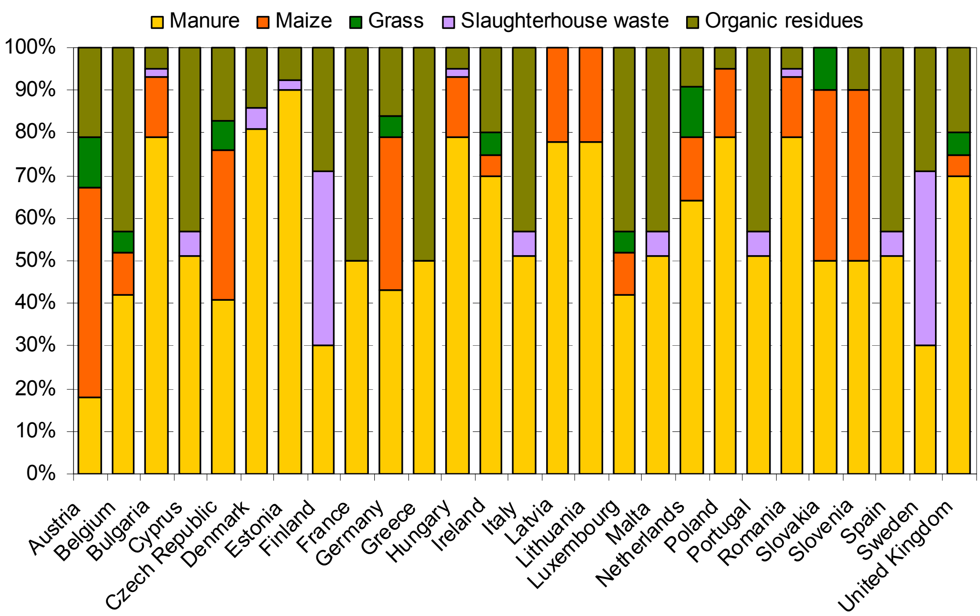

Figure 6. Average composition of substrates in agricultural biogas installations.

The main factor determining the amount of produced energy and the avoided GHG emissions is the composition of the substrate. However, this composition is rather variable and changes over time, due to changes in prices and availability. Nevertheless, based on the collected data an average substrate composition per country was made (Figure 6). Five main substrate types were distinguished, i.e. manure, maize, grass, slaughterhouse waste and organic residues. The category organic residues comprises all kinds of organic waste, e.g. food processing waste, organic household waste, agricultural residues, etc. Given the highly variable composition and lack of data, all these

[10] For example, EurObsv'ER reports no production of electricity from "other biogas" which includes agricultural biogas, while the IEA Bioenergy Task 37 Country Report for the UK reports over 1000 GWhs produced from animal and plant biomass. In this case the latter figure is presented in the RE balance for the UK. Similarly, the UK NREAP only reports 1 ktoe of energy crops produced in 2006, however, other studies put this figure to almost 482 ktoe (Dworak T, Elbersen B, Van Diepen K et al (2009) Assessment of inter-linkages between bioenergy development and water availability. ENV.D.2/SER/2008/0003r. ECOLOGIC, Berlin). http://ec.europa.eu/environment/water/quantity/pdf/2009Bioenergy.pdf)

'organic residues' were grouped into one category. For the several countries no information was available, due to absence of biogas production until now, or lack of data. For these countries we used the composition of comparable countries for which we did have information. Data of Hungary was used for Bulgaria and Romania, data of Spain was used for Cyprus, Malta and Italy, data of Latvia was used for Lithuania, data of Belgium was used for Luxembourg and data from United Kingdom was used for Ireland.

2.3 Farm based survey

A minimum of 100 questionnaires had to be completed in each of the eight case study regions. To reach enough farmers with and without RE investments, the aim was to collect approximately 50 questionnaires from farms with RE investments, and 50 questionnaires from farms without RE investments. These questionnaires were collected as randomly as possible, resulting in a realistic overview of the farms and farmers in each region. In Table 5 the exact numbers of completed questionnaires as used for the analysis are given.

Table 5 Numbers of questionnaires in each of the 8 case study regions as used in the analysis

Region	*Farms with RE (own investment)*	*Farms with RE (someone else invested)*	*Farms without RE*	*Total*
Carinthia	61	3	33	97
Upper Austria	79	2	22	103
Saarland	49	17	35	101
Brandenburg	47	8	45	100
Soria	23	27	50	100
Valencia	7	0	93	100
Warminsko-Mazurskie	42	7	49	98
Mazowieckie	50	1	83	134
Total	**358**	**65**	**410**	**833**

2.4 Farm structure analysis

The farm systems analysis with FSSIM uses information from the SEAMLESS database (see par. 1.6.2). Region specific information on farm practices used is e.g. crop management (fertiliser use, irrigation application, labour use), yields, crop prices, rotation schemes, and livestock farming (milk production, revenues, weights of animals). This information is available in the SEAMLESS database for only a subset of the European NUTS-2 regions, including Brandenburg and Castilla y León. For specific information on farm practices in the other regions of interest, alternative data sources had to be used, which however makes a good approximation possible. For Soria, part of Castilla y León, information specifically applicable to this region was collected. For Saarland, Mazowieckie, Warminsko-Mazurskie, and Northern Upper Austria, information from regions comprising the subset of well-defined regions in the SEAMLESS database was used as a proxy (Table 6). Region specific characteristics such as climate and soil type, farm structure and current crop composition are marginally different from the proxy regions, which may result in slight differences in response between the regions.

Table 6 Regions from which information on farm practices was used as substitutes for the regions in this analysis.

NUTS region	*information from NUTS region (SEAMLESS database, available additional regional data sources)*
Brandenburg	Brandenburg
Saarland	Brandenburg
Mazowieckie	Zachodniopomorskie
Warminsko-Mazurskie	Podlaskie
Northern Upper Austria	Schwaben
Soria	Castilla y León, with additional information for Soria specifically

3 Results of the analyses

3.1 RE Balance

On-farm production of renewable energy for the agriculture sector in EU-27 is presented in a consolidated renewable energy balance (Table 7). This balance represents the best available estimate of the current situation of renewables on farms across Europe, based on the information presently available. It must be stressed again here that the coverage of technologies is not consistent across all countries, meaning that the figures in Table 7 are underestimations for most cases.

Table 7 Renewable Energy balance for EU-27 in 2008 (in ktoe)

Final energy	Import on farm	Production on farm	Export from farm	Consumption on farm		Remarks:
Electricity	761,3	**8022,2**	**8019,7**	**763,8**		Input
from solar PV	-	25,6	25,6	0,0		Unrealistic input
from wind	-	7288,3	7288,3	0,0		**Calculation**
from solid biomass	-	17,8	17,8	0,0		No disaggregation possible
from biogas	-	689,8	687,3	1,2		Assumption
from...	-	0,8	0,8	0,0		"-" = Not Known
Heating	2,1	**3835,2**	**0,2**	**3837,1**		
from solar	-	8,8	0,0	8,8		
from solid biomass	-	3743,1	0,0	3743,1*		
from biogas	-	25,7	0,2	25,5		
from green gas	-	0,0	0,0	0,0		
from geothermal	-	36,7	0,0	36,7		
from	-	20,8	0,0	20,8		
Cooling		**0,0**	**0,0**	**0,0**		
Biofuels for transport	124,6	**0,0**	**0,0**	**124,6**		
Biofuels for machinery	7,6	**0,0**	**0,0**	**7,6**		
TOTAL FINAL ENERGY	**895,6**	**11857,4**	**8019,9**	**4733,0**		
Intermediate fuels						
Biogas	-	**1819,3**	**0,0**	**1819,3**		
TOTAL INTERMEDIATE ENERGY	**-**	**1819,3**	**0,0**	**1819,3**		
Primary fuels						
Total energy crops	**0,0**	**13401,1**	**8675,2**	**822,4**		
Oilseeds, cereals, sugar crops etc	0,0	10955,4	8175,0	832,8		
Woody crops	0,0	373,5	373,4	0,0		
Forest wood	**5687,8**	**5158,0**	**5158,0**	**5687,8**		
Agro waste	**36,9**	**4923,9**	**3298,3**	**1114,1**		
Plant waste	-	322,7	233,6	114,2		
Manure	-	60,5	67,1	231,3		
Other waste	36,9	36,2	13,7	59,5		
TOTAL PRIMARY ENERGY	**5724,7**	**23483,0**	**17131,5**	**7624,3**		

**of which 2539,8 ktoe is consumed by farm households for space heating*

Note: Totals are not the sum of the respective sub-categories, but a sum of individual categories across MSs, hence they might differ (i.e. the sum of total energy crops as primary production is larger than the sum of oilseeds, cereals, sugar crops and woody crops, because more MS had data available for total energy crop production than for its sub-categories; the sub-categories must not be interpreted as a division of the totals, but as the representation of the best available, yet incomplete data for the different crop types). Also rows do not always add up to zero because of incompleteness in the basic data)..

For the same reason it is also difficult to make a very detailed analysis of the relative contribution of farmers in the different individual MSs to the sector's production of renewables on a European level; nevertheless, the RE balance reveals a number of broad trends which should be taken into account when considering the role of the agricultural sector as supplier and consumer of renewable energy.

Total on-farm production of final energy from renewable sources in the EU-27 amounts to 11.8 Mtoe. Most of on-farm RE production – over 8 Mtoe – is exported as electricity. The 3.8 Mtoe of heat production is mostly for own consumption and complements the small amount of heat delivered to the sector from outside (0.3 Mtoe[11]), pointing to the agriculture sectors' low level of

[11] Eurostat, 2001: http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database

dependency on heat generated outside of the farms. Primary production (energy crops, forest wood, waste and manure) exceeds 23 Mtoe. Part of this is applied in the production of biogas used for generation of final energy (heat, electricity), part is exported from farm to the biofuel sector and a (still small) part represents lignocellulosic (woody) crops used mainly for combustion for power generation.

3.1.1 Most important renewable energy sources on European farms

As can be seen from Figure 7, wind is by far the most prevalent resource used for production of renewable electricity in agriculture, contributing around 90% of the total, all of which is exported to the electricity grid. The success of wind electricity is due to many factors: a mature technology, generous support schemes in many countries, the possibility of many different ownership models for farmers (from sole ownership, to partial ownership through cooperatives or joint ventures with project developers, to only acting as landlords) and other[12].

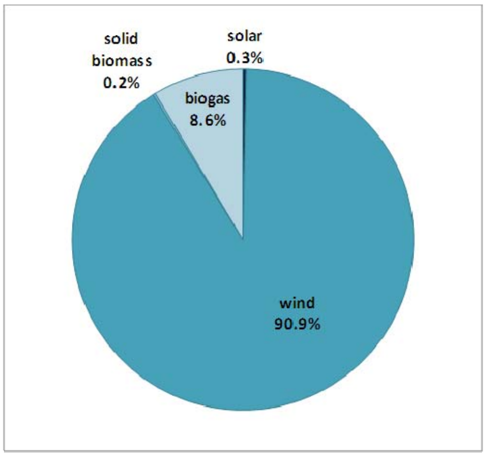

Figure 7 Breakdown of on-farm renewable electricity production per source in EU-27 in 2008

The second largest contributor to renewable electricity produced on European farms is biogas with almost 700 ktoe. While this represents under 10% of the total renewable electricity produced on farms, it has to be noted that farm biogas production in the EU has enjoyed strong growth in the past few years, and agricultural plants (including the processing of biomass imported from other sectors) now produce much more than the other two important biogas production methods, landfill plants (36%) and wastewater treatment plants (12%), most of it recovered in the form of electricity (EurObserv'ER 2011).

Other renewable electricity options, such as solar PV and combustion of solid biomass currently represent fringe options, only taken up by farmers in two or three countries to a limited extent.

In terms of uptake of different renewable electricity options by farmers in individual MS, it is clear from Figure 8 below that German and Spanish farmers have benefitted most from the growth of the European wind sector, mainly by leasing their land to wind energy developers. By encouraging the planting of energy crops, Germany is also developing its agricultural biogas sector. The country is now the leading European biogas producer, alone accounting for over half of European primary energy output and biogas-sourced electricity output (EurObserv'ER 2011). Here we would again like to warn the reader that incomplete country data overstates the differences between MSs, nevertheless, it is clear where the largest part of the on-farm renewable energy development took place.

[12] For a more detailed discussion of wind markets and the role of wind energy in agriculture, please see Annex I.2.

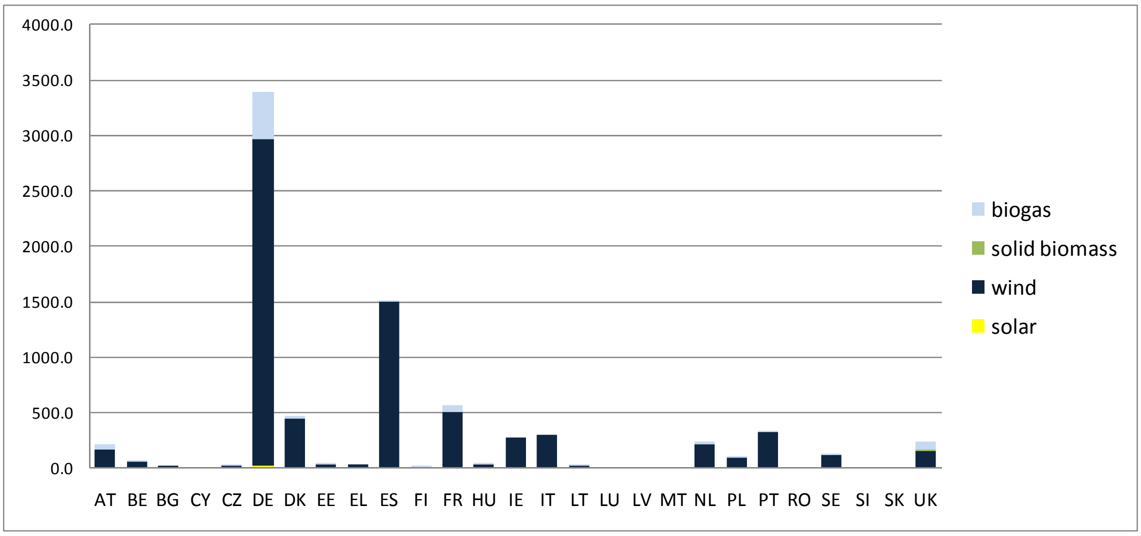

Figure 8 Renewable electricity production in the agriculture sector in 2008 per MS (in ktoe)

In terms of renewable heat, solid biomass (wood & wood wastes) is by far the predominant source used by farmers, and in contrast with renewable electricity, which is exported from farms to the national grid, heat from solid biomass is mainly consumed where it is generated, for farm household space heating, by using traditional combustion methods. Biogas is used for production of heat much less then it is used for production of electricity, contributing only around 1% to the total renewable heat production and consumption in agriculture. This might partly be due to the fact that so far, renewable heat has been much less stimulated than renewable electricity, but also due to accounting methods, which in official statistics only account for heat sold and not that consumed on-site. Finally, there a few country-specific options worth mentioning because they represent the most important source of renewable heat in the sector, such as recovering heat from the cooling of milk in the Netherlands and heat pumps in Denmark.

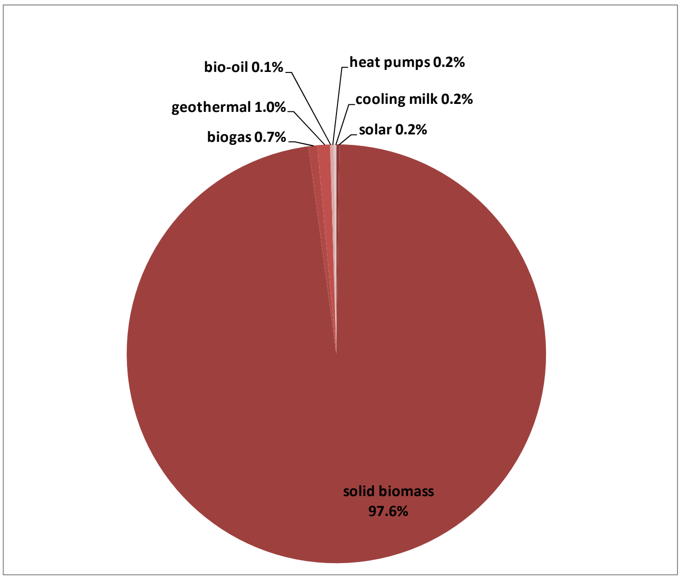

Figure 9 Breakdown of renewable heat production per source in EU-27 in 2008 (in ktoe)

Eastern European countries with the largest number of farms also produce and consume the largest amounts of heat from solid biomass (in absolute terms), as can be seen from Figure 10. This is probably due to a relatively low consumption of fossil energy.

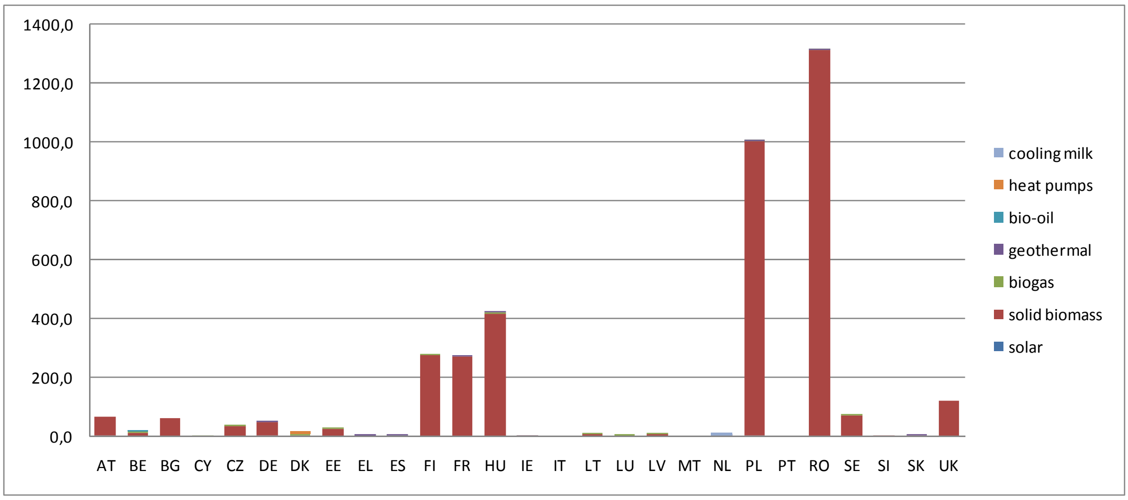

Figure 10 Renewable heat production in the agriculture sector in EU-27 in 2008 (in ktoe)

Most of the figures for total energy crops and agro waste presented here come from the NREAPs (categories B1 and B2 in table 7 of the NREAPs) and where those were missing they have been complemented with country-specific data on biofuel and woody crop production (which appear in the column "export from farm") and our own assumptions on energy crops used for production of biogas (which are reported in the column "on-farm consumption"). Due to use of different data sources using not always consistent assumptions and data gaps, the totals in different categories often do not add up (the total production of energy crops is larger than the sum of total export from farm and total on-farm consumption or the total production of the two sub-categories of energy crops do not add up to the total of the category); the difference could be attributed to the underreporting of mainly biogas use of crops or could in some cases also represent a surplus available for export. While taking due note of the data shortcomings, it is still possible to state that a much larger proportion of total energy crops in Europe is used for the production of first generation biofuel than for biogas.

3.1.2 Interaction with other sectors

Currently (reference year 2008), the agricultural sector produces between 7 – 8 times the amount of renewable electricity it consumes, making it a large net exporter of renewable electricity to other sectors. Either by direct investment in electricity installations, by leasing land or by growing crops used in by others in the power generation process, European farmers already contribute more than 10% to the total renewable electricity production in Europe (2008, EurObserv'Er 2011). In terms of renewable heat, farmers seem to be rather self-sufficient, requiring only minor imports from the grid, but also consuming most of the heat they produce from renewable sources for their own need. European farmers are of course also the most important producers of feedstock for the production of biofuels, which represents the largest part of the energy crops grown in Europe. Currently however, there are important discussions on the GHG performance of biofuels produced from first generation biofuel crops and their possible indirect land use change (ILUC) effects. A sensitivity analysis regarding this issue was beyond the scope of this study.

3.1.3 Projections for 2020

Projected on-farm RE production in the EU-27 following NREAP projections is presented in Table 8. Final energy amounts to 42 Mtoe, an increase of 250% as compared to 2008. Electricity production is expected to rise to almost 36 Mtoe, a 3-4 fold increase compared to 2008 (Figure 11).

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Table 8: Renewable Energy balance for EU-27 in 2020 under the NREAP (left) and NREAP+ scenario (right) (in ktoe)

NREAP (left)

Final energy	Import on farm	Production on farm	Export from farm	Consumption on farm
Electricity	-	**35894,7**	**35885,5**	**9,2**
from solar PV	-	653,4	653,4	0,0
from wind	-	32692,7	32692,7	0,0
from solid biomass	-	31,5	31,5	0,0
from biogas	-	2516,2	2507,0	9,2
from…	-	0,8	0,8	0,0
Heating	-	**6127,7**	**0,8**	**6126,9**
from solar	-	304,4	0,0	304,4
from solid biomass	-	5327,8	0,0	5138,1
from biogas	-	238,3	0,8	237,2
from green gas	-	0,0	0,0	0,0
from geothermal	-	224,4	0,0	224,4
from ….	-	32,8	0,0	32,8
Cooling		0,0	0,0	0,0
Biofuels for transport	-	-	-	-
Biofuels for machinery	-	-	-	-
TOTAL FINAL ENERGY	**-**	**42022,4**	**35886,3**	**6136,1**
Intermediate fuels				
Biogas	-	**6456,6**	**366,7**	**6456,6**
TOTAL INTERMEDIATE ENERGY	-	**6456,6**	**366,7**	**6456,6**
Primary fuels				
Total energy crops	**0,0**	**25538,5**	**10441,2**	**2715,4**
Oilseeds, cereals, sugar crops etc	0,0	10535,3	7569,9	2779,4
Woody crops	0,0	3216,3	3216,3	0,0
Forest wood	**5687,8**	-	-	**5687,8**
Agro waste	**0,0**	**21388,7**	**13922,8**	**3965,1**
Plant waste	0,0	-	-	-
Manure	0,0	-	-	-
Other waste	0,0	-	-	-
TOTAL PRIMARY ENERGY	**5687,8**	**46927,2**	**24364,0**	**12368,3**

NREAP+ (right)

Final energy	Import on farm	Production on farm	Export from farm	Consumption on farm
Electricity	-	**62499,2**	**61424,9**	**22,8**
from solar PV	-	881,9	881,9	0,0
from wind	-	53797,0	53797,0	0,0
from solid biomass	-	43,0	43,0	0,0
from biogas	-	7777,3	6702,9	22,8
from…	-	0,0	0,0	0,0
Heating	-	**7864,8**	**1,6**	**7863,1**
from solar	-	415,8	0,0	416,1
from solid biomass	-	6517,7	0,0	6517,7
from biogas	-	601,0	1,6	599,1
from green gas	-	0,0	0,0	0,0
from geothermal	-	276,3	0,0	276,3
from ….	-	53,9	0,0	53,9
Cooling		**0,0**	**0,0**	**0,0**
Biofuels for transport	-	-	-	-
Biofuels for machinery	-	-	-	-
TOTAL FINAL ENERGY	**-**	**70364,0**	**61426,4**	**7885,9**
Intermediate fuels				
Biogas	-	19046,3	403,3	18643,0
TOTAL INTERMEDIATE ENERGY	-	**19046,3**	**403,3**	**18643,0**
Primary fuels				
Total energy crops	**0,0**	**28063,3**	**14208,9**	**3484,3**
Oilseeds, cereals, sugar crops etc	0,0	13499,5	9848,7	3484,3
Woody crops	0,0	4360,3	4360,3	0,0
Forest wood	**5687,8**	-	-	**5687,8**
Agro waste	**0,0**	**28010,3**	**18923,5**	**5036,3**
Plant waste	0,0	-	-	-
Manure	0,0	-	-	-
Other waste	0,0	-	-	-
TOTAL PRIMARY ENERGY	**5687,8**	**56073,6**	**33132,4**	**14208,4**

Note: consumption of solid biomass for space heating by farm households is assumed to remain at 2539,5 ktoe in both scenarios. The rationale is that the number of farm households that need to heat their homes is unlikely to increase (in fact, it is more likely to decrease following a steady trend from previous years and in this sense this figure could be an overestimation), hence the increase in renewable heat goes on account of productive heat uses.

This would represent almost 35% of the total renewable electricity predicted to be produced by 2020 according to the NREAPs[13]. Under the more ambitious NREAP+ scenario, electricity generation is expected to show a much stronger leap as compared to the current situation (62 Mtoe or an almost eight-fold increase). Production of heat (6 Mtoe in 2020) is showing a more modest increase, approximately doubling in size (and representing only some 5% of the renewable heat & cooling target set in the NREAPs). The main reason for this is that traditional solid biomass-based heat used for farm household heating is assumed to remain relatively constant in the near future, and only the productive heat uses (that is, uses for productive activities, such as drying, heating greenhouses or as input to other industrial process) are assumed to increase following the NREAP-based growth rates. For on-farm use of biofuels we did not make estimates for 2020, as they are expected to follow the development of the country transport fuel mix and should in principle reach 10% of total fuel consumption, as mandated by the RES directive. On the other hand, production of crops for biofuel purposes is captured in the primary fuels section of the balance.

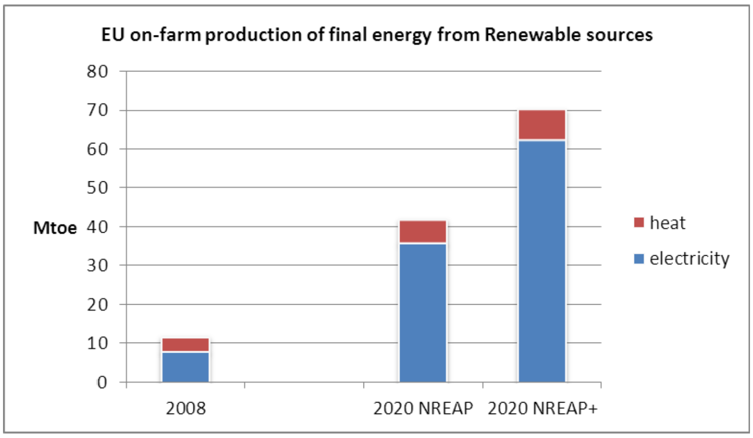

Figure 11 Estimated on-farm production of final energy from renewable souces in the EU

In terms of primary energy, the NREAPs expect the production of energy crops in 2020 to almost double to 25 Mtoe. Agricultural waste is expected to become a much more important source of primary energy, approximately quadrupling its contribution to around 21 Mtoe, thus almost matching energy crops. Following the logic for solid biomass-based heat development, the import of wood on farm is also assumed to remain constant.

In both 2020 scenarios, wind electricity continues to dominate the on-farm renewable electricity generation mix. This is remarkable, since the general expectation is that RE will not be dominated by a single technology or system (Edenhofer 2011). Due to MSs ambitious targets for wind electricity and the high likelihood that on-shore wind will continue to be the predominant technology, it is fair to assume that it will continue its fast expansion on agricultural land as it would elsewhere. While the projected 5-7 fold increase in wind electricity from turbines installed on farmland seems rather high, it is in line with the sector's average 30% annual growth (IEA 2010) and the fact that in more than half EU MSs, half or more of the technical potential for wind is located on agricultural areas (EEA 2009). At the same time, the strong bias towards large turbines (>1 MW), might represent a limiting factor for smaller farms. In addition, large installations require high capital investments (about 1.23 million euro/MW according to (EWEA 2010), unlikely to be possible for farmers alone. This situation makes land lease the most likely (although not exclusive) income stream related to wind electricity for farmers.

The production of biogas on farms is projected to increase 3 to 10 fold in the 2020 scenarios, without and with farm-specific incentives, respectively. Renewable electricity produced from agricultural biogas is estimated to more than triple in the coming decade even without farm-specific incentives, although its relative contribution to the sectors' renewable electricity production would remain below 10% (in the

[13] Total renewable electricity and heat & cooling production in 2020 following the NREAPs are projected at 103,1 and 111,6 Mtoe, respectively, see Table 1 in Beurskens and Hekkenberg (2011) http://www.ecn.nl/publications/default.aspx?nr=ECN-E--10-069

NREAP scenario) or rise just above that in the NREAP+ scenario. Biogas-based heat is projected to remain modest. Only if policy stimulation is moving towards rewarding consumption of renewables, rather than production, and heat being the most efficient application for biogas, it is likely to become a more attractive way of using biogas (provided a continuous demand for heat can be ensured). Finally, upgrading biogas into green gas and feeding it into the natural gas grid is becoming an increasingly interesting option for some natural-gas depending countries, like Germany and the Netherlands. Although it is difficult to estimate how much of the agricultural biogas could be used in such a way, it is very likely that demand for biogas will increase even faster than predicted here.

3.2 GHG Balance

The GHG performance of RE was analysed for 2008 and for two scenarios for 2020, i.e. a pure NREAP scenario and the NREAP+ scenario. The avoided and saved GHG emissions were calculated for the following types of RE produced on farms: electricity from solar PV, electricity from wind, electricity from solid biomass, heating from solar, heating from solid biomass, heating from geothermal, biofuels from energy crops and biogas (including both electricity and heating).

Table 9. Calculated avoided and saved GHG emissions (in kton CO_2-eq) from RE on farms for 2008

Country	Elec solar PV	Elec wind	Elec solid biomass	Heat Solar	Heat solid biomass	Heat geo-thermal	Biogas	Biofuel energy crops	2nd gen. energy crops	Total
Austria	1	1059		5	283		209	28		1583
Bulgaria		185			300			251		737
Belgium		301			50		31	7	74	463
Cyprus							9			9
Czech Republic		154		3	172		68	47	16	461
Germany	177	23557	65	12	180	13	2848	1914	29	28795
Denmark		3607			5		375	437		4424
Estonia		309			120		5			434
Greece		272				41		1		314
Spain		10152		3		27	103	110	1	10395
Finland		39		0	1136		1	-2	598	1772
France		3372			1010	31	529	3250	100	8291
Hungary		180		4	1647	8	58	11		1908
Ireland		1634		0	2				37	1672
Italy		1636						94	379	2110
Lithuania		83			41		3	160		286
Luxembourg		10					38			48
Latvia		10			31		3	12		56
Netherlands		1258				9	148	0	2	1417
Poland		933		7	5625	17	1	702	1015	8300
Portugal		2195					6			2202
Romania		97		1	5542	4		756	1	6402
Sweden		596			297		3	191	217	1304
Slovenia					16		39	3		57
Slovakia		5			14	3	2	141		165
United Kingdom		1015	54		428		538	639	132	2806
EU-27	177	52658	119	35	16898	154	5017	8752	2600	86411

3.2.1 Saved and avoided GHG emissions from RE on farms in 2008

Table 9 shows the calculated avoided and saved GHG emissions from RE on farms. The total calculated GHG savings from RE on farms is 86 Mton CO_2-eq. This is equivalent to 18% of the total GHG emissions from the agriculture sector in the EU in 2008, as reported to the UNFCCC or listed by the EU Rural development report (DG-AGRI 2010). However, most of these savings are not accounted under the UNFCCC sector Agriculture, but under the UNFCCC sector Energy, only the saved GHG emissions from manure storage for biogas production are accounted under the sector Agriculture. Most GHG savings are due to wind energy (53 Mton CO_2-eq), followed by solid biomass for heating (17 Mton CO_2-eq), biofuels (8.8 Mton CO_2-eq), biogas (5.0 Mton CO_2-eq) and second generation energy crops (2.7 Mton CO_2-eq). The other RE types only have a marginal effect on the total GHG savings. Germany contributes for 25% to the total GHG savings, mainly from wind energy and biogas, followed by Spain with 15%, mainly from wind energy.

Biogas

In terms of GHG performance, biogas is most interesting, since not only GHG from fossil fuel combustion are saved, but also GHG emissions from manure storage might be avoided. Table 10 presents the overview of how the net GHG savings are composed. Electricity production from biogas avoids most GHG emissions (5.2 Mton CO_2-eq), whereas the savings from heat production are low (0.1 Mton CO_2-eq), since in most cases there is no nearby demand for heat. Under optimal circumstances about 50% of the energy produced could be used for heating, however, based on the collected data from Theme 1 only about 2.6% of the produced biogas is currently used for heating. The avoided emissions from manure storage are estimated at 1.5 Mton CO_2-eq in 2008. For countries that have on average a high share of manure in the substrate, e.g. Denmark and Hungary, the saved GHG emissions from manure storage can be higher than the avoided GHG emissions from fossil fuels. Besides avoided GHG emissions, emissions also occur during the production of biogas, for 2008 about 1.8 Mton CO_2-eq. Most of these emissions are related to the cultivation of energy crops. Particularly countries as Germany, Austria and Netherlands have high emissions from the cultivation of silage maize and grass. In case no energy crops are used, e.g. for Denmark and Spain, the GHG performance is better.

Table 10 Overview of avoided GHG emissions and emissions from the production of biogas per country (2008)

Country	Avoided GHG emission from manure storage	Avoided GHG emission fossil fuels for electricity	Avoided GHG emission fossil fuels for heating	GHG emissions from biogas production	Net avoided GHG emissions
Austria	23.1	294.6		108.7	209.0
Belgium	5.9	19.6	11.7	6.0	31.2
Cyprus	4.5	4.5	1.4	1.5	8.9
Czech Republic	10.4	62.8	16.9	22.4	67.7
Denmark	205.8	177.5	24.7	32.8	375.2
Estonia	2.8	1.9	0.9	0.4	5.2
Finland	0.1	0.3	0.6	0.1	0.9
France	221.3	443.4		136.1	528.6
Germany	540.7	3417.4		1109.8	2848.3
Hungary	38.3	20.1	12.4	12.7	58.2
Latvia	1.3	0.9	0.9	0.6	2.6
Lithuania	1.3	0.5	1.5	0.7	2.5
Luxembourg	4.7	16.3	24.0	6.9	38.1
Netherlands	126.5	173.0	9.9	161.4	148.1
Poland	0.5	0.5	0.3	0.2	1.0
Portugal	2.4	4.8		0.8	6.3
Romania	0.5	2.4		0.7	2.2
Slovenia	6.6	45.4		13.0	39.0
Spain	43.6	65.3	5.3	11.4	102.8
Sweden	0.4	1.0	2.3	0.6	3.1
United Kingdom	231.7	442.7		136.1	538.2
EU-27	1472.2	5194.8	113.0	1762.8	5017.2

Energy crops

The energy crop areas were the basis for the calculation of GHG emissions and savings from biofuel production and from electricity generation based on co-firing of second generation (i.e. lignocellulosic) energy crops (*Miscanthus*, switchgrass, canary reed, poplar and willow). For 2008 the areas were estimated in the BiomassFutures project [14], based on different EU statistics and country information. Figure 12 shows the energy crop areas per country, as used in the GHG calculations. Rapeseed is the main biofuel crop with large areas in France, Germany and Poland. Sunflower is more important in East and South European countries. Cereals and sugar beet are only limited used for biofuel production. The area of second generation energy crops is still limited in 2008 (about 100000 ha), and mainly located in northern EU countries (Finland, Sweden and Poland). With the MITERRA-Europe model the average GHG emission per hectare of energy crop was calculated for each MS. In addition to the emissions from cultivation, as calculated by MITERA-Europe, the default values from the Renewable Energy Directive are used for transport and processing (rapeseed and sunflower to biodiesel and wheat, barley, grain maize and sugar beet to bioethanol).

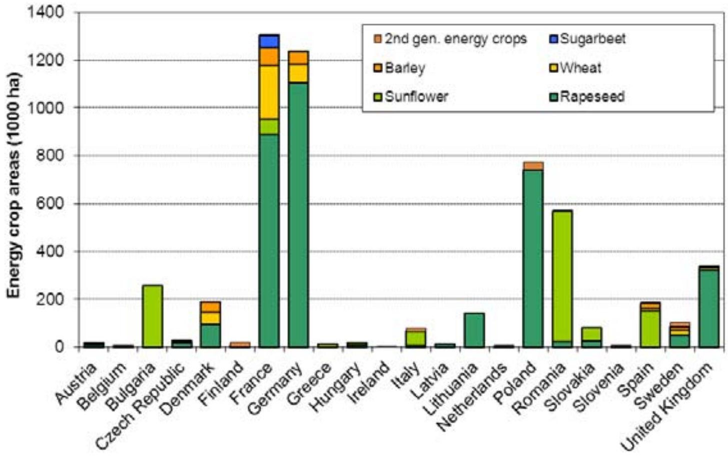

Figure 12. Energy crop areas per MS, data are based on 2006-2008, as collected in BiomassFutures project and calculated by MITERRA-Europe (www.biomassfutures.eu)

3.2.2 Saved and avoided GHG emissions from RE on farms in 2020

In the 2020 NREAP scenario the total calculated GHG savings from RE on farms is 315 Mton CO_2-eq, which is equivalent to 65% of the total GHG emissions from the UNFCCC sector Agriculture in the EU in 2008 (487 Mton CO_2-eq). For the 2020 NREAP + Agri scenario these savings are even higher up to 512 Mton CO_2-eq, which is equivalent to 105% of the total GHG emissions from the sector Agriculture. Most GHG savings are due to wind energy (about 73%), followed by biogas, solid biomass for heating and electricity from second generation energy crops (Figure 13).

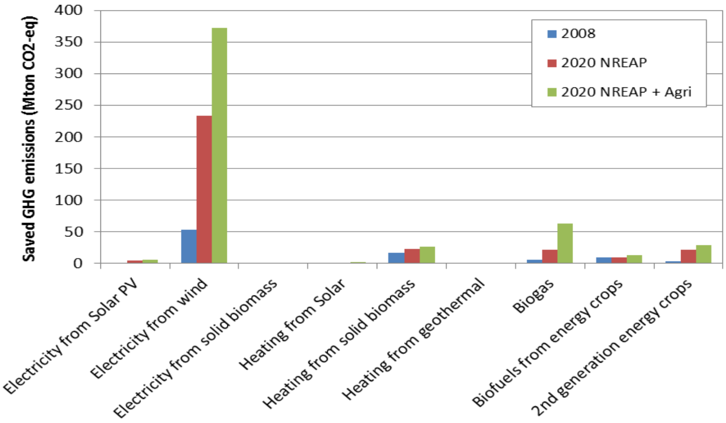

Figure 13. Saved and avoided GHG emissions from RE on farms for 2008 and the two 2020 scenarios

[14] http://www.biomassfutures.eu/

The other RE types only have a minor contribution to the total GHG savings. In the NREAP scenario Germany has the highest contribution to the total GHG savings (27%), followed by France (15%) and Poland (11%). In the NREAP + Agri scenario France equals Germany with both a contribution of 25%), mainly due to a very large increase of wind energy in France.

For energy crops the saved GHG emissions were calculated using CAPRI scenario data for 2020 including the biofuel target of 10%. The following parameters were changed compared to the simulation for 2008: crop areas, livestock numbers, crop yields, fertiliser inputs, GHG emission factors for fertiliser production. According to the projections the area of biofuel crops slightly decreases, whereas the area for second generation energy crops strongly increases (from 100,000 ha to more than 800,000 ha). France and Germany have the highest GHG savings from energy crops for biofuels, while Poland has the largest GHG savings from second generation energy crops.

3.2.3 Discussion

GHG performance RE types

In Figure 14 the GHG performance for the main RE types are compared for the EU-27, based on the data for 2008 and for the 2020 NREAP scenario. Per unit of produced energy, wind energy and biogas have the highest GHG savings in 2008, whereas biofuels have the lowest GHG savings. The good performance of biogas is due to the avoided emissions from manure storage. Without these avoided emissions the GHG performance of biogas would be lower, i.e. 5.0 ton CO_2-eq/toe. However, the GHG performance of biogas depends on the substrate composition. When energy crops are the main substrate the GHG performance will be lower. In addition, there is a risk of conversion of grasslands to arable land for cultivation of energy maize, as has occurred in Germany. This will even further lower the GHG performance due to the loss of soil organic carbon. The low GHG savings from biofuels is due to the high GHG emissions from cultivation of energy crops. The first generation energy crops (rapeseed, sunflower, sugar beet, and cereals) require relatively high nutrient inputs, which results in high N_2O emissions. The GHG performance of second generation energy crops, such as grass crops as *Miscanthus* and switchgrass and woody crops as poplar and willow, is much better, since these crops do not require high nutrient inputs and these crops have also a positive effect on soil organic carbon stocks.

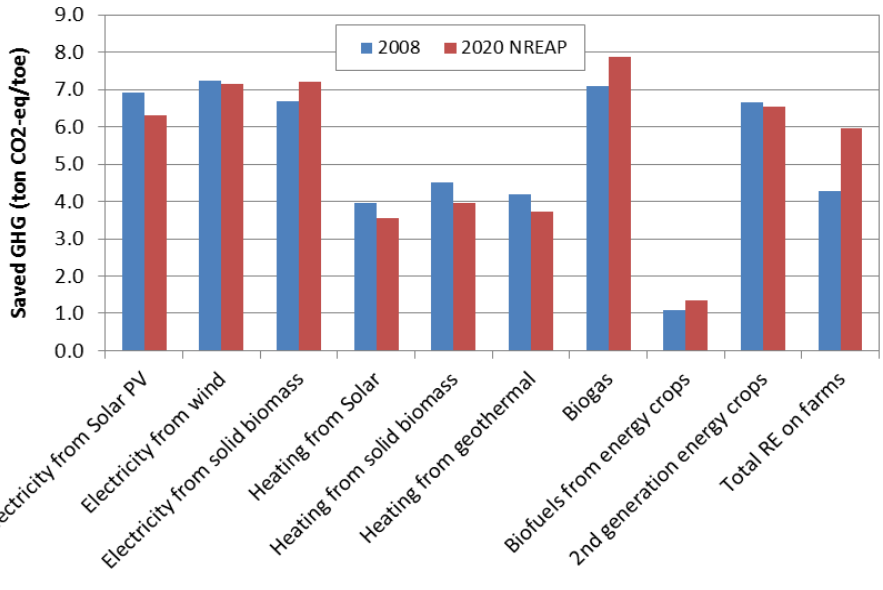

Figure 14. GHG performance of RE types for 2008 and 2020 NREAP scenario

For 2020 the relative GHG savings per unit of produced RE is slightly lower for most RE types. The main reason for this lower GHG performance is the change in fossil fuel mix, which results in other GHG emission factors (Table 1). However, this is very dependent on country and RE type. For biogas and biofuels from energy crops the performance is better due to higher crop yield and less overfertilisation of the energy crops, which lower the emissions from cultivation.

Uncertainties

The main uncertainties related to the amount of saved and avoided GHG emissions are related to the amount of renewable energy produced. For biogas the uncertainty is mainly related to the substrate composition. This composition is highly variable in time, and depends on prices and availability. Especially, the ratio between manure and other substrates affects the results, since manure has a much lower energy yield compared to energy crops (mainly silage maize) and other organic residues. However, the GHG balance is positively affected by avoided GHG emissions from manure storage.

Two other parameters that affect the GHG performance of biogas production are the assumed reduction of GHG from manure and the leakage of methane from the biogas plant. For both parameters few literature is available and they depend on the type of installation. According to Mistry and Misselbrook (2005) the methane leakage for on-farm Anaerobic Digestion is 3% and for centralised Anaerobic Digestion 1%. Based on this data we assumed an average of 2% for all countries. However, according to Vogt et al. (2008) methane leakage might be between 2.5 up to 15% of biogas produced. Countries with many small farm-scale installations (e.g. Germany) have therefore a higher risk on methane leakage compared to countries with larger more centralised installations (e.g. Denmark).

To have some further insight in uncertainties and the effect of selected parameter values, we applied a sensitivity analysis for the GHG savings of biogas. The CH_4 leakage factor, the GHG emission reduction factor for manure storage and the composition of the substrate were included. The effect of changing these parameters was compared to the base result of 2008 (CH_4 leakage factor at 2% and GHG emission reduction factor at 95%). The CH_4 leakage factor has a significant effect on the net GHG savings, with 1% leakage the net saved GHG emission would be 8% higher, while a 5% leakage factor would reduce the net GHG savings by 24% (Figure 15). The effect is even larger when no manure is involved, a 5% leakage with a substrate of purely maize would decrease the net GHG savings by 56%, whereas a 8% leakage would result in negative net GHG savings. According to Vogt et al. (2008) leakage might be between 2.5 up to 15% of biogas produced, thus negative GHG savings are not unrealistic.

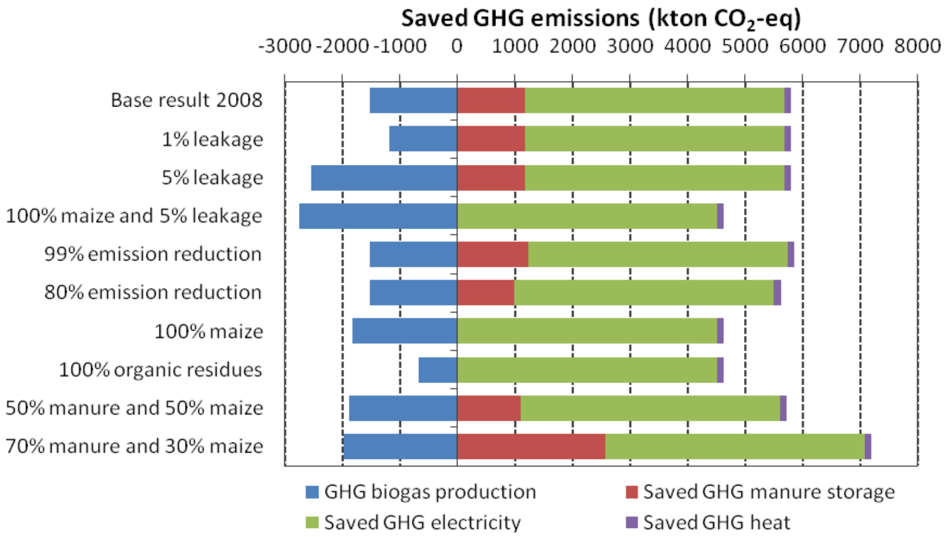

Figure 15. Sensitivity analysis for effect of CH_4 leakage, emission reduction and substrate composition on the saved GHG emissions of biogas

The effect of the emission reduction factor of stored manure is less pronounced, a decrease from 95% to 80% would results in a decrease of 4.4% of the net GHG savings. In contrast, the effect of substrate composition on the net GHG savings is significant. In general, the net GHG savings will be higher when more manure is included. However, since the energy content of manure is low, a purely manure fed digester is often not economically viable, because of the low biogas production.

For biofuels from energy crops we also compared the default value for cultivation (e_{ec}) of the RED with the result of the GHG assessment by MITERRA-Europe. For most countries both values are comparable, although for some countries the differences are large and on average the values of MITERRA-Europe somewhat higher. These differences are due to two main reasons: 1) the RED values are not country specific, and do not account for country characteristics and yield levels; 2) emissions from organic soils are not included in the default value of the RED, whereas MITERRA-Europe does account for these emissions, which results of much higher GHG emissions for countries with peat areas, e.g. Finland and Netherlands.

3.3 Farm based survey

The results of the questionnaire are presented in detail in Annex IV. In this part, only the results for the main objectives are presented. First, the farm and farmer characteristics of farms with and without RE investments are described. Secondly, the reasons for RE investments, unexpected problems of RE investments, and consequences of RE investments are described for different RE types. Thirdly, barriers for RE investments are described for each case study region. Finally, the most striking and unexpected results are discussed, and the results are compared with literature.

3.3.1 General information

Overall, farmers who invested in RE more frequently have a successor than farmers without RE investments. Also, farmers with RE investments indicated more frequently that they earn a net farm income above the regional average than farmers without RE investments (Table 11). Other economic characteristics of the farm (availability of other sources of income, solvability, and amount of investments in non-RE) were not different between farms that invested in RE and farms that did not invest in RE. This is however not the case in every region. For instance, in Warminsko-Mazurskie the farms with RE investments have more frequently other sources of income (Annex IV: Table 58), and in both German case study regions the farms with RE investments have less frequently a successor (Annex IV: Tables 33 and 43). The farm and farmer characteristics are somewhat different between different RE types. For instance, especially the farmers invested in PV and biogas indicated that they have an above average farm income. Especially the farmers who invested in solar thermal energy have a high solvability, and the farmers who invested in biomass have the most non-RE investments (Table 12).

Table 11 Number of RE investments reported by farmers in the survey

	RE type												
	Wind	PV	Solar thermal	Solid biomass	Farm crushed biofuels	Other biofuel crops incl. grasses	Woody biomass	Heat pipeline	Biogas	Geothermal	Hydro	Other	All
Saarland	1	39	3	2		1	1		4	2			57
Brandenburg	5	27	2	6		1	1		11			1	56
Mazowieckie	6	3	9	8				3			2	5	31
Warminsko-Mazurski	3	5	2	6		4	4			1		5	
Valencia		6							1				7
Soria	3	9	1		9							2	21
Carinthia		7	17	23	6	12	12	6	4	1	1		71
Upper Austria	5	23	18	27		8	8	18	18	1		2	137
Total	23	119	52	64	15	25	25	27	38	5	3	13	420
Idem (%)	5.5	28.3	12.4	15.2	3.0	6.0	6.0	6.4	9.0	1.2	0.7	3.1	100

For all eight case study regions a probit model was built (e.g., Annex IV: Table 9) to investigate if the responses are affected by several factors simultaneously. All developed probit models show very clearly that none of the farm and farmer characteristics contribute to the explanation whether farmers invested in RE. This is, however, due to the extreme overrepresentation of farmers that did invest in RE versus those who did not. This resulted in levelling out the differences found in the univariate analyses.

Table 12 Overview of farm and farmer characteristics for farms with and without RE investments

Question	% invested in RE (n=423)	% not invested in RE (n=410)	p-value[1]
Availability of a successor			**0.0001***
Yes	40	33	
No	14	26	
Not yet known	46	41	
Annual net farm income			**0.0005***
Above regional average	52	40	
Below regional average	48	60	
Other sources of income			0.1811
Yes	57	52	
No	43	48	
Solvability			0.2527
0-0.2	7	9	
0.2-0.4	11	9	
0.4-0.6	22	17	
0.6-0.8	23	23	
0.8-1.0	37	42	
Investments in non-RE			0.2856
≥10%	54	50	
<10%	46	50	

[1]p-value indicates whether the distribution of answers is different between farms invested in RE and farms without RE investments.
**Significant at 5% level.*

Table 13 Overview of farm and farmer characteristics for farms with different RE types

	RE Type					
Question	% invested in Wind (n=31)	% invested in PV (n=113)	% invested in Solid biomass (n=56)	% invested in Biogas (n=36)	% invested in Solar thermal (n=42)	% invested in Biomass (n=26)
Availability of a successor						
Yes	45	41	48	56	52	50
No	13	10	7	3	3	15
Not yet known	42	49	45	41	45	35
Annual net farm income						
Above regional average	38	65	48	61	45	56
Below regional average	62	37	52	39	55	44
Other sources of income						
Yes	54	54	63	49	68	63
No	46	46	37	51	32	37
Solvability						
0-0.2	3	4	6	6	5	4
0.2-0.4	13	12	7	23	5	17
0.4-0.6	16	23	19	28	15	35
0.6-0.8	32	27	24	23	18	13
0.8-1.0	36	34	44	20	57	30
Investments in non-RE						
≥10%	63	58	54	64	49	74
<10%	37	42	46	36	51	26

3.3.2 Reasons for RE investments on farms

The farmers who invested in RE (n=423) gave as main reasons to invest: the desire to contribute to an environmentally friendly energy supply, getting a guaranteed price during a fixed period of time, the desire to (produce one´s own energy in order to) be independent from rising energy prices, and the desire to diversify sources of income. The farmers indicated that a problem with the energy supply for farm or household, and the possibility to join an initiative (e.g. in the neighbourhood) were no reasons to invest in RE. The farmers did not have a clear opinion whether the subsidies (national/regional or EU) are a reason for RE investments. Most farmers indicated that they do not agree nor disagree that subsidies were a reason for RE investments (Table 13).

Various reasons have been reported to invest in different types of RE (Table 14). For instance, in the case of PV the subsidies (national/regional/EU) did not appear as a reason for investment, while they did motivate farmers to invest in solar thermal, solid biomass and heat pipelines. Further analysis of the survey results, however, showed that subsidies have played a significant role in PV investment, but only for farmers who did not invest much in general (data not shown here). Thus, investment subsidies appear to play a crucial role in allowing farmers to invest in PV *who otherwise could not have afforded this investment*. Feed-in-tariffs (providing a guaranteed price for a fixed period of time) apparently played a strong role in stimulating farmers to invest in wind turbines, PV panels, solid biomass equipment, heat pipelines and biogas installations. Availability of residues on the farm has been a further motivation for farmers to invest in solid biomass, heat pipeline and biogas.

Table 14 Overview of the reasons for RE investments on farms for 7 different RE types

	RE type							
	Wind (n=31)	*PV (n=113)*	*Solar thermal (n=43)*	*Solid biomass (n=57)*	*Biomass (n=27)*	*Heat pipeline ((n=26)*	*Biogas (n=37)*	*All*
Contributing to an environmentally friendly energy supply	+	+	+	+	+	+	+	+
Problem with energy supply for farm/household	-	-	-	-	-	-	-	-
Getting a guaranteed price/ income for a fixed period of time	+	+		+		+	+	+
National or regional subsidies were available		-	+	+		+		
EU subsidies were available		-						
Opportunity to join an initiative in the neighbourhood/ unions/ communities/ foundations.		-					-	-
Producing own energy to be independent from rising costs for energy prices	+	+	+	+	+	+	+	+
Making better use of residues and waste from farm (e.g., manure, crop residues)		-		+		+	+	
Need to diversify sources of income	+	+		+	+	+	+	+

A '+' sign means the farmers agree with the statement (median score of 1 or 2), a '-' sign means that the farmers disagree with the statement (median score of 4 or 5), and an empty cell means that the farmers agree nor disagree with the statement (median score of 3).

Table 15 shows that feed-in tariffs are more relevant for farmers who did not invest much at all, who are satisfied with the return on investment and who report an increased farm income. This applies especially to investments in PV (data not shown).

Table 15. Relationship between feed-in tariff as reason to invest in RE, and other farm characteristics

Answer	***Significant correlation with mentioning feed-in tariff as reason for investment***
High solvability	-
Low solvability	
Low non-RE investment	+
High non-RE investment	
Sufficient return on investment	+
Insufficient return on investment	
Increased farm income	+
Investment costs	+

RE investments on farms with sufficient solvability are not significantly increased by subsidies (data not shown). Subsidies are thus only effective for farms with low solvability. Returns on investment improved significantly both by feed-in tariffs and subsidies. Interestingly non-EU subsidies appear to be significant for investing in Solar Thermal energy, EU subsidies for Wind.

3.3.3 Financing RE investments

Private funds are the main sources used when investing in RE (Table 16). This mostly relates to money from the farm, but also personal funds play a significant role. Subsidies (local, regional, national or EU-based) are more frequently used than bank loans but the height of the subsidies (bank loans) have not been assessed.

Table 16 Source of investment funds (number of farmers)

	RE type							
	Windturbine (n=31)	PV (n=113)	Solar thermal (n=43)	Solid biomass (n=57)	Woody biomass (n=27)	Heat pipeline (n=26)	Biogas (n=37)	All
Personal funds	14	34	38	34	14	11	11	156
Money from the farm	5	52	32	35	20	14	22	180
Bank loans	13	59	9	18	5	15	29	155
Loan with subsidised interest rate	3	13	3	10	1	5	6	41
Subsidies (total)	7	31	25	40	16	18	24	160
Of which local, regional	2	9	6	14	4	3	6	44
national	2	10	10	13	5	4	3	47
co-financed by EU	3	12	9	13	6	11	15	69

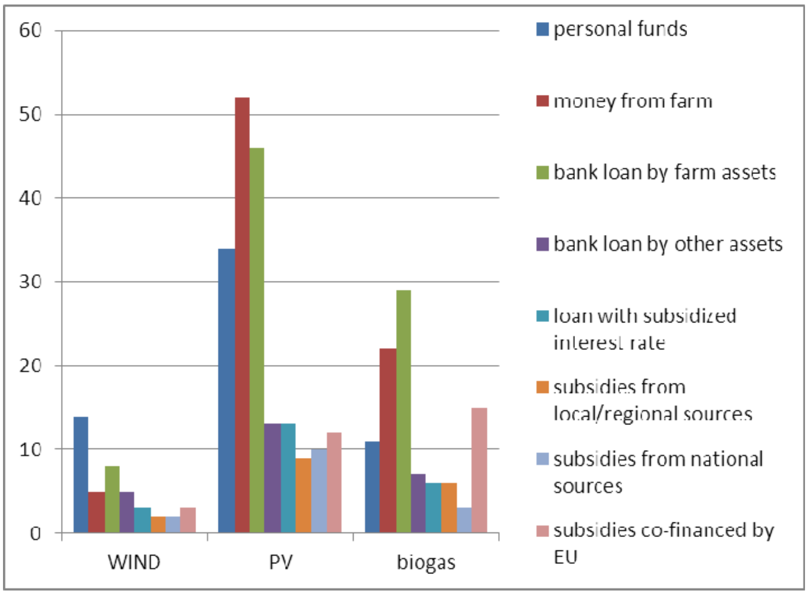

Figure 16. Numbers of farmers investing in wind energy, PV or biogas, differentiated in types of funding

The relevance of subsidies in the case regions is showing large variation, with subsidies playing an important role in Austria (especially Upper Austria) (Figure 17; Annex IV: Figures 3 and 8).

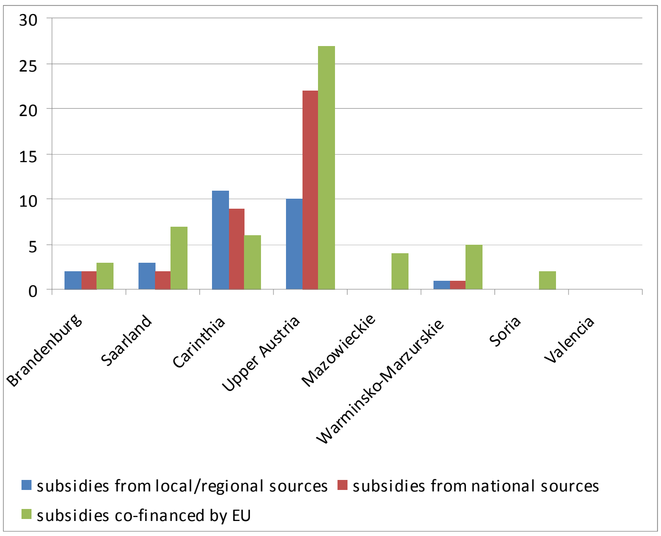

Figure 17. Subsidies used to invest in RE installations

All case countries have implemented measures to promote RE investment (see policy overview: Annex I.3). Most measures were taken by Austria, only Germany and Austria providing grants to fund RE investments. Only in Upper Austria the availability of subsidies was a reason for RE investments (Annex IV: Table 27). The low use of subsidies by German farmers is due to the fact that this country has installed the highest feed-in tariffs of the case countries. In the policy overview it can be found that in Germany, Austria en Spain feed-in tariffs are used to promote the production of RE. These feed-in tariffs are a reason to invest in the case study regions in these countries. Poland does not have feed-in tariffs and consequently this was also not mentioned as a reason to invest (Annex IV: Table 77).

As only in Austria the subsidies are used to finance the RE investment, only in this case study region results on unexpected problems around subsidies are reliable. The farmers in Carinthia did not experience problems in the procedure to get subsidies, but the farmers in Upper Austria did. Moreover, the farmers in Upper Austria also experienced unexpected problems in the procedure to get a permit, and the costs of a permit were perceived higher than expected. Most likely, the main reasons for the difficulties that Upper Austrian farmers declared with acquiring permits is not predominantly the bureaucracy but the long duration of the procedure. Although the procedure for obtaining permits is the same in Carinthia, farmers there didn`t state to have problems with it. One reason for this might be that in the recent past a lot of RE installations (mainly biogas plants) were installed in Upper Austria and farmers in this region were more confronted with this problem.

Whether the return on investment was sufficiently high did not depend on the use of subsidies. A non-significant correlation of 0.04 ($p=0.4237$) was found between farmers indicating the return on investment was high enough and subsidies as a reason for RE investments. In addition, a correlation of -0.05 was found between farmers indicating the return on investment was high enough and having financed the RE investment with subsidies. Analysing the different RE types separately showed the same result. In contrast, a significant correlation was found (correlation of 0.09, $p=0.09$) between farmers indicating the return on investment was high enough and a guaranteed price as a reason for investment. Also a highly significant correlation (correlation of 0.34, $p<0.0001$) was found between reports of increased farm income and a guaranteed price as a reason to invest in RE. This applies also to RE types separately, highest correlations being found for wind (0.62), biogas (0.29), solar thermal (0.28) and PV (0.27). These results indicate that, in farmers eyes, a guaranteed price contributes more to a high return on investment and a higher farm income than investment subsidies.

3.3.4 Unexpected problems associated with RE investments on farms

The opinions of farmers on unexpected problems in relation to RE-investments ranged strongly between and within case regions (answer: neither agree nor disagree). The farmers only clearly indicated that obtaining assistance with the RE technology (for supply, installation, advise, or maintenance) was not a problem (Table 17).

Some differences can be seen with respect to the unexpected problems for different RE types (Table 17). For instance, for PV and solar thermal no unexpected problems were experienced, but for biogas unexpected problems were experienced, such as high investment costs, low profitability, and difficulties with procedures and acceptance. Moreover, it was also experienced that the reliability of the biogas technology was lower than expected. It has to be mentioned however that the perceived profitability for biogas is different between Germany and Austria. In Austria ($n=22$) it was perceived that the profitability was to be lower than expected (median score of 1), while this was not the case in Germany ($n=11$, median score of 4). This is probably related to the smaller size of the installations in Austria. In the other countries the number of biogas plants was too low for country specific conclusions.

Especially in Upper-Austria unexpected problems were experienced with long procedures and costs of obtaining permits and subsidies (Annex IV: Table 22), notwithstanding the fact that a one-stop shop system has been introduced in the Austrian NREAP (see previous section). In Saarland, no unexpected problems at all were experienced (Annex IV: Table 37), which can be explained by the high number of PV installations.

Table 17 Overview of the unexpected problems for RE investments on farms for 7 different RE types

	RE type							
	Windturbine (n=31)	PV (n=113)	Solar thermal (n=43)	Solid biomass (n=57)	Biomass (n=27)	Heat pipeline (n=26)	Biogas (n=37)	All
Total investment costs were higher than expected		-	-	+			+	
Selling RE products was more difficult than expected		-	-					
Profitability of the investment was lower than expected		-	-				+[1]	
Availability of subsidies was lower than expected		-						
Procedure to get a subsidy was more difficult than expected		-					+	
Cost of obtaining a permit were higher than expected		-	-				+	
Procedure to get a permit was more difficult than expected							+	
RE technology supply, installation, advise, or maintenance service in region was more difficult to obtain than expected		-	-					-
Availability of resources for RE was lower than expected		-	-				+	
More know-how required to start implement RE than expected		-	-					
Prices offered for RE produced on the farm is lower than expected		-				-		
Uncertainty about RE price levels is higher than expected		-						
Availability of loans was more difficult than expected		-						
Procedure to get loans for RE investment was more difficult than expected		-				-		
Reliability of current RE technology was lower than expected; the technology will be sooner out-dated than thought		-					+	
Acceptance of RE was lower than expected		-					+	

[1] Significantly different answers for Germany (profitability not perceived as lower than expected) and Austria (profitability perceived lower as expected).
A '+' sign means the farmers agree with the statement (median score of 1 or 2), a '-' sign means that the farmers disagreed with the statement (median score of 4 or 5), and an empty cell means that the farmers agreed nor disagreed with the statement (median score of 3).

3.3.5 Impacts of RE investments for farms

The farmers indicated that the RE investment did not result in less attention for other agricultural activities, selling more food/feed crops, having more livestock, buying more fertilisers, buying more fuels, having a more diverse cropping pattern and new jobs. The farmers mentioned that the RE investment did result in a higher total farm income (Table 18). Some differences can be seen about the consequences of different RE types. For instance, only with biogas new jobs are created, and only with solid biomass and biogas the farmers spend more time on the farm.

Table 18 Overview of the impacts of RE investments on farms for 7 different RE types

	RE type							
	Windturbine (n=31)	PV (n=113)	Solar thermal (n=43)	Solid biomass (n=57)	Biomass (n=27)	Heat pipeline (n=26)	Biogas (n=37)	All
The cropping pattern is more diverse	-	-						
Other agricultural activities on my farm get less attention	-	-	-	-				-
I sell more food/feed crops	-	-					-	-
I have more livestock	-	-	-	-		-	-	-
I buy more fertilisers	-	-	-	-	-	-	-	-
I buy more fuels	-	-	-	-	-	-	-	-
I spend more time working on the farm - including the RE activity	-	-		+	-	-	+	
The total farm income is higher	+	+	+	+	+			+
Jobs are created for family, partners or employees	-	-	-				+	-

A '+' sign means the farmers agree with the statement (median score of 1 or 2), a '-' sign means that the farmers disagreed with the statement (median score of 4 or 5), and an empty cell means that the farmers agreed nor disagreed with the statement (median score of 3).

3.4 Impacts of RE on farms

Specific impacts of the implementation of on-farm RE have been studied by analysing the survey in combination with using the survey results as input for further farmer level modelling with FSSIM to assess farmers (future) response and impacts of RE on farmer's income and environmental indicators. The farm level modelling also enabled us to further elaborate conclusions on suitability of the different types of RE production and conditions required for adoption of RE production. The following paragraphs describe the findings related to the implementation of different RE production types wind turbine establishment, implementation of photovoltaics, biogas, biomass, and biodiesel.

The farmers' responses to involvement of different RE experiments with FSSIM are set up in order to answer the questions as presented in Table 19. From the table it also becomes clear that not all questions are answered with results of similar FSSIM experiments in every case region.

Table 19 Main questions answered in relation to RE activities, regions and assessment level

Question	***Type of RE-activity (region)***	***Assessed at farm type level/regional level***
What should be the price level of RE-energy to make it an economically feasible competing activity (and what levels of support are needed (feed-in price levels) to make it happen?	*Biogas* (N-U-Austria, Saarland, Brandenburg) *Perennial biomass* (Brandenburg, Warmisko-Mazurskie) *Biomass* (Carinthia, Valencia) *Rape* (Mazowieckie)	Farm type level
What are the income effects of RE?	*Biogas* (N-U-Austria, Saarland, Brandenburg) *Perennial biomass* (Brandenburg, Warmisko-Mazurskie) *Rape* (Mazowieckie)	Farm type level and total region
What are the main land use changes expected to come from different RE activities?	*Biogas* (N-U-Austria, Saarland, Brandenburg) *Perennial biomass* (Brandenburg, Warmisko-Mazurskie) *Rape* (Mazowieckie)	Farm type level and total region
What are the main environmental gains from RE activities in terms of GHG mitigation and nitrogen leaching risks at farm level?	*Biogas* (N-U-Austria, Saarland, Brandenburg) *Perennial biomass* (Brandenburg, Warmisko-Mazurskie) *Rape* (Mazowieckie)	Farm type level
What are the employment effects of RE in terms of additional labour needs?	*Biogas* (N-U-Austria, Saarland, Brandenburg) *Perennial biomass* (Brandenburg, Warmisko-Mazurskie) *Rape* (Mazowieckie)	Farm type level and total region

Before the questions from the above table are answered in following sub-sections, first a discussion is given of the findings regarding investment levels in RE as derived from the survey results and from literature review. These investment costs are discussed in relation to capacities of the different RE installations and the level of revenues and pay-back time.

3.4.1 Investment levels in RE at different capacities

Wind turbines

Survey data from all farmers who solely invested in RE from wind turbines were used to derive a relationship between farmers' investment costs and the installed capacity (kW) of their wind turbine installation[15]. Figure 18 shows the linear relationship between farmers' invested costs and the capacity of their wind turbine installation.

[15] This only refers to farmers who invested themselves in a wind turbine. However, it should be emphasised that the survey results showed that in the majority of installed wind capacity on agricultural land farmers are not the owners, but large energy or investment companies often renting lad from the farmer for which he/she receives a stable rent for a long period of time. The assessment presented here therefore only refer to the cases where farmers invest themselves in wind, which is not always the most common practice in all EU regions.

Operation and maintenance costs have been assessed at 0.6-0.7 c€/kWh for young turbines. For older installations, this can increase to 1.5-4.5 ct. Total costs for installing and operating a medium-sized on-land wind turbine (including capital costs and applying a 5% annual discount rate, a 40 year lifetime and a 75% load factor which may be optimistic) has been calculated at 4.8 c€/kWh (EWEA 2010).

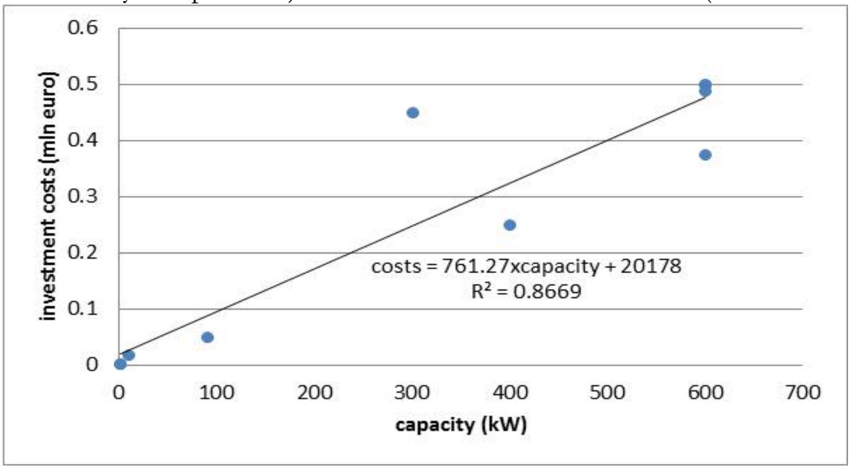

Figure 18. Relationship between farmers' investment costs and the capacity of their wind turbine installation, derived from the questionnaire (n = 10).

Annual gross revenues and payback time were calculated at a mean electricity price of 0,17 €/kwh which is slightly above the European average, but below the German tariff. Costs for operation and maintenance has been set at 0,05 €/kwh. At an annual operation period of 1750 hours, average payback time is 3.5 years which is extremely short. Examples of production capacity, investment costs and payback time are presented in Table 20. Farmers who chose to invest under a relatively long recovery period are mostly either fairly young or have a successor (Table 20).

Table 20. Example of farmers who attended to the survey and solely invested in wind turbine establishments: return, payback time, at energy price of 0.17 euro/kWh.

NUTS region	capacity (kW)	costs (mln €)	revenues (€/yr)	time to earn back (yr)	age	successor
Northern Upper Austria	10	0.02	2975	7	45	n
Mazowieckie	1	0.003	297.5	8	39	n
Warminsko-Mazurski	600	0.5	178500	3	52	y
Warminsko-Mazurski	0.6	0.004	178.5	21	54	y

Small installations tend to have higher payback time but for installations larger than 300 kw, the differences are relatively small (Figure 19).

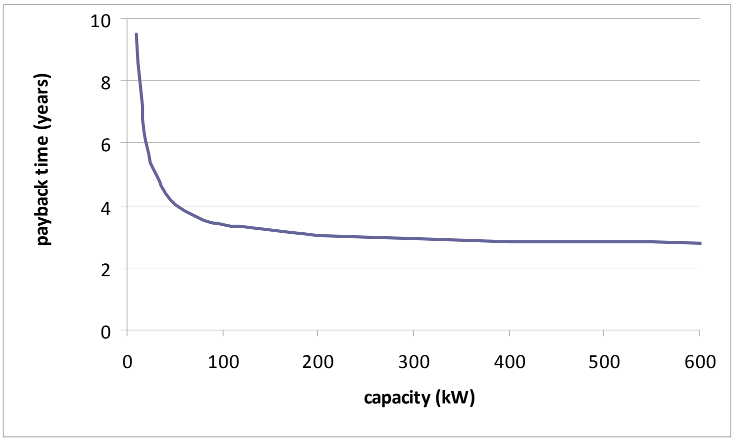

Figure 19. Calculated payback time for wind turbines in the survey.

Implementation of photovoltaics

By selecting all farmers from the survey population who purely invested in RE from photovoltaics, a relationship between their investment costs and the capacity (kW) of their installations could be derived. Figure 20 shows this linear relationship between farmers' investment costs and the installed capacity.

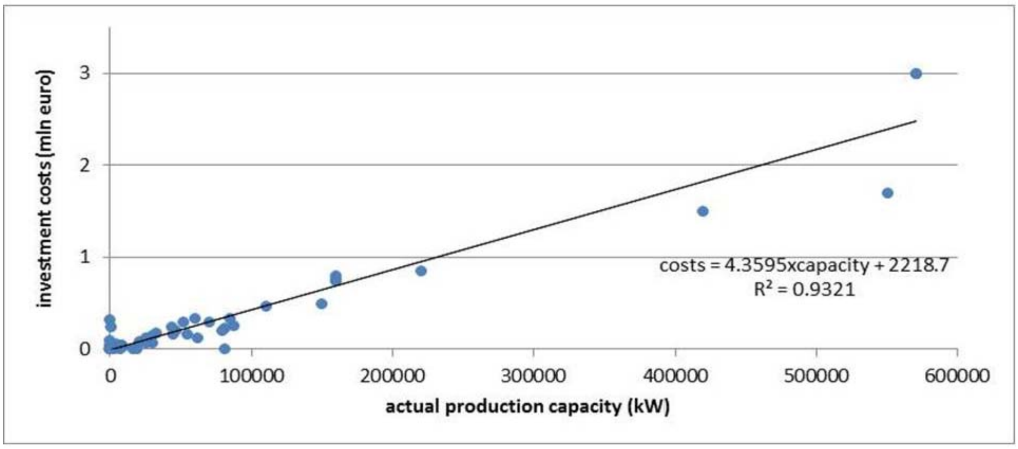

Figure 20. Relationship between farmers' invested costs and the capacity of their photovoltaic installation, derived from the questionnaire (n = 25).

The (annual) production capacity of on-farm photovoltaics can be converted into cash, taking the local energy price (euro/kWh) into account. These will be the (annual) gross revenues to the farmers. Dividing the farmers' investment costs by their annual gross revenues, will give the time needed to earn back the investment. As is the case for wind turbine investors, farmers who chose to invest under a relatively long recovery period are mostly either fairly young or have a successor (see Table 21).

Table 21. Examples of farmers who attended to the survey and solely invested in photovoltaics: revenues and time needed to earn back the investments are calculated for an energy price of 0.17 euro/kWh.

NUTS region	***actual production capacity (kWp)***	***costs (mln €)***	***revenues (€/yr)***	***time to earn back (yr)***	***age***	***successor***
Northern Upper Austria	4,500	0.02	765	26	56	y
Carinthia	8,000	0.04	1360	29	37	n
Brandenburg	62,000	0.13	10540	11	43	n

Saarland	44,000	0.25	7480	33	46	y
Mazowieckie	800	0.003	136	22	65	y
Valencia	8,000	0.05	1360	35	36	n
Valencia	570,000	3	96900	31	61	y

Small installations (peak capacity <100 kWp) tend to have a higher payback time, but for installations larger than 100 kwp the differences are relatively small (Figure 21).

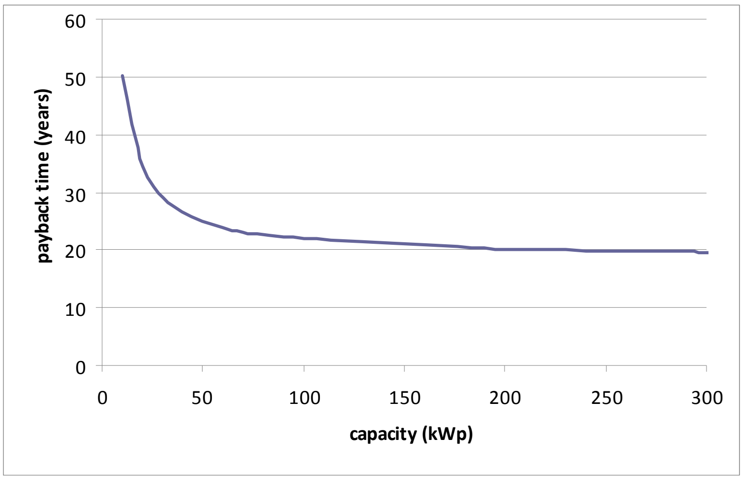

Figure 21. Calculated payback time for PV panels in the survey.

Biogas application

By selecting all farmers in the survey who invested only in biogas installations, a relationship between their investment costs and the capacity (kW) of their installations could be derived. Figure 22 shows this linear relationship between farmers' investment costs and the installed capacity.

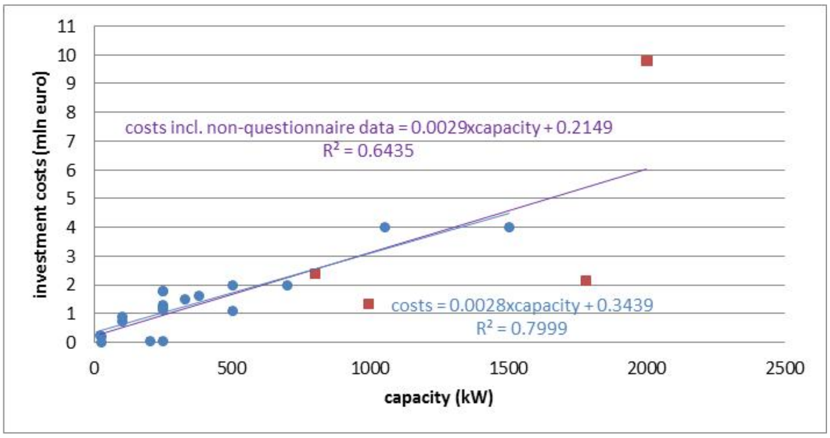

Figure 22. Relationship between farmers' investment costs and the capacity of their biogas installation, derived from the questionnaire (blue dots, n = 19) and from literature (red squares, n = 4).

The annual production capacity of on-farm biogas installations can be converted into cash, taking the local energy price (euro/kWh) into account. These will be the annual gross revenues to the farmers. However, from these gross revenues, operation and maintenance costs, labour costs, costs for purchased co-products and the interest over the investment should be subtracted. These costs add up to 60% of the annual gross revenues for small installations and to 90% for large installations (yearly biomass digestion capacity >36 kton). Dividing the farmers' investment costs by their annual net revenues, will give the time needed to earn back the investment. This pay-back time is shown against the capacity for small and large installations in Figure 23.

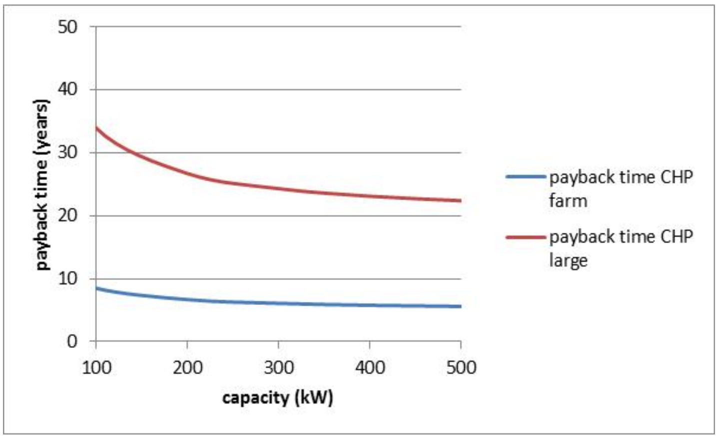

Figure 23. Pay-back time and actual capacity for small and large biogas installations

Survey results show that farmers who chose to invest under a relatively long recovery period are in general either fairly young or have a successor. Moreover, arable as well as livestock farmers have invested in biogas installations, even if they resp. do not have livestock or produce crops themselves. Obviously, their installations receive inputs from farms in the neighbourhood.

3.4.2 Competing price levels for RE activities

In this section we investigate what the price of renewable energy need to be to make it an economically feasible activity. What feed-in prices are needed to make it happen? For this first analysis the cost levels of different RE activities are estimated and then it is discussed to which extent these can be compensated for by present price levels. This will be discussed per type of RE activity, starting with biogas.

Biogas

In the case of biogas, the impact of the maize or straw price was simulated with FSSIM. It was assumed that not all farmers would invest in a biogas installation given the high investment costs. Farmers that invest would buy feedstocks (maize, straw, manure, and other farm products) from farmers nearby. Simulations were made in order to assess at which price feedstock supply would be assured. The level of the farm gate price was raised stepwise for silage maize and straw. An increase in the silage maize price will lead farmers to increase silage maize area.

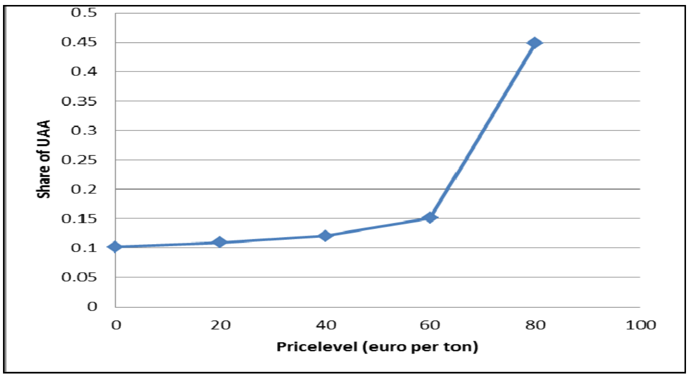

Figure 24 Increases in share of farm area under silage maize on farm in Saarland following an increase of farm gate prices (euro per ton)

Different farm gate maize price changes were simulated for farm types located in Brandenburg, Saarland, and Northern Upper Austria, while price changes were simulated for straw on alternative farm types located in Soria. Results for a large arable farm in Saarland are presented here as an example (Figure 24). A stepwise increase of the farm gate maize price by 20, 40, 60 or 80 Euro per ton will lead to an increase of silage maize area on this farm from 10 to 45%. Largest changes occur only after the farm gate price is exceeding the baseline price plus 60 Euro. However, when comparing results between different farms in different regions, the results show (Table 22) that farmers' response to increased price levels start at very different levels per region. In Upper Austria the response is already observable at small deviations from the price level of 13 Euro per ton. The present market price of fodder maize is quite variable per year and per region. A preliminary analysis suggests that large increases in the production of energy maize are more likely to take place in Upper-Austria and Brandenburg rather than in Saarland.

Table 22. Capacity of biogas installation for ten farmers per farm type, based on their investment capacities and their crop production.

NUTS region	*optimal price level – max. acreage of crop (€/ton)*	*farm type speciali sation*	*crop*	*yield (ton/ ha)*	*area at opti- mal price level (ha)*	*max. available for biogas (ton)*	*capacity (MJ)*	*capacity ten farmers (MJ)*	*ten farmers' average invest- ment capacity (from survey; €)*	*capacity by investment ten farmers (from relationship Figure 22; kWh)*
Branden-burg	40	Arable/ Cereal	energy maize	25.7	59.9	1540.9	7507049	75070493	14426000	129
Branden-burg	40	Arable/ Fallow	energy maize	25.7	118.3	3043.6	14828428	148284281	-	0
Branden-burg	20	Dairy cattle/ Others	energy maize	25.7	90.7	2334.6	11374303	113743031	1845000	14
Branden-burg	40	Arable/ Cereal	energy maize	25.7	77.9	2004.5	9766045	97660447	14426000	129
Upper Austria	13	Dairy cattle/ Perm. grass	energy maize	9.0	0.0	0.4	1929	19293	772190	4
Upper Austria	13	Arable/ Cereal	energy maize	9.0	9.2	82.8	403221	4032210	305780	0
Upper Austria	13	Dairy cattle/ Perm. grass	energy maize	9.0	0.0	0.4	1709	17089	772190	4
Upper Austria	13	Arable/ Cereal	energy maize	9.0	9.5	85.7	417294	4172940	305780	0
Saarland	80	Dairy cattle/ Perm. grass	energy maize	26.2	56.3	1473.8	7180342	71803424	2331580	18
Saarland	80	Dairy cattle/ Perm. grass	energy maize	26.2	62.0	1623.2	7908362	79083620	2331580	18
Saarland	80	Dairy cattle/ Others	energy maize	26.2	61.7	1616.8	7876922	78769224	-	0
Soria	250	Arable/ Fallow	wheat straw	4.4	21.1	36.6	99168	991680	2795370	22
Soria	250	Arable/ Cereal	wheat straw	4.4	59.5	103.5	280119	2801187	484140	1
Soria	100	Arable/ Fallow	wheat straw	4.4	4.2	7.3	19745	197451	2795370	22
Soria	180	Arable/ Fallow	wheat straw	4.4	20.2	35.1	94977	949775	2795370	22

For dairy farms in Brandenburg and Saarland (Table 22), increases in maize price have an impact on the feeding strategy on farms, although this differs between the regions. At increased prices for maize, the farms start to use more protein-rich feed stock bought from elsewhere on the farm and start to sell more of the maize. This effect is large in Brandenburg, and only marginal in Saarland, as in Saarland the dairy farms are growing a quite diverse range of crops on their farm and the increase in the maize area goes at the expense of area for other non-feed crops (i.e. rye, barley, triticale and grassland), instead of competing with use of maize for fodder. On the Brandenburg dairy farm (Table 22) the use of feed rich in protein increases from 32 tonnes to 64 tonnes with a price increase between 20 to 40 euro per ton for maize.

Perennial biomass crops

Perennial biomass cropping is already adopted by Austrian (Northern Upper Austria), German (Brandenburg and Saarland), and Polish (Warminsko-Mazurskie and Mazowieckie) farmers as became clear from the survey. It were especially the Polish farmers who invested most and solely in this RE-type. From a study on biomass cost and supplies in the EU (Elbersen et al. 2011), yields (in tons dry matter/ha) and costs (in euro/ton dry matter) could be derived at NUTS 2 levels. The yields in ton dry matter/ha of dedicated perennial cropping can be converted into cash, taking the market price into account. This will determine the (annual) gross revenue for a farmer. Whether the net revenues (gross revenues minus costs) would make dedicated perennial cropping economically feasible (break-even yield) depends on the market price.

To identify which market price would make this an economically attractive activity, the impact of an introduction of a perennial biomass crop was simulated in FSSIM. As a perennial biomass crops, *Miscanthus* and willow was used. Different price levels of *Miscanthus* and willow were assumed, and the price at which *Miscanthus* and willow would be introduced in the cropping rotation in Brandenburg and Warminsko-Mazurskie could be identified. In most cases introduction occurred in the simulations at a price range between 75 and 90 euros, with maxima often at slightly higher price levels of 80 – 110 euros per tonne (see Table 23).

Table 23. Capacity of Miscanthus and willow per farm under optimal price levels. Lower heating values of 17 MJ/kg for Miscanthus and 20 MJ/kg for willow were used.

NUTS region	*optimal price level (max. acreage of crop; €/ton)*	*farm type specialisation*	*crop*	*yield (ton/ha)*	*area at optimal price level (ha)*	*maximum availability for perennial biomass (ton)*	*capacity (MJ)*
Brandenburg	90	Arable/Cereal	*Miscanthus*	28.1	70.8	1986.6	33,771,516
Brandenburg	80	Arable/Fallow	*Miscanthus*	28.1	262.4	7365.9	125,221,139
Brandenburg	90	Arable/Cereal	*Miscanthus*	28.1	93.3	2620.1	44,541,750
Warminsko-Mazurski	80	Arable/Cereal	*Miscanthus*	24.3	64.5	1567.3	26,644,662
Warminsko-Mazurski	0	Arable/Cereal	*Miscanthus*	24.3	0.0	0.0	0
Warminsko-Mazurski	80	Arable/Cereal	*Miscanthus*	24.3	3.5	84.5	1,435,846
Warminsko-Mazurski	0	Arable/Cereal	*Miscanthus*	24.3	0.0	0.0	0
Brandenburg	110	Arable/Cereal	willow	8.9	71.7	639.7	12,794,384
Brandenburg	110	Arable/Fallow	willow	8.9	2.6	23.2	463,551
Brandenburg	110	Arable/Cereal	willow	8.9	0.0	0.3	6009
Warminsko-Mazurski	100	Arable/Cereal	willow	10.0	184.5	1842.5	36,849,917
Warminsko-Mazurski	110	Arable/Cereal	willow	10.0	0.0	0.4	8,001
Warminsko-Mazurski	100	Arable/Cereal	willow	10.0	11.7	117.3	2,345,174
Warminsko-Mazurski	110	Arable/Cereal	willow	10.0	0.0	0.3	6,242

However, an attractive price for these perennial crops is not sufficient to stimulate this RE activity. Other studies have already shown that farmers also take other considerations into account when converting land to dedicated energy cropping (see Section 3.6.3 on constraints). A main reason to not shift to perennials is the long term conversion (average plantation has a lifetime of 15 to 20 years) which makes a farmer less flexible in responding to market developments. Furthermore, initial investment costs for setting up a perennial plantation also influence the farmer's decision.

Biomass from forestry on farms

Solid biomass from farm forestry activities can be used for electricity and heat generation. From a Dutch study on annual additional growth of forests (Spijker et al. 2007), the additional average growth figure of 1.02 tons of dry matter branch wood per ha of forest could be derived. When this average is converted from tons to kWh per ha, the (yearly) yields of farm forestry by-products can be calculated. Combined with the local energy price (euro/kWh) it gives the financial return. Gathering costs are estimated at 69 euro/ha, pre-treatment costs at about 13 euro/ton, and transportation costs up to about 30 km at 11 euro/ton.

Depending on the local energy price, the level of return is high enough to induce farmers to use their farm forestry by-products for energy. For farmers in Carinthia – a region identified as having opportunities to develop solid biomass – with forest on their farm, it was assessed at what electricity price this activity would become feasible. Results show that an energy price of about 0.02-0.04 euro/kWh at farm gate would make it an attractive activity for a farmer. These costs make up 10% of the final energy price which is presently at around 0.2 euro/kWh.

Biomass from citrus tree cuttings

Cuttings from citrus trees can be used for energy. According to a study reporting on citrus plantations (DiBlasi et al. 1997), biomass growth is 1.2 tons of dry matter branch wood per ha. When converted into kWh per ha, the (yearly) financial yields of citrus tree cuttings can be calculated, taking the local energy price (euro/kWh) into account. However, chipping and palletising of harvested branches from citrus plantations and transportation implies costs. Total chipping and palletising costs are estimated at 12.6 euro/ton and transportation costs up to about 30 km at 11 euro/ton.

Depending on the local energy price, farmers may or may not collect their prunings for energy purposes. For Valencia – where biomass from citrus tree cuttings may be attractive – an energy price of about 0.2 euro/kWh at factory gate would be needed to make using citrus tree cuttings for energy economically attractive. This is too high compared to present average EU prices for electricity which range between 0.1 to 0.25 euro/kWh as delivered from an energy plant. To conclude, collecting cuttings from citrus plantations is not an attractive RE activity unless significant support is provided.

Nowadays, the cuttings are incorporated into the soil, as they provide organic matter and reduce fertilisation needs. The incorporation of cuttings into the soil is compulsory for those farmers that wish to receive subventions from Spanish Royal Law (RD 4/2001) on organic farming methodologies. This may further reduce the attractiveness of using prunings for energy.

3.4.3 Simulated land use changes caused by maximising silage maize area for biogas and by maximising dedicated perennial cropping and stimulation of rape seed cropping

Considering biogas, FSSIM results show that an increase of maize area due to increasing feed-in tariffs would occur mainly at the expense of other cereal crops. Maximising the maize area would go at the expense of permanent grassland on dairy farms in Saarland. This is not the case in Upper Austria. Although the conversion of permanent grassland is discouraged by Cross Compliance policy (see Annex III of Council Regulation (EC) No 73/2009) and the protection of permanent grassland is a compulsory standard under the GAEC issue 'Minimal level of maintenance', the implementation of this measure at national and regional level still allows a loss (or gain) of 10% of 'permanent pastures' at national or regional level. This is why in this study the impacts on permanent grasslands of RE developments were included in the farming impact assessment with FSSIM.

Evidence of large changes in permanent grassland areas, in spite of Cross Compliance policy, were given for Germany by Lind et al. (2009) who showed that regional thresholds in loss of permanent grassland under the cross compliance policy in the period from 2003 to 2009, were already exceeded by five federal sates in Germany. A further in-debt study by NABU (2009) in three federal states showed that one of the drivers of permanent grassland loss was increased energy maize cultivation. In a study by King (2010) the protection of permanent grassland in the EU is further investigated. It concludes that 'semi-natural grasslands continue to decline, because there is no coherent and consistent approach to the regulatory and support framework that currently exists'. This regulatory framework includes the GAEC standard under the Cross Compliance policy.
However, it has to be borne in mind that these changes in land use would only occur in the rather hypothetical case that silage maize prices increase drastically beyond the baseline price assumption (see Figure 24 above) which already includes the implementation of the Renewable Energy Directive.

Maximising *Miscanthus* and willow area in Warminsko-Mazurskie would replace cereal crops, such as barley and rye, but also less intensive categories like fallow and set-aside and permanent grassland, while competing less with maize and rape. This is visualised by the stacked column diagram of Figure 25, which is exemplary for the FSSIM results of changing farm gate prices for willow on arable farms. In this case, willow acreages are highest at a farm gate price of 100 euros per tonne.

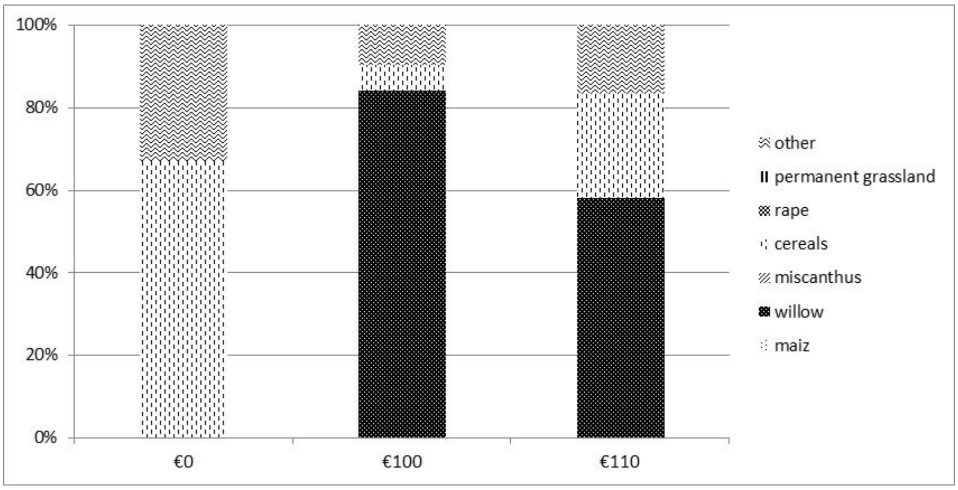

Figure 25 Stacked column diagram showing results of farm based analysis of changing willow prices on arable farm type 61201114 in Warminsko-Mazurskie.

Rape seed would replace maize and *Miscanthus*, while there is also room for cereals at higher price levels of rape. This is visualised by the stacked column diagram of Figure 26, which is exemplary for the FSSIM results of changing farm gate prices for rape on arable farms. In this case, rape acreages start to grow as from 400 Euros per tonne. Below that price from a purely economic point of view *Miscanthus* production seems to provide a larger gross margin to a farmer.

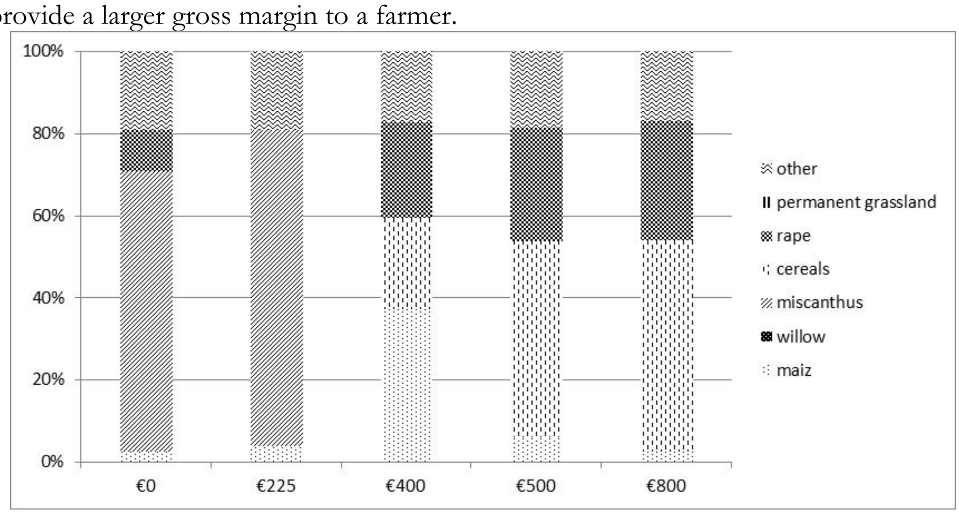

Figure 26. Stacked column diagram showing results of farm based analysis of changing rape prices on arable farm type 53201115 in Mazowieckie.

Table 24. Capacity of rape seed for a farm type in Mazowieckie under optimal price levels. Lower heating values of 17 MJ/kg for rape seed were used.

NUTS region	optimal price level (max. acreage of crop; €)	farm type specialisation	crop	yield (ton/ha)	area (ha) at optimal price level	maximum availability for perennial biomass (ton)	capacity (MJ)
Mazowieckie	800	Arable/Cereal	rape	2.8	80.2	224.5	3,816,180

Table 24 shows the price level of 800 Euro/ton rapeseed which is the price at which the response of the farmer is maximum in terms of rape seed acreages. These acreages, combined with the (expected) average regional yields, provide the maximum availability (in tons) of rape seed for biodiesel. The results make us conclude that limited potential for increased rape seed production for biodiesel can be expected for this farm type region combination as expected market prices in 2020, as modelled by CAPRI for the baseline scenario in 2020, only amount to 399 Euro per ton in this region.

3.4.4 Simulated income effects of RE activities

Changes from current acreages of RE crops to maximum acreages under optimal prices as indicated in the previous paragraph will have implications for farm family incomes. FSSIM calculates these changes in farm family income. Results show that an increase of maize area due to increasing feed-in tariffs would lead to a slight increase in farm income through the price guarantee (Table 25). Introducing willow will lead to a fair increase in income in Brandenburg as well as in Warminsko-Mazurskie. This increase is considerably higher than when farmers in Brandenburg and Warminsko-Mazurskie would introduce *Miscanthus* on their farms. However, these income effects are only due to changes in acreages. Costs for installation, operation, transportation, etc. are not taken into consideration here.

3.4.5 Simulated employment effects of biogas, dedicated perennial cropping and rape seed cropping

Changes from current acreages of RE crops to maximum acreages under optimal prices as indicated in the previous paragraph would also have implications for labour use on farms. FSSIM calculates these hypothetical changes in farm employment. Results show that an increase of maize area due to increasing feed-in tariffs would lead to a slight increase in labour use through the price guarantee (Table 26). Especially in Warminsko-Mazurskie, labour inputs would rise due to the introduction of willow on farms. Increasing the price for rape would lead to a large increase in labour input, although one can doubt whether this will ever happen as 800 Euro per ton will probably never be reached in normal market situations.

It is also surprising to see that perennial crops could create additional labour, but could also decline the number of working hours. The effect on labour is very much dependent on what type of crops are exchanged and this depends strongly on the farming type.

Whether the additional labour requirement or a decline in labour would be positive or negative depends strongly on the farm and regional circumstances. Firstly, additional labour demand can only be positive if there is also labour available. This depends on the labour situation on the farm, but also the season in which labour is especially required. In regions where lands are abandoned because of lack of labour availability, the introduction of crops with low labour requirement could bring in an opportunity to earn extra income and to maintain lands in productive conditions.

Table 25. Potential changes in farm family income from current feed-in tariffs to feed-in tariffs at which the acreages of the focal crops are maximum.

NUTS region	***farm type***	***RE type***	***crop***	***optimal price level (€/tonne)***	***change in farm family income (%)***	***change in farm family income (k€)***
Brandenburg	53201009	biogas	energy maize	40	3	0.64
Brandenburg	53202009	biogas	energy maize	40	8	1.50
Brandenburg	53208009	biogas	energy maize	no difference with current level	0	0
Brandenburg	63201009	biogas	energy maize	40	4	1.25
Brandenburg	53201009	perennial biomass	*Miscanthus*	90	1	0.21
Brandenburg	53202009	perennial biomass	*Miscanthus*	80	3	0.56
Brandenburg	63201009	perennial biomass	*Miscanthus*	90	9	2.81
Brandenburg	53201009	perennial biomass	willow	110	3	0.64
Brandenburg	53202009	perennial biomass	willow	110	52	9.75
Brandenburg	63201009	perennial biomass	willow	110	31	9.67
Mazowieckie	53201115	seed oil	rape	800	53	46.51
Upper Austria	52205911	biogas	energy maize	no difference with current level	0	0
Upper Austria	53201911	biogas	energy maize	no difference with current level	0	0
Upper Austria	62205911	biogas	energy maize	no difference with current level	0	0
Upper Austria	63201911	biogas	energy maize	no difference with current level	0	0
Saarland	53205008	biogas	energy maize	80	8	3.07
Saarland	63205008	biogas	energy maize	80	8	4.14
Saarland	63208008	biogas	energy maize	80	12	5.02
Warminsko-Mazurskie	53101114	perennial biomass	*Miscanthus*	80	46	15.29
Warminsko-Mazurskie	53201114	perennial biomass	*Miscanthus*	no difference with current level	0	0
Warminsko-Mazurskie	61201114	perennial biomass	*Miscanthus*	80	43	2.15
Warminsko-Mazurskie	63201114	perennial biomass	*Miscanthus*	no difference with current level	0	0
Warminsko-Mazurskie	53101114	perennial biomass	willow	100	35	11.63
Warminsko-Mazurskie	53201114	perennial biomass	willow	110	59	40.09
Warminsko-Mazurskie	61201114	perennial biomass	willow	100	31	1.55
Warminsko-Mazurskie	63201114	perennial biomass	willow	110	57	32.96

Table 26. Simulated changes in farm labour use from current feed-in tariffs to feed-in tariffs at which the acreages of the focal crops are maximum.

NUTS region	***farm type***	***RE type***	***crop***	***optimal price level (€/tonne)***	***change in labour use (%)***	***change in labour use (hours)***
Brandenburg	53201009	biogas	energy maize	40	3	311
Brandenburg	53202009	biogas	energy maize	40	8	2121
Brandenburg	53208009	biogas	energy maize	no difference with current level	0	0
Brandenburg	63201009	biogas	energy maize	40	3	351
Brandenburg	53201009	perennial biomass	*Miscanthus*	90	3	311
Brandenburg	53202009	perennial biomass	*Miscanthus*	80	8	2121
Brandenburg	63201009	perennial biomass	*Miscanthus*	90	-2	-234
Brandenburg	53201009	perennial biomass	willow	110	31	3211
Brandenburg	53202009	perennial biomass	willow	110	-11	-2916
Brandenburg	63201009	perennial biomass	willow	110	-5	-586
Mazowieckie	53201115	seed oil	rape	800	46	8988
Upper Austria	52205911	biogas	energy maize	no difference with current level	0	0
Upper Austria	53201911	biogas	energy maize	no difference with current level	0	0
Upper Austria	62205911	biogas	energy maize	no difference with current level	0	0
Upper Austria	63201911	biogas	energy maize	no difference with current level	0	0
Saarland	53205008	biogas	energy maize	80	5	235
Saarland	63205008	biogas	energy maize	80	6	312
Saarland	63208008	biogas	energy maize	80	4	189
Warminsko-Mazurskie	53101114	perennial biomass	*Miscanthus*	80	-18	-1357
Warminsko-Mazurskie	53201114	perennial biomass	*Miscanthus*	no difference with current level	0	0
Warminsko-Mazurskie	61201114	perennial biomass	*Miscanthus*	80	-17	-600
Warminsko-Mazurskie	63201114	perennial biomass	*Miscanthus*	no difference with current level	0	0
Warminsko-Mazurskie	53101114	perennial biomass	willow	100	23	1734
Warminsko-Mazurskie	53201114	perennial biomass	willow	110	2	282
Warminsko-Mazurskie	61201114	perennial biomass	willow	100	26	918
Warminsko-Mazurskie	63201114	perennial biomass	willow	110	2	323

3.4.6 Simulated effects of RE activities on GHG emissions and nitrogen leaching

In the farm based simulations with FSSIM, the effect of maximising RE activities compared to the baseline situation can be calculated for a selection of environmental effects (i.e. nitrogen use, nitrogen leaching, GHG emissions and GHG savings).

Impact of the maize area increases are depicted in Figure 27 (A. farm GHG emissions due to crop production; B. other impacts and C. GHG emissions and savings). Following a four-fold increase of silage maize area coverage, crop related GHG emissions would be doubled (Figure 27B).

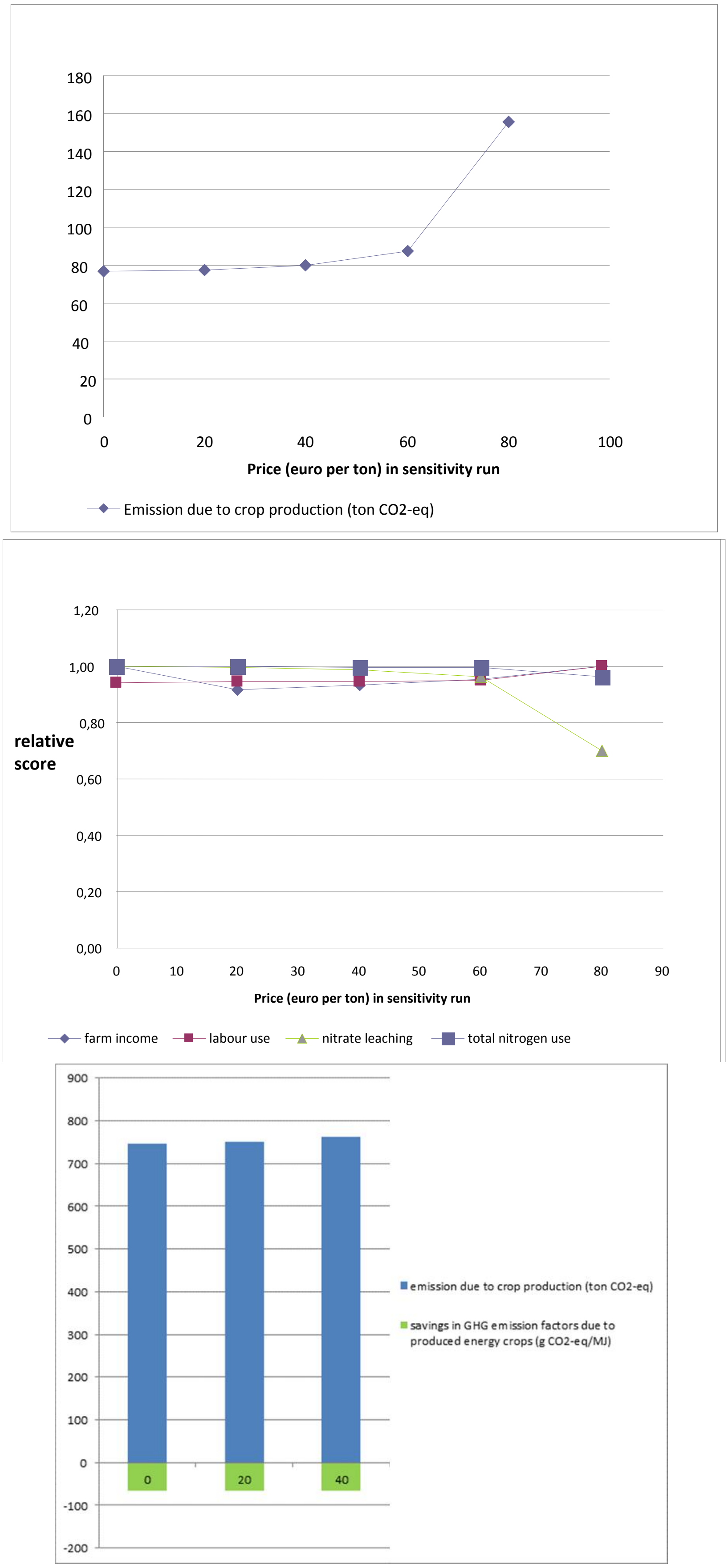

Figure 27 A (top): Total GHG emissions due to cropping under different crop prices, B (centre): Combined socio-economic and nitrate leaching effects; C (bottom): GHG emission from cropping and savings in GHG emissions due to energy crops.

Farm income, labour use and nitrogen use would not be affected much (Figure 27C) as the values for silage maize are similar to those of the crop that is replaced (mostly wheat), but nitrogen leaching would be reduced with one third during the last step (raising the maize price from 60 to 80 Euro per ton).

However, whether changes in GHG savings and nitrate leaching would be positive or negative depends largely on the type of activities replaced by RE activities. In some cases (farms in Warminsko and Brandenburg) an increase in nitrogen leaching would occur, as fallow or grassland based activities would be replaced with perennial biomass crops, leading to a higher nitrogen use and thus leaching.

Table 27 gives an overview for the effects on change in farm GHG savings of different farm types in different regions, where the maximum positive or negative change is indicated with the highest possible introduction of RE activities in terms of acreage as compared to the baseline situation. In this hypothetical case, large changes could sometimes be observed, e.g. in the case of rape in Mazowieckie as the maximum acreage of RE activities is shown, so the extreme situation of large scale RE introduction.

Table 27. Simulated environmental effects at farm level of an increased acreage of energy crops, calculated at the maximum acreage of those crops on the farms. As the maximum acreage is shown (at different farm gate prices for different farms), the changes in environmental effects can be large. At lower prices, less significant changes would be simulated.

NUTS region	***farm type***	***RE type***	***crop***	***optimal price level (€/tonne)***	***change in farm GHG savings (%)[1]***
Brandenburg	53201009	Biogas	energy maize	40	0
Brandenburg	53202009	Biogas	energy maize	40	0
Brandenburg	53208009	Biogas	energy maize	no difference with current level	0
Brandenburg	63201009	Biogas	energy maize	40	0
Brandenburg	53201009	perennial biomass	*Miscanthus*	90	10
Brandenburg	53201009	perennial biomass	willow	110	7
Brandenburg	53202009	perennial biomass	willow	110	7
Brandenburg	63201009	perennial biomass	willow	110	7
Mazowieckie	53201115	Rape	rape	800	24
Upper Austria	52205911	Biogas	energy maize	no difference with current level	0
Upper Austria	53201911	Biogas	energy maize	no difference with current level	0
Upper Austria	62205911	Biogas	energy maize	no difference with current level	0
Upper Austria	63201911	Biogas	energy maize	no difference with current level	0
Saarland	53205008	Biogas	energy maize	80	0
Saarland	63205008	Biogas	energy maize	80	0
Saarland	63208008	Biogas	energy maize	80	0
Warminsko-Mazurskie	53101114	perennial biomass	*Miscanthus*	80	4
Warminsko-Mazurskie	53201114	perennial biomass	*Miscanthus*	no difference with current level	0
Warminsko-Mazurskie	61201114	perennial biomass	*Miscanthus*	80	4
Warminsko-Mazurskie	63201114	perennial biomass	*Miscanthus*	no difference with current level	0
Warminsko-Mazurskie	53101114	perennial biomass	willow	100	3
Warminsko-Mazurskie	53201114	perennial biomass	willow	110	3
Warminsko-Mazurskie	61201114	perennial biomass	willow	100	3
Warminsko-Mazurskie	63201114	perennial biomass	willow	110	3

[1] *a negative number for GHG savings implies reduced GHG savings while a positive number implies an increase in GHG savings.*

From the changes in acreages of the various crops, as well as from changes in livestock, simulated effects on greenhouse gas emissions have been calculated, based on inputs (fertiliser and pesticide production, seeding material, soil N2O emissions) and cultivation operations (diesel use). These emissions due to cropping and livestock farming are contrasted with the emissions saved due to RE application from on-farm RE cropping (Table 27) and are calculated according to the same methodology that was used in Chapter 0 to assess the GHG balance. The results show that maize based biogas applications would have no effect on the emission savings while for perennials there would be generally an increase in savings.

3.5 Interpretation of survey and modelling results

3.5.1 Consequences of RE for Rural Development

The survey outcome can also be used to study the relationship between RE and rural development. Although the questionnaire was not designed specifically to obtain insight in rural development in the case study regions, the outcome of some questions (average level of investment, return on investment and impact on farm income) can be used to determine differences between dynamic and less dynamic regions with respect to RE investments and its impacts.

The average amount of money spent on the RE investment was ranging between €36,840 for Warminsko-Mazurskie and €1,095,323 for Brandenburg (Table 28). In most countries, farmers in the more dynamic region invested more in RE than farmers in the low dynamic region (generally two to three times as much). Differences may be explained by higher investment capacity caused by larger and more profitable farms in more dynamic regions plus the dominant type of RE found in a given region (Saarland is not very suited for – large scale - wind turbines while Brandenburg is considered as one of the more favourable wind regions in Germany). Exception is (less dynamic) Valencia, where the average invested amount (nearly one million Euro) is about three times as high as the average investment reported for (more dynamic) Soria. In contrast to the fact that farmers in less dynamic regions tend to spend less on RE investments, their satisfaction on the returns in Germany and Spain tends to be higher. This can be explained by the fact that the income and employment effects appears to be stronger in weaker regions[16]. Exceptions are Poland and Northern Upper Austria, where RE investors are showing a remarkable 97% satisfaction rate.

Table 28. RE investments and satisfaction on returns in dynamic and less dynamic regions

NUTS region	***Dynamic or Less Dynamic***	***Average RE investment (Euro)***	***ratio Dynamic / Less dynamic***	***Amount invested / average farm income[17]***	***ratio Dynamic / Less dynamic***	***Satisfaction on return on investment***
Saarland	Less dynamic	339,043		17		93%
Brandenburg	Dynamic	1,095,323	3.2	34	2.0	91%
Warminsko-Mazurskie	Less dynamic	36,840		15		81%
Mazowieckie	Dynamic	76,650	2.1	8	0.5	51%
Valencia	Less dynamic	995,286[1]		50		81%
Soria	Dynamic	305,224	0.3	15	0.3	33%
Carinthia	Less dynamic	175,697		9		72%
Northern Upper Austria	Dynamic	339,043	1.9	17	1.9	97%

[1] average for Valencia mostly determined by one farm investing 3 mln € in PV.

[16] Data not shown here. The difference is, however, not significant.

[17] Average farm income 2005-2007, expressed as Farm net value added (FNVA) per Average Work Unit. Source: Farm Economics Overview (FADN, 2007 DATA). Directorate-General For Agriculture And Rural Development, 2010.

Regional satisfaction figures are partly explained by dominant RE types in the different case regions. Highest satisfaction on investment returns have been observed for PV (76% satisfaction, most frequently found in Germany and Upper Austria), solar thermal (73%, mostly reported in Carinthia), biomass (72%, most frequently reported in Austria), and wind (61%, evenly distributed). Farmers are less happy with returns on heat pipeline (42%) and biogas (37%). Extremely high satisfaction figure for Valencia is easily explained by the fact that in this region only PV investments have been reported.

Farmers in Austria, Poland and Valencia clearly indicated that RE production leads to a higher total farm income, but there is no clear difference in this respect between less and more dynamic regions. The most frequent number of income contributions are reported for wind, PV, solar thermal, biomass and solid biomass investments (Table 29).

Also other questions in the questionnaire can be used as indicators for rural development, for instance the statement on the employment for the own farm. Only the farmers who invested in biogas mentioned that jobs are created for family, partners or employees (Annex IV: Table 121). For all other RE investments the farmers stated that no jobs were created. With the results of the questionnaire it was not possible to measure employment effects outside the farm.

Another question included statements about regional developments. These statements are filled-in by both farmers who invested in RE and farmers without RE investments. The results are summarised per case study region (Table 29). Overall, the farmers indicated that there was an observable change due to RE in the region, which was especially true for both German regions, and the less dynamic regions Carinthia and Warminsko-Mazurskie. In Soria, the farmers who have invested in RE observe a change due to RE, but the farmers without RE investments did not observe that change. Overall, the farmers had no clear opinion about the other statements (answer: neither agree nor disagree). In some regions, however, the farmers had more outspoken opinions. For instance, the farmers in Austria are positive about the effect of RE on the region, and in Germany the farmers mentioned that the economic situation of farming is improving due to RE. In Spain, however, the farmers were negative about effects of RE on rural development, they mentioned for instance that the economic situation of farming is not improving due to RE, presumably because of insufficient added value of RE.

Table 29 Overview of the opinion of farmers about consequences of RE investments

Question	***Case study region***								
	Saarland (n=101)	*Brand (n=100)*	*Carinthia (n=66)*	*Upp A (n=103)*	*Warm (n=98)*	*Maz (n=134)*	*Valencia (n=100)*	*Soria (n=100)*	*All*
There is an observable change due to RE in my region	+	+	+		+			+-[1]	+
Farm land rents and farm land prices have increased due to RE	+	+					-	-	
Costs of fodder for livestock have increased due to RE, animal raising farmers complain		+		-				-	
Market prices for agricultural products have improved due to RE			-	+			-	-	
Enterprises in my region which use inputs from agriculture or forestry find it increasingly difficult to source their feedstocks and to compete with energy use.		+	+						
Economic prospect and quality of life is improving in my area			+	+			-	-	
Overall economic situation of farming is improving due to RE	+	+	+	+			-	-	
RE accelerates modernisation and innovation in my area		+	+	+			-	-	
RE improves acceptance of farming			+	+					

[1]There was a significantly different answer for farmers who had invested in RE (agreed with the statement (+)), and the farmers without RE investments (disagreed with the statement (-)).
Upp A=Upper Austria, Brand=Brandenburg, Warm=Warminsko-Mazurskie, Maz=Mazowieckie.
A plus-sign means that the farmers agreed with the statement, a minus-sign means that the farmers disagreed with the statement, and an empty cell means that the farmers did not give a clear opinion about the statement (agree nor disagree).

From the results of the questionnaire it can be concluded that no clear differences are found in rural developments between the dynamic and less dynamic regions.

3.5.2 Impacts on regional level

For all 20 farm types that were simulated with FSSIM, changes in income and labour input were assessed for various crop price levels. From the SEAMLESS database, current data on farm family income and labour inputs were derived, so that the incomes and labour inputs at the price levels at which the acreages of the focal crops would be maximum could be compared to the current values. The percentages of change in incomes and labour inputs per farm could be converted to changes at regional level by taking the number of farms of the specific farm type in the region into account. Table 30 and Table 31 show the simulated changes in income and labour use respectively, from current farm gate prices to prices at which the acreages of the focal crops are at their maximum. Potential changes per farm can be summed to get insight into regional consequences.

Table 30 Simulated changes in income from current farm gate prices to prices at which the acreages of the target crops are maximum.

NUTS region	*RE type*	*crop*	*optimal price level (maximum acreage of crop; €)*	*increase in income (mln €) - region*	*increase in income (%) - region*
Brandenburg	biogas	energy maize	various	0.91	1.00
Saarland	biogas	energy maize	80	1.02	7.12
Soria	biogas	soft winter wheat	various	20.50	0.52
Brandenburg	perennial biomass	*Miscanthus*	various	1.06	1.17
Warminsko-Mazurskie	perennial biomass	*Miscanthus*	various	35.56	2.22
Brandenburg	perennial biomass	willow	110	5.53	6.10
Warminsko-Mazurskie	perennial biomass	willow	various	80.59	5.04

The largest contribution of RE activities to the regional farm income would be expected in case of maximisation of biogas production based on silage maize in Saarland and from willow production in both Warminsko-Mazurskie and Brandenburg. However, these are theoretical examples as price levels at which a maximum response can be expected are not likely to be similar to real market prices in order to make such a response competitive, unless important bonus payments are added to the market price.

The effects on labour increase were also assessed by up-scaling to the full farming population. The results are shown in Table 31.

Table 31 Simulated changes in labour use from current farm gate prices to prices at which the acreages of the target crops are maximum.

NUTS region	*farm type*	*RE type*	*crop*	*optimal price level (maximum acreage of crop; €)*	*increase in labour input (mln h) - region*	*increase in labour input (%) - region*
Brandenburg	all simulated farm types	biogas	energy maize	various	0.70	1.47
Saarland	all simulated farm types	biogas	energy maize	80	0.07	4.11
Soria	all simulated farm types	biogas	soft winter wheat	various	-5.41	-1.03
Brandenburg	all simulated farm types	perennial biomass	*Miscanthus*	various	0.52	1.09
Warminsko-Mazurskie	all simulated farm types	perennial biomass	*Miscanthus*	various	-8.15	-1.26
Brandenburg	all simulated farm types	perennial biomass	willow	110	-0.09	-0.18
Warminsko-Mazurskie	all simulated farm types	perennial biomass	willow	various	12.71	1.97

The results show that maximised biogas production based on maize would have the potential to create the largest increase in additional labour in a region as is confirmed by the figures for Saarland and to a lesser extent for Brandenburg. That additional RE activity through perennials cropping could also lead to a decline is calculated in Brandenburg and Warminsko-Mazurskie. This is to be explained by the fact that perennials are being exchanged in these region-farm type combinations for more labour intensive crops.

In Saarland, increasing the farm gate prices for silage maize from 20 to 80 €/ton would lead to a fair increase in income and a significant increase in employment for the region as a whole. In Brandenburg and Warminsko-Mazurskie, the introduction of willow for perennial biomass production would especially increase the farm and regional income. For the 20 farm types simulated with FSSIM, the share of the farms' areas in the regional utilised agricultural area is known. Hence, implications of changes in acreages of RE crops on the farms could be calculated for the regions as a whole. Table 32 shows the results.

Table 32 Implications of changes in acreages of RE crops at regional level for the price levels at which the acreages of the RE focal crops would be maximum.

				share of regional UAA optimal price level (%)							
NUTS region	**RE type**	**crop**	**optimal price level (max. acreage of crop; €)**	**maize**	**willow**	**Miscanthus**	**cereals**	**rape**	**permanent grassland**	**other**	**total cropped area**
Brandenburg	biogas	energy maize	40	1	0	0	5	1	0	1	8
Saarland	biogas	energy maize	40	2	0	0	6	1	0	1	10
Soria	biogas	energy maize	40	3	0	0	2	5	0	6	16
Brandenburg	biogas	energy maize	no difference with current level								
Warminsko-Mazurskie	perennial biomass	*Miscanthus*	90	1	0	1	4	1	0	1	8
Brandenburg	perennial biomass	*Miscanthus*	90	1	0	2	5	1	0	1	10
Warminsko-Mazurskie	perennial biomass	*Miscanthus*	80	3	0	5	2	3	0	3	16

Especially for Saarland, remarkable changes in maize area could be expected if farm gate prices for energy maize change from 20 to 80 €/ton. The three farm types in Saarland that were simulated with FSSIM together constitute 77% of Saarland's utilised agricultural area. Their responses would lead to an increase of the maize area in Saarland with 23% (attaining a coverage of 34% of the region's utilised agricultural area). This would go mainly at the expense of permanent grassland.

Due to e.g. differences in crop mix and biophysical circumstances, the price levels at which the acreages of the focal crops would be maximum vary over the farm types and regions. In Brandenburg, the price levels at which the acreages of energy maize would be maximum are assessed at 40 €/ton, while for Saarland, these farm gate prices would be 80 €/ton; in Northern Upper Austria changing prices at levels close to the baseline already lead to a change in areas of energy maize. From the FSSIM results it is difficult to say whether less dynamic regions would require higher or lower farm gate prices than dynamic regions

3.5.3 Interpretation of results of farm impacts

The results in previous sections demonstrate the complex interplay in which RE could impact on farms and the wide range of possible impacts of RE dependent on type of RE, region, farm type and indicators considered (i.e. investment costs, capacity, income, labour, GHG emissions, nitrogen leaching, land use changes). There are large differences between farm responses in different regions, and between different farm types in one region, which is dependent on the regional biophysical possibilities and current cropping and livestock activities present at the farm. For example, an extensive cereal based large scale farm in Brandenburg responds differently to the same price for energy maize than a dairy farm in Saarland. Our analysis manages to capture these region and farm specific responses through the use of regionally different data sets and differentiation of options per region, as based on the questionnaire and the data underlying the farm simulations and description of activities. Projections are lacking for the prices of perennial biomass crops across regions, making it difficult to estimate what are plausible levels of these crops in the future and how likely their introduction is.

- With respect to simulated ***land use changes*** (Table 23), maximising land based RE activities may come at the expense of cereals and in some cases permanent grasslands (in a dairy region like Saarland) [18]. As the projected prices generally fall short of expected prices for large scale land use changes, such changes seem not very likely towards 2020.
- With respect to simulated ***income effects*** (Table 25), if farms are considered as a unit for producing inputs for biomass or biogas installations, without having the installations on each farm, the income effect is positive, with a small positive effect (1-10%) in German, Austrian and Spanish regions, and a large positive effect in Polish regions (Section 3.4.4).
- With respect to simulated ***environmental effects*** (Table 27), in case of higher prices for silage maize, the maize area would increase at the expense of cereal crops and (permanent) grasslands. As maize is a slightly more intensive crop with higher nitrogen inputs, this would lead to negative environmental impact for nitrogen, and in case of conversion of permanent grasslands also erosion and loss of soil carbon (Section 3.4.6). Energy maize is a suitable crop (i.e. high energy content and biomass yield) for energy production and could provide an easy option for farmers, but with its negative environmental effects an increasing acreage might not be desirable. The production of energy from by-products (i.e. manure, citrus cuttings, straw) or perennial biomass crops is then preferably. In the case of by-products, their production makes existing farm activities more profitable, as usually disposed of products are used, leading to an additional income and requiring some additional labour. Provision of additional labour could be an obstacle, if labour availability is limited on the regional scale. One aspect not considered in this study is the long-term soil fertility, if by products like straw, citrus cuttings and manure are used for energy production instead of used on field. Especially manure, and to a lesser extent straw and citrus cuttings bring nutrients and carbon to the soil, improving the soil carbon stocks and nutrient availability. If such by-products are no longer used on or left on soils, a loss of soil carbon stocks and nutrient availability could occur, effectively leading to carbon loss from the soil. Therefore, the return of residual materials from biogas and biomass installations is important to ensure the carbon and nutrient supply to the soil.
- With respect to simulated ***employment effects*** (Table 26) of maximising on-farm RE activities, the results of our analysis generally show a positive labour effect, implying that more labour is required on the farm. These effects would be most pronounced on the Polish farms, with large increases in labour required on farm, due to changes to RE activities. The effects would be smaller, and still mostly positive for other regions. For some farm types, reductions are calculated due to changes in the cropping pattern, moving away from more intensive crops towards less intensive RE activities, if these are profitable enough (Section 3.4.6).

The different types of RE effect the farm differently. Wind and PV are relatively straightforward, requiring an upfront investment and not effecting the farm operation (i.e. choice of crops, management of crops) to a considerable extent. Some PV installations, especially large scale, could be placed on land suitable for cropping, but this is most likely only a small share of the farm area. These RE types are highly dependent on the expected future energy price, and connected to this the risk farms run on their investment, if energy prices would fall to too low levels. Feed-in tariffs for these type of RE will support their uptake, but could be costly.

[18] Permanent grassland is protected against conversion in the Cross Compliance policy (see Annex III of Council Regulation (EC) No 73/2009). The protection of permanent grassland is a compulsory standard under the GAEC issue 'Minimal level of maintenance'. However, the implementation of this measure at national and regional level still allows a loss (or gain) of 10% of 'permanent pastures' at national or regional level. This is why in this study the impacts on permanent grasslands of RE developments were included in the farming impact assessment with FSSIM.

Biogas and biomass as RE types affect the farm more profoundly, by altering the choice of crops or animals, and in case of biogas, requiring large on farm installations with high investment costs, in at least a subset of the farms producing manure or crops for biogas installations. In the results presented in this section, the focus was on understanding likely changes to occur on the farm level, in case of favourable prices for different RE crops. With high energy price (i.e. electricity, diesel), prices for primary products (i.e. straw, maize, manure, rape seed, willow, *Miscanthus*) will also be high, due to an increased demand.

3.6 Barriers and opportunities

3.6.1 Introduction

In this section an overview is given of the main opportunities of RE development at farm and regional level and the main barriers for RE development. The overview of opportunities is mainly derived from the survey results and the outcome of the farm level modelling. The barriers for RE development were derived from the survey results, a literature review on barriers. All these results are integrated and presented in an integrative manner in which comparisons are made between the case regions and also against the observations derived from the literature review.

3.6.2 Opportunities of RE on farms

RE activities on farms may provide opportunities for farmers. Main opportunities listed by farmers (see Table 33) include long term energy supply at fixed cost levels and the provision of an extra source of stable income and generally a higher farm income. That these opportunities are important is confirmed by the large number of farmers in practically all case regions indicating that these three aspects are among the main reasons to involve in RE activities. The first opportunity on long term energy supply for a stable price is seen as an important factor in the light of overall expectations on future energy price increases.

RE provides an opportunity to diversify income, while it is also considered a *stable* income source over a longer time-span, both elements being reported as reasons to invest. In all but the Mazowieckie region this is confirmed by the farmers that were asked to indicate the reasons that favoured their involvement in RE. Only in two of the regions favourable Returns on Investments are reported as an important reason to get involved in RE.

In the category of opportunities of lower importance are the fact that RE investments enable farmers to make more optimal use of the residues and wastes and that it creates more work on a farm. This first factor is only perceived to be an opportunity in 3 of the 8 case regions and refers to both the cost effectiveness but also to the environmentally friendly aspects of this issue. The latter can be seen as both an opportunity but also as a barrier as is discussed in the next section. An opportunity on farms where there is more family and/or hired workforce available. The larger average number of employees on farms with RE involvement in the Spanish, Brandenburg and Carinthia regions confirms that this is an opportunity. That RE activities create jobs is confirmed by the results of the survey and the additional farm level analysis in Brandenburg.

The next and final opportunity identified is based on the outcome of the GHG balance calculations of RE activities in the EU. It turns out that present RE activities already contribute significantly to GHG savings (86 Mton CO2-eq mainly in non-agricultural UNFCCC sectors, which is equivalent to 18% of GHG emissions in the UNFCCC sector Agriculture in 2008) and that this contribution may increase further towards 2020.. Although in the survey this aspect was not directly identified as an opportunity by farmers themselves, farmers generally did state that environmental concerns and the wish to contribute to a more environmentally friendly energy supply was an important reason to involve in RE (socially expected answers may play a role here though). The important contribution of RE to GHG mitigation in agriculture is clearly acknowledged as an important opportunity to farming in general.

Table 33 Overview of opportunities for farms coming from RE activities as distilled from the integration of results of the different analysis activities in this study.

	Confirmed to be important opportunity for farmers involved in RE in:								Source
	Brandenburg	*Saarland*	*N-Upper Austria*	*Carinthia*	*Mazowiecki*	*Warminsko-Mazurski*	*Valencia*	*Soria*	
More independent from rising energy costs: RE-activities provides (extra) (environmentally friendly) energy supply at long term stable price level	+	+	+	+	+	+	+		Survey
Diversifies/increases income at farm: Re-activities are extra opportunity for farmers to get additional and stable income source (guaranteed price) on farm for fixed period of time	+	+	+	+		+	+	+	Survey/FSSIM
Good/sufficient return on investments in RE				+					Survey/FSSIM
Leads to higher farm income	+	+			+	+	+	+	Survey/FSSIM
Re provides (income and/or cost reduction) opportunity for making more optimal use of residues and waste	+			+		+			Survey
RE accelerates modernisation and innovation/quality of life, overall economic situation in a region	+	+	+	+				+	Survey
Creates more work on the farm			+						Survey/FSSIM
Opportunity to contribute to environmentally friendly energy supply	+	+	+	+	+	+		+	
RE-development at farms contributes to reaching GHG mitigation targets in the farming sector									Survey/EU wide GHG assessment

A '+' sign means the farmers agree with the statement (median score of 1 or 2) on this opportunity being an important reason for involving in RE / an empty cell indicates that the farmers disagree or do not agree nor disagree with the opportunity being relevant for involving in RE.

The discussed factors can be seen as the main opportunities for farmers created by RE activities, but it became also clear that RE activities provide a positive contribution to the wider region and thus to rural development, especially through the contribution to a more stable, higher and diversified farm income and more jobs. In addition, farmers with RE involvement showed strong agreement on the positive contribution of RE activities to overall regional innovation, modernisation and economic growth potential and increases in quality of life. However, the farmers not being involved in RE were more indecisive on these positive regional contributions of RE.

3.6.3 Barriers for on-farm Renewable Energy

The farmers without RE investments (n=410) gave their opinion of the perceived barriers for RE investments on their farms (Table 34). The main barriers most often identified by farmers in most regions were the high investment costs, the low profitability, uncertainty about profitability, long and complicated procedure to get access to subsidies and/or a permit.

The survey confirmed that high investment costs and uncertainty on returns are also important barriers: It was noted that farmers with above average income and/or larger farms were overrepresented in the group of farmers with RE involvement in Austria, Poland (Mazowiecki) and Spain but not in Germany. A trend seen in all case study regions was that farms with RE have on average more land available.

Other barriers were also mentioned but only in specific regions confirming that clear differences occur. Overall it was seen that both in Poland and even more so in the two Spanish regions the number of statements confirmed to be barriers by the farmers was much higher and related to a wider range of issues. For instance, the farmers in Mazowieckie indicated that beside all barriers already summarised above the absence of the possibilities to sell the energy/biomass was a barrier. In Spain the absence of subsidies was an additional barrier to the other barriers already summed and in Soria the difficulty of getting loans for RE investments could be added to the list. In Austria the adaptation of the farm advisory services was mentioned as a large need, to improve response on opportunities for not obviously farm-related RE types such as windmills, PV and solar thermal installations.

Table 34 Overview of the barriers for RE investments on farms in the 8 case study regions

	Case study region								
	Saarland (n=35)	Brand (n=45)	Carintia (n=33)	Upper A (n=22)	Warm (n=49)	Mazo (n=83)	Valencia (n=93)	Soria (n=50)	All
The investment costs are too high	+	+	+	+	+	+	+	+	+
There are no possibilities to sell the energy / biomass (e.g. absence of a purchaser)	-	-				+			
The profitability is too low (e.g., long pay-back time)	+		+	+		+	+	+	+
There is no subsidy available/ subsidies that were available before are no longer available							+	+	+
The procedure to get a subsidy is difficult/too much bureaucracy	-				+	+	+	+	+
It is too costly or time consuming to get a permit		-			+		+	+	+
It is difficult to get permits for RE investment		-			+			+	
There is too much uncertainty about profitability of RE products			+		+	+	+	+	+
It is difficult to get loans for RE investment				-				+	
Reliability of RE technology is too low	-	-	-	-				+	

Upper A=Upper Austria, Brand=Brandenburg, Warm=Warminsko-Mazurskie, Mazo=Mazowieckie.
A '+' sign means the farmers agree with the statement (median score of 1 or 2), a '-' sign means that the farmers disagree with the statement (median score of 4 or 5), and an empty cell means that the farmers agree nor disagree with the statement (median score of 3).

3.6.4 Synthesis

Overall it is clear that there is not one main barrier determining all up-take of RE, but it is generally the combination and total number of different barriers that determines up-take. In this study it can certainly be concluded that the higher number of barriers perceived by farmers in both Spanish and Polish case regions is an explanation for the significantly lower number of farmers indicating to have interest in investing in RE in the future than is the case in the German and Austrian regions.

Lack of subsidy availability, or complicated processes to obtain a subsidy, were not necessarily seen as a barrier. RE development can profit from investment subsidies and/or feed-in tariffs that create long term security on sufficient returns on investments. This is in line with studies by Banks et al. (2007), Monteiro et al. (2011) and Wilkinson (2011) that conclude that the main drivers for RE development are financial incentives and, to a lesser extent, investment subsidies. Feed-in-Tariffs are in place in Germany and Austria while Spain has alternative stimulation measures. The survey indicates that farmers in Spain apparently are not well able to get access to subsidies.

The lack of investment subsidies and the complications with getting access to these, as particularly identified in Spain and Poland in this study, are also confirmed in other studies of McComick and Kaberger (2007), Banks et al. (2007), Nilsson et al. (2011) to be of relevance in more EU countries McCormick and Kaberger (2007) concluded for instance in a study in six EU member states that investment grants are critical for making bioenergy sufficiently competitive with fossil energy. But they also concluded that know-how and governmental administrative capacity are key barriers and this is not confirmed in this study. The farmers in Saarland, Brandenburg and Soria even mentioned that having no know-how is not a barrier at all. Finally, McCormick and Kaberger (2007) mentioned that the supply chain coordination is a key barrier, which include the lack of contracts with energy companies, and the availability of companies for purchasing, harvesting, refining and transporting of biomass. In the survey of this project, this issue was not discussed as such with the interviewed farmers, but what was indicated by some of the interviewed farmers in Mazowieckie as a barrier was lack of possibilities to sell the energy/biomass. In other case study areas especially in Germany there were however very little farmers that agreed with this issue being a barrier. Also absence of companies harvesting, refining and transporting the energy was not a key barrier, particularly not in Austria and Germany.

Adams et al. (2011) also described that the ability to make a profit was among the most important drivers for RE involvement. In this study this is indeed also confirmed as low profitability and also uncertainty about profitability were confirmed to be key barriers by most of the farmers in almost all case regions of this study. Large concerns about profitability among our farmers can partly be explained from the fact that biogas is one of the main RE activities in several of the case regions. In this type investment levels are very high and profitability of it has been rather low in the last couple of years, also in Germany (Wilkinson 2011). For other forms of RE the investment levels and risks for limited profitability could be lower and it is therefore interesting to further investigate the perceived concerns about profitability to the different types of RE.

What was also identified in the study by Adams et al. (2011) and which was further investigated in this study through the farm level modelling is that the impossibilities to invest/shift to more profitable options are a key barrier for bioenergy investments. The results in the farm level modelling in this study show however that shift to more energy cropping at the expense of food and fodder will be made at very different price levels per region and per farm type. They also confirm that indeed competition with food crops is there and that financial incentives are needed to make farmers shift, but from our assessment it seems logical that the size of the incentives need to be adapted to regional circumstances.

Other barriers indicated by Adams et al. (2011) were land availability, climate change mitigation, reducing fossil fuel dependency and potential attractiveness of the growing bioenergy market. The findings of Adams are mostly congruent with the findings of the current project, as farmers in the survey indicated that economic drivers (guaranteed price for fixed period of time and need to diversify sources of income), environmental reasons and independency from rising energy costs were identified as the main drivers for starting RE activities. However there was one exception and that was land availability. In this study it was not identified as a barrier, the farmers in Germany, Soria and Warminsko-Mazurskie even specifically indicated that land availability is not a barrier.

Analysing a questionnaire, Snakin et al. (2010) concluded that the **factors influencing bioenergy development** in Finland were rising energy costs, government subsidies, bioenergy market expansion, compensating of decreasing agro-product prices, and the wish to cut farm production costs. These drivers were all economic drivers, and most of these drivers can be compared with the reasons for RE investments found in the current study, such as the desire to be independent from rising energy costs.

Besides confirmation of our findings regarding barriers the literature inventory results also confirm that stimulation measures can be of large influence and mainly compensate the barriers. In the German situation the study by Bankset al. (2007) indicates for example that in Germany the introduction of biogas plants was successful due to the introduction of the "Renewable Energy Law". The law requires grid operators to prioritise RE electricity to get access to the grid above fossil based alternatives. In the survey in this study this factor was not mentioned to be a reason for take up of RE, but in the focus group discussions it became clear that this was an important factor stimulating the take up of RE in Germany and even more so the absence of this law in Spain and Poland a reason to not take up RE electricity activities on farms as getting access to the grid was seen as an important reason, unless large investments were made to improve the capacity of the grid. For large wind park investments this may often occur and costs are part of the investment, but for farmers investing in RE this is not a feasible option. .

Wilkinson (2011) reviewed the **drivers behind the adoption of on-farm anaerobic digestion** in Germany. They concluded that feed-in-tariffs were the main driver for biogas development, while the biophysical and socio-economic character of farming in Germany provided the fertile ground for the financial incentives. For instance, the intensive animal production and the fact that farmers have to comply with the EU Nitrates Directive are drivers for biogas investments.

Ravel and Gregersen (2007) reviewed the **drivers for biogas** plants in Denmark since the 1970s. They mention that some specific Danish circumstances have been beneficial, such as policies for decentralised CHP, existence of district heating systems, implementation of energy taxes in the 1980s and the preference of Danish farmers to cooperate in small communities. They also mention that the current setback in biogas plants is mainly caused by a shift in energy and environmental policies and limited availability of organic waste.

Wind energy

Several studies describe the drivers for the success of wind energy investments, but none of them specifically concerns agriculture. Below some studies are described, and if possible a link with the findings of the current project is made.

According to Abbad (2010), available policies and political will have been crucial for the expansion of wind energy in Spain. Evolving a pure feed-in tariff regulation to a market+premium regulation has led to the **success of wind energy expansion in Spain**. Another factor adding to the success was the regulation that RE is sold to the wholesale market, but given priority over conventional electricity, thus guaranteeing the sale of all units of RE. RE producers receive a premium on top of the market price to ensure that the market price plus the premium approximately equal the (former) feed-in tariff. In addition, there are companies that offer packages including access and production forecasts. Results of our questionnaire suggest that one of the main reasons for investing in wind turbines in Soria was getting a guaranteed price (results not shown) are in accordance with the findings of Abbad (2010). Further, farmers in Soria did not complain about a lack of supply, installation, advice, or maintenance services (Annex IV: Table 97).

Stenzel and Frenzel (2008) report that a long-term, stable investment horizon and low barriers for new market entrants (to induce competition in an emergent industry) have been **crucial factors for the success of wind energy**. They also mention that policy-makers need to remember that RE markets are government induced and investors want to avoid being trapped with investments in markets that change with the political weather. As an example they mention the hesitance of banks to provide new credit for independent and small-scale wind farms in Germany when political support was uncertain in the period 1995 to 1998. According to the authors, feed-in tariffs are the reasons for wind energy investments in Germany and Spain, which is in accordance with the finding of the current project.

Fragoulis (1994) mentions that the Greek Islands have potential for 2400 MW wind energy production, of which in 1994 only 30 MW was operational. Barriers identified include the fact that islands are not easy to visit, and the lack of infrastructure, both factors increasing installation costs. The author reports that the **lack of a well-designed tariffs policy limits current wind energy production**. This is in agreement with Abad (2010), Stenzel and Frenzel (2008), and confirms findings of focus group meetings and the survey which identified guaranteed prices as the most important reason to invest in renewable energy capacity.

Research on **local acceptance of wind-energy parks**, for instance in France and Germany was done by Jobert *et al.* (2007). Factors affecting acceptance include visual impact, ownership, information availability and options of participation. While it is not easy to compare acceptance of wind-energy parks to that of a single wind turbine at a farm, the results of our questionnaire suggest that farmers did not experience real unexpected problems regarding the acceptance of the wind turbines (Annex IV: Table 111).

Solar energy

Several studies describe the drivers for the success of solar energy investments. Rowlands (2005) reviewed advantages and disadvantages of feed-in tariffs for investments in photovoltaic systems in Europe. According to this study, the greatest level of activity on RE occurred in countries with feed-in tariffs (e.g., Germany and Austria), while countries that abandoned feed-in tariffs (e.g., Italy) experienced stagnation in the development of RE capacity. Feed-in tariffs further catalyse small groups and companies, rather than solely large corporations, to participate in RE development. These small companies can probably include farms. The results are based on several European studies (Faber et al. 2001; Haas 2002; Huber et al. 2001; Hvelplund 2001; Lauber 2004; Meyer 2003). The findings of these studies are in accordance with the results of the questionnaire applied in our project, which indicated a guaranteed price for a fixed period of time to be the most important reason to invest in PV (Annex IV: Table 113). The results also show that the farmers were not disappointed about the profitability of PV investments (Annex IV: Table 114), and that they are thus satisfied about the feed-in tariffs.

Candelise (2010) mentioned that domestic PV investments in the UK are generally not profitable under the current cost, market and regulatory conditions. The initial costs are too high and the current policy framework is not enough to make PV systems financially viable. They concluded that high enough feed-in tariffs, as well as the achievement of target cost reductions, would make PV systems financially attractive and would likely increase PV deployment in the UK.

Luthi (2010) investigated the factors determining the effectiveness of PV policies in German, Spain and Greece. Main reasons for PV development in Germany were a feed-in tariff guaranteed for 20 years combined with no major administrative delays and a quick grid connection. In addition, except for ground mounted plants, no permissions are needed for installing a PV plant. Although the guaranteed feed-in tariffs expand the time for return on investment in Spain, here the bureaucratic administrative process and unstable PV policies are considered as main barriers for successful PV development. Two months are needed for grid connection. In Greece, the feed-in tariff is high and guaranteed for 10 years. Barriers in this country include complex and time consuming administrative processes, unstable PV policies and problematic access to the grid. According to the author, the PV diffusion appears to be largely unrelated to return on investment, but is showing a strong correlation with apparent policy risks. As a consequence, installed PV capacity does not increase proportionally to the level of return. Instead, it is highly sensitive to the consistency and stability of the support. They mentioned that a feed-in tariff is an important condition for growing installed PV capacity, but it only results in effective deployment if policy risks are carefully managed. The findings of Luthi (2010) for Germany and Spain are comparable with our findings. Farmers in Germany were satisfied about their investments and did not perceive difficulties (Annex IV: Tables 37, 39, 47 and 49). Farmers in Spain listed the administrative process as a barrier for RE investment, as well as difficulties in obtaining permits, subsidies and loans (Annex IV: Tables 89 and 102).

Impact on Rural Development

There are several prerequisites for on-farm RE development to be contributing to Rural Development objectives as these have been formulated for the EU. These refer to incomes generated by on-farm RE production and to local (or regional) employment effects. Farmers are most likely to profit from RE revenues if they are responsible for the investments. We have seen above, that this is usually the case. Farmers tend to invest with private resources, either linked to the farm or personal funds. Bank loans are however also important. Sometimes, investments are done by non-farmers. If this is the case, only part of the revenues will become available for the farm while usually, the remainder is transferred outside the village or even the region.

There are, however, large differences between RE types and distribution of the original investment. On the one hand, PV panels, wind mills and other installations (ovens) will be purchased outside the region while installation costs are very limited. On the other end of the spectrum, biogas installations and other complex utilities require considerable efforts in terms of setting up and all kinds of construction work that need to be done *in situ*. Here, a larger part of the investment costs can be expected to remain within the region.

Employment benefits of RE development are showing similar variation patterns. PV, wind turbines, hydro, geothermal all require very little time for operation and management. All RE based on biomass, on the other hand, will require local (farm, village, region) labour efforts. These will therefore provide more work and offer better perspectives in terms of Rural Development. Farmers in the survey already indicated that generation of new jobs is basically related to biogas installations.

4 Conclusions

The substantial production of Renewable Energy (RE) on farms is a relatively recent development. This study is one of the very first to systematically survey the production of RE on farms across the EU. The study reveals that there is a large potential in the production and use of RE on farms in Europe. The agricultural sector could certainly provide an increase in their production of RE of more than 20% within eight years (2020), with an associated strengthening of farm income and positive effects on rural development. But this conclusion should definitely be interpreted with caution, since reference data about the current production and use of RE are not readily available at a reasonable level of accuracy across the EU, and for the different types of RE. Also, the profitability of the production of RE on farms very much depends on issues like guaranteed feed-in tariffs, and reliable long-term incentives and regulations. The following conclusion can be drawn from the study.

- Current ***on-farm production of final energy*** from renewable sources is mainly related to the production of electricity. The much smaller amount of renewable heat produced is generally used directly on the farm; electricity is mainly exported. Most energy is produced by wind turbines, plus solid biomass for heating.

- Following projections defined in NREAPs, ***RE production in 2020*** will grow considerably. Electricity production could show a four to five-fold increase by 2020. Production of heat will be modest. First generation energy crop production is expected to double. Energy from agricultural waste will increase five-fold. Under the more ambitious NREAP+ scenario, electricity production could reach 62.5 Mtoe (eight times the 2008 levels); but differences for heat and energy crops are considerably smaller. Agricultural waste will surpass first generation energy crops as supplier of primary energy..

- Reductions in GHG emissions by 2020 which mainly occur in other UNFCCC accounting sectors (energy, transport) are expected to quadruple to 315 Mton CO_2-eq (NREAP scenario), equivalent to roughly two thirds of total reported GHG emissions from the sector Agriculture. Under the more ambitious ***NREAP+*** scenario, GHG savings amount to 512 Mton CO_2-eq (about the same amount as the current emissions from the sector Agriculture). The dominance of wind is increasing. Other major contributors are biogas, solid biomass for heating and electricity and second generation energy crops. Germany remains the largest contributor under the NREAP scenario (27% of total savings), but it is caught up by France in the NREAP+ scenario (both 25% of savings).

- Wind is the most ***efficient way to reduce GHG emissions*** (limiting emissions with over 7 ton CO_2-eq/toe in 2008), but efficiencies of biogas, PV/solar thermal energy and solid biomass for electricity are almost as high as the one of wind energy, as are second generation biofuel crops. Heating options (solar, solid biomass, geothermal) are about half as efficient as wind energy in reducing GHG emissions. First generation energy crops achieve very little reduction per toe. Biogas efficiency in reducing GHG emissions will increase in 2020 due to the reduced use of energy crops.

- Notwithstanding a projected increase of ***dedicated energy cropping***, especially woody crops, their contribution to RE generation in 2020 will remain modest (6 to 7% of total primary energy).

- ***Biogas has huge potential*** for energy production but under present conditions application of energy crops is reducing its potential for GHG emission reduction. Also, farmers are often facing low returns on investment (with the exception of Germany), limiting their willingness to invest.

- Main ***reason for farmers to invest*** in RE is that it represents an additional and stable income source, often guaranteed for longer periods of time. Farmers also appreciate not being subject to future energy price increases, while they wish to contribute to environmentally friendly energy production.

- The main impact of RE production is its contribution to ***farm income***. In some regions, depending on the RE mix it can generate on-farm jobs, most increase being related to biogas and solid biomass. PV, solar thermal and wind do not generate more job opportunities, but may have an impact on regional development via indirect effects of enhanced and stabilised farm incomes (multiplier effects) and on regional technical infrastructure development.

- Biogas based on dedicated crops, stimulated by high feed-in tariffs, may in some regions lead to ***loss of permanent grasslands***, although this is increasingly being discouraged by EU policies.

- ***External investors*** can provide capital and bear risks for large investments, e.g. for wind turbines. Involvement of large non-agricultural investors or electricity companies may lead, however, to less economic returns for the agricultural sector and the rural economy, since these investors tend to be non-local companies; returns from such investments will hardly benefit local entrepreneurs.

- ***Competitive potential*** for RE including biogas and dedicated crops at price levels expected in 2020 is showing large variations by region and farm types. This confirms the need for tailored stimulation measures.

- Entrepreneurship by farmers is challenged by the ***need to cooperate*** beyond present levels. Especially substantial investments in large-scale biogas plants and wind farms will not be possible without extended co-operation.

5 Recommendations

Given the results and conclusions of this study, the following recommendations are formulated.

1. Currently, reliable ***statistics on on-farm RE*** production are lacking within the European Union. It is recommended that collection of data of on-farm RE be organised in a structured way, using similar definitions and system boundaries across the EU. Ideally, data collection should be included in present FADN data collection patterns.

2. While ***National Renewable Energy Actions Plans*** prepared by Member States by the end of 2010 in most cases do not treat the agricultural sector as a separate category for energy production, they tend to rely on farming as a major source of RE and biomass as primary fuel is one of the few elements in the NREAPs that can be directly attributed to farms. This combination is unfortunate and it is recommended that additional requirements are formulated for future RE action plans with respect to identifying sources of biomass feedstocks.

3. Our survey clearly shows that ***feed-in tariffs*** are very effective with respect to enhancing on-farm RE investment and production. Investment subsidies are showing lower impacts. In order to effectively stimulate on-farm RE production, farmers should be offered stable, preferably guaranteed, prices for fixed periods of time, preferably dedicated to small-scale farm-level RE development (as opposed to e.g. large scale RE projects like off-shore wind parks). Farmers have indicated to accept lower prices if those are guaranteed over time.

4. The relation between RE and ***Rural Development*** (RD) is generally not elaborated in the NREAPs. RE types like wind energy, PV energy, solid biomass and bioenergy crops can contribute significantly to farm incomes. PV and wind are safe options that do not require extra management. Woody biomass and biogas can provide additional jobs on farms. It is suggested to further integrate RD and RE stimulation programs, especially at regional levels.

5. While on-farm RE implementation could help save rural ***employment*** or generate new on-farm jobs (mainly solid biomass and biogas), the potential impact of on-farm and rural RE for employment development outside agriculture should be investigated. Defining and implementation of policies to realise the potential employment should be made part of programs aiming at solving the economic crisis. [19]

6. The relevance of ***bioenergy cropping*** in national action plans is often considerable. Action plans that build on biomass should include more explicit and clear cropping stimulation measures. The same applies to a certain extent to the use of agricultural waste material in RE production.

7. ***GHG reduction efficiency*** of first generation biofuels and biogas produced from high energy crop shares is very limited. The feeding of more animal manure and agricultural waste instead of first generation crops like maize into biogas plants should be stimulated as it can substantially increase the GHG reduction efficiency of biogas plants.

[19] Including National Reform Programs as they recently have been defined. A preliminary analysis of these plans (as presented at http://ec.europa.eu/europe2020/tools/monitoring/recommendations_2011/_index_en.htm) shows that renewable energy is playing an important role for Germany, Spain and Austria but less so for Poland. Grid (stability) is discussed for Poland and Germany, as well in some of the comments presented by the Commission.

8. Although the perspectives of ***decentralised production of renewable energy*** are large in many countries, infrastructural requirements to accommodate its production will have to be guaranteed. The European Commission can play a significant role in encouraging MS's to invest in grid (stability) development, e.g. for rural (low voltage) grid development and upgrade, financing of demonstration/pilot projects where rural intelligent grids with high share of RE on farms are considered, and developing micro-credit schemes at the national level (guaranteed by EU funds) for RE installed on farms.

9. Procedures to obtain ***permits*** for RE production often can be a barrier for farmers willing to invest in RE capacity. Procedures for permits should be optimised and simplified, guaranteeing stability of prevailing regulation patterns, preferably for a period of at least 10 years.

10. To safeguard that the potential benefits of RE production in the rural area will benefit the agriculture, this sector should study which ***forms of cooperation*** are best adapted to answer the challenges of the transition from fossil energy to RE in Europe. This may require a change in farming systems and entrepreneurship, and may require more cooperation between farmers.

11. Although ***investment subsidies*** do not seem to have had a major effect on the development of on-farm RE, in specific cases they can offer a stimulus to farmers to invest in RE production, especially in building woody biomass CHP plants, wood chip heating systems and biomass transportation systems. Combined with proper long-term feed-in tariffs this is a powerful incentive to stimulate RE development in the agricultural sector.

12. The ***image of the agricultural sector*** in Europe may benefit considerably from the production and use of RE if the public is kept well informed about the impacts. Farmers in our study indicate that they seriously take into account the perception of their activities by the local community. This may positively influence the investment climate and quality of life in the rural countryside. To achieve this, it is important to react to perceived negative side-effects early on. Examples include local concentration of biogas plants leading in some cases to high transport volumes and dominance of maize fields.

List of abbreviations

CAP	Common Agricultural Policy of the EU
CAPRI	Large-scale economic model for agriculture CAPRI (Common Agricultural Policy Regional Impact assessment). See Britz W (2005) CAPRI Modelling System Documentation. Common Agricultural Policy Regional Impact Analysis. Bonn, Germany: available at: http://www.agp.uni-bonn.de/agpo/rsrch/capri/capri-documentation.pdf, 2005.
CHP	Combined Heat and Power
CSP	Concentrated Solar Power
EU27	the 27 member states of the EU collectively
FSSIM	FSSIM, a bio-economic farm model for simulating the response of EU farming systems to agricultural and environmental policies. See Louhichi K, Kanellopoulos A, Janssen S et al (2010) Agricultural Systems 103(8):585-597
GHG	Greenhouse Gas
ILUC	Indirect Land Use Change
IPCC	International Panel on Climate Change
ktoe	kilotonnes of oil equivalent
kWp	peak capacity in kW
MITERRA	MITERRA-EUROPE: Integrated assessment of nitrogen losses from agriculture in EU-27. See Velthof G, Witzke D, Asman H, Klimont W, Oenema Z (2009) Journal of Environmental Quality 38(2):402
MS	Member State
Mtoe	Megatonnes of oil equivalent
NCV	Net Caloric Value
NREAP	National Renewable Energy Action Plan (in this report generally indicating the RE targets set by the EU Members States for 2020)
NREAP+	2020 Scenario for conditions enhancing increased agricultural investments in RE
NUTS	EU common classification of territorial units for statistics
PV	photovoltaic
RD	rural development
RDP	(national) Rural Development Programme
RE	renewable energy
RED	EU Renewable Energy Directive (2009)
RES	renewable energy sources
SEAMLESS	Integrated assessment of agricultural systems – A component-based framework for the European Union. See Van Ittersum MK, Ewert F, Heckelei T *et al.* (2008) Agricultural Systems 96(1-3):150-165
toe	tonnes of oil equivalent
UNFCCC	United Nations Framework Convention on Climate Change

References

Andersen E, Elbersen B, Godeschalk F, Verhoog D (2007) Farm management indicators and farm typologies as a basis for assessments in a changing policy environment. Journal of environmental management 82(3):353-362.

Blanco Fonseca M, Burrell A, Gay H, Henseler M, Kavallari A, M'Barek R, Pérez Domínguez I & Tonini A (2010) Impacts of the EU biofuel target on agricultural markets and land use: a comparative modelling assessment. In Impacts of the EU biofuel target on agricultural markets and land use: a comparative modelling assessment, JRC Technical and Scientific Reports, 130. Sevilla, Spain: Institute of Prospective Technological Studies, Joint Research Centre of the European Commission.

Capros P, Mantzos L, Tasios N, De Vita A, Kouvaritaksi N (2009) EU energy trends to 2030 – update 2009. EC, Brussels.

DG-AGRI (2010) Rural development in the European Union. Statistical and Economic Information. European Commission, Directorate General Agriculture and Rural Development, Brussels.

Di Blasi C, Tanzi V, and Lanzetta, M. (1997) A study on the production of agricultural residues in Italy. Biomass and Bioenergy **12**(5): 321-331.

Dworak T, Elbersen B, Van Diepen K *et al.* (2009) Assessment of inter-linkages between bioenergy development and water availability. ENV.D.2/SER/2008/0003r. ECOLOGIC, Berlin.

Edenhofer O, Pichs-Madruga R, Sokona Y, Seyboth K, Arvizu D, Bruckner T, Christensen J, Devernay J-M, Faaij A, Fischedick M, Goldstein B, Hansen G, Huckerby J, Jäger-Waldau A, Kadner S, Kammen D, Krey V, Kumar A, Lewis A, Lucon O, Matschoss P, Maurice L, Mitchell C, Moomaw W, Moreira J, Nadai A, Nilsson LJ, Nyboer J, Rahman A, Sathaye J, Sawin J, Schaeffer R, Schei T, Schlömer S, Sims R, Verbruggen A, von Stechow C, Urama K, Wiser R, Yamba F, Zwickel T (2011) IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation - Summary for Policy Makers. In: Edenhofer O., Pichs-Madruga R, Sokona Y, Seyboth K, Matschoss P, Kadner S, Zwickel T, Eickemeier P, Hansen G, Schlömer S, v. Stechow C (ed). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA,

EEA (2008) Maximising the environmental benefits of Europe's bioenergy potential. EEA Technical Report 10/2008. Copenhagen.

EEA (2009) Europe's onshore and offshore wind energy potential. An assessment of environmental and economic constraints. EEA Technical Report No 6/2009. European Environmental Agency Copenhagen.

EurObserv'ER (2011) Various Barometers on EU Renewable Energies. http://www.eurobserv-er.org/default.asp

EWEA (2010) Wind Energy Factsheets. http://www.ewea.org/index.php?id=1611. European Wind Energy Association Brussels.

Fritsche UR, Rausch L, Schmidt K (2006) Life-Cycle Analysis of Renewable and Conventional Electricity, Heating, and Transport Fuel Options in the EU until 2030. Final report for the European Environmental Agency (EEA). Öko-Institut e.V., Darmstadt, Germany.

IAE (2010) CO_2 emission from fuel combustion – highlights. Paris.

IEA (2010) Renewables Information. International Energy Agency, OECD/IEA, Paris,

Janssen S, Andersen E, Athanasiadis IN, van Ittersum MK (2009) A database for integrated assessment of European agricultural systems. Environmental Science & Policy 12(5):573-587.

Janssen S, Louhichi K, Kanellopoulos A, Zander P, Flichman G, Hengsdijk H, Meuter E, Andersen E, Belhouchette H, Blanco M, Borkowski N, Heckelei Th, Hecker M, Li Hongtao, Oude Lansink A, Stokstad G, Thorne P, Van Keulen H & Van Ittersum M (2010) A Generic Bio-Economic Farm Model for Environmental and Economic Assessment of Agricultural Systems. Environmental Management 46: 862-877.

King M. (2010), An investigation into policies affecting Europe's semi-natural grasslands. A report by The Grasslands Trust commissioned by the European Forum on Nature Conservation and Pastoralism & co-funded by the European Commission (DG Environment). http://www.efncp.org/download/European-grasslands-report-phase1.pdf

Lesschen JP, van den Berg M, Westhoek HJ, Witzke HP, Oenema O (2011) Greenhouse gas emission profiles of European livestock sectors. Animal Feed Science and Technology 166-167:16-28.

Louhichi K, Kanellopoulos A, Janssen S *et al.* (2010) FSSIM, a bio-economic farm model for simulating the response of EU farming systems to agricultural and environmental policies. Agricultural Systems 103(8):585-597.

Lind B, Stein S, Kärcher A. and Klein M (2008) Where have all the flowers gone? Grünland im Umbruch. Hintergrundpapier und Empfehlungen des BfN (Bundesamt für Naturschutz). BfN, Bonn.

Mistry P, Misselbrook T (2005) Assessment of methane management and recovery options for livestock manures and slurries. London: Department for Environment Food and Rural Affairs, Sustainable Agriculture Strategy Division. http://www.defra.gov.uk/science/project_data/DocumentLibrary/AC0402/AC0402_3589_FRP. pdf

NABU (Naturschutzbund) (2009) Landwirtschaftliche Flächennutzung im Wandel – Folgen für Natur und Landschaft. Eine Analyse agrarstatistischer Daten. NABU, Berlin. http://imperia.verbandsnetz.nabu.de/imperia/md/content/nabude/landwirtschaft/gruenland/gap-reform.pdf

Pehnt M (2006) Dynamic life cycle assessment (LCA) of renewable energy technologies. Renewable Energy 31(1):55-71.

REN21 (2011) Renewables 2011 Global Status Report. REN21 Secretariat, Paris.

Stenzel T & Frenzel A (2008) Regulating technological change—The strategic reactions of utility companies towards subsidy policies in the German, Spanish and UK electricity markets. Energy Policy 36 (7):2645-2657.

Te Buck S, Van Keuelen B, Bosselaar L, Gerlagh T (2010) Methodology for the calculation and recording of the amounts of energy produced from renewable sources in the Netherlands. Publication number 2DENB1014. NL Agency.

Velthof G, Witzke D, Asman H, Klimont W, Oenema Z (2009) Integrated assessment of nitrogen losses from agriculture in EU-27 using MITERRA-EUROPE. Journal of Environmental Quality 38(2):402.

Vogt Rea (2008) Optimierungen für einen nachhaltigen Ausbau der Biogaserzeugung und -nutzung in Deutschland. Endbericht zum Forschungsvorhaben 032 75 44 des BMU. IFEU, Heidelberg, pp. 24, 33.

Wilkinson KG (2011) A comparison of the drivers influencing adoption of on-farm anaerobic digestion in Germany and Australia. Biomass & Bioenergy 35(5):1613-1622.

Zwart KB, Oudendag DA, Ehlert PAI, Kuikman PJ (2006) Duurzaamheid co-vergisting van dierlijke mest. Alterra Report, 1437. Wageningen, pp. 72.

LIST OF SEPARATE BACKGROUND DOCUMENTS

Annex I Background Document – Information, Policy and Market Review

Annex II Background Document – RE Balance

Annex III Background Document – GHG Balance

Annex IV Background Document – Farm Survey

Annex V Background Document – Farm based simulations