MITIGATION CAPACITY OF RENEWABLE ENERGY PRODUCTION AT EU FARMS

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ABSTRACT: This paper analyses the potential role of EU *on-farm RE production* in the near future (2020) as projected in National Renewable Energy Action Plans (NREAPs) and the related GHG mitigation. In this project which was commissioned by the European Commission (DG-Agri), both are assessed at the level of EU Member States (MS) by means of consolidating RE and GHG balances including primary (biomass including energy crops, wood, waste, manure, etc.), intermediate (biogas produced on the farm) and final energy (electricity and heat generated on farms). As a start, on-farm RE production was estimated for 2008. Next, development up to 2020 was assessed using two scenarios for on-farm RE production. Results show that total EU on-farm RE production in 2008 amounted to 11.8 Mtoe; 8.0 Mtoe of electricity and 3.9 Mtoe of heat. Projected on-farm 2020 RE production amounts to 42 Mtoe under the NREAP scenario, an increase of 250% as compared to 2008. Under the more ambitious NREAP+Agri scenario, electricity generation is expected to amount to 62 Mtoe (an eight-fold increase). GHG emission reduction under the NREAP scenario rises to 315 Mton CO2-eq in 2020, which is equivalent to 65% of the total reported GHG emissions from the UNFCCC sector agriculture in the EU in 2008. Savings under the NREAP+ Agri scenario amount to 512 Mton CO2-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 and solid biomass for heating and electricity from second generation energy crops.

1 INTRODUCTION

Following ambitious objectives in the EU Directive on the promotion of the use of energy from renewable sources (2009/28/EC) a range of national and EU policies have been implemented to increase production of Renewable Energy (RE). It remains unclear how the generic targets can be realised and what contribution specific RE types (e.g. solar, wind, geothermal, bioenergy) will have, how many greenhouse gas (GHG) emissions will be reduced or prevented, and what contribution may be expected from specific sectors like agriculture.

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.

If well organised, RE production on farms may thus bring a substantial benefit to farmers and society on a European level. Policies to specifically stimulate the development of on-farm RE should be sought in the Rural Development Programme (RDP). Under the 2008 CAP Health Check additional funds of around 1 billion Euro were made available for projects in renewable energy and climate change. In addition to this, Member States (and regions) have drawn up rural development programmes subsidiary to national support schemes, state aid programmes, regional development policies, etc., all of which can include measures to stimulate RE production. This means that farmers often have different opportunities to obtain support for RE development including investment subsidies.

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. For this 2 extreme scenarios were set-up with varying levels of support for on-farm RE development.

2 RENEWABLE ENERGY: EUROPE'S POSITION

In the EU in 2011 71% of newly installed electric capacity in the EU came from renewables, with PV accounting for almost half of the total (REN21, 2012). Renewable Energy's share in electricity consumption in the EU in 2010 approached 20%; and renewables represent 12.4% of the gross final energy consumption, compared to 11.5% in 2009.

There are, however, large differences between regions and RE types. Europe has a relatively strong position in wind energy, with 41% of the global capacity in 2011. Germany and Spain being the third and fourth nations in wind capacity (after China and the USA). 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). Wind energy is also an important electricity source continuously growing in other EU countries such as Italy, France, Portugal (who passed Denmark in 2011 to join the list of world's top 10 countries in wind capacity). Strong growers in wind capacity are Romania, Cyprus and Greece.

Also for PV, the EU is leading with almost 75% of the world's installed capacity in 2011. Not surprisingly 3 of the 5 leading countries are in the EU. Germany and Spain host more than half of all PV capacity in the world and other PV leading countries in the EU include Italy and the Czech Republic (REN21, 2012).

Worldwide demand for biomass for energy amounts to 53 EJ of which 86% is used for production of heat, almost 10% goes to electricity generation and combined heat and power (CHP) and the remaining to liquid biofuels. Significant increases in biomass use for power generation and liquid fuels were seen. 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, 2012).

The European Union comsumes 85% of the pellets produced globally, the major biogas market is also in the EU with Germany consuming almost 61% of the total primary biogass. The main consumers of bioethanol are in North and Latin America, while the EU is the lead consumer for biodiesel.

The top five countries—Germany, Sweden, Finland, the U.K., and the Netherlands—accounted for almost two-thirds of EU electricity production from solid biomass (including MSW), with Germany accounting for the largest share (17.6%). Other major producers include Poland, Italy, Denmark, and Austria (REN21, 2012).

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.

3 APPROACH AND METHODS

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:

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

3.1 Methodology used for RE energy balance

The renewable energy balance approach designed at ECN (Bole et al., 2011) aims to capture all the flows of renewable energy produced and consumed by, as well as imported to and exported from the agricultural sector (see Figure 1).

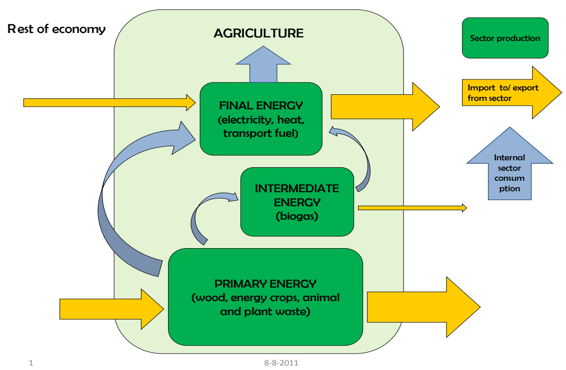

Figure 1: RE flows in the agriculture sector

The set-up of the balance is illustrated in Figure 2 covering the same categories as specified in the flow diagram of Figure 1. In Figure 2 it also becomes clear that per category of energy and fuels it needs to be specified whether it is imported on the farm, produced on the farm, exported from the farm and consumed either on farm or by the farm household.

	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					
....					

Figure 2: RE balance set-up

Final energy

- o 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 times fraction of electricity produced by renewable sources on a national level.
- o The category "biofuels" covers all types of biofuels and was in certain cases calculated according to the following rule: on-farm import of biofuels is fuel consumption agriculture sector times fraction of biofuels in national transport fuel mix.
- o 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

- o Biogas in its basic form (as produced in methanisation plants) is currently not transported, hence its import to farms is described as "unrealistic".
- o 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.
- o On farm consumption of biogas refers to biogas use for production of electricity and heat.

Primary fuels

- o Although the flow of the considered primary fuels 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.
- o Production represents the heat content (NCV) of the biomass used as primary fuel.
- o 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 energy balance definitions can be found in Pedroli and

Langeveld (Eds.) (2011). For this study the same balances were prepared for the actual situation (data were derived for the base year 2008, but if no data available another year was used) and for the year 2020 for the 2 scenario situations, which are explained in the next.

A large number of data sources were consulted for filling in the energy balances per country. For a detailed overview of sources consulted in each country see Pedroli and Langeveld (Eds.) (2011). Overall it should however be mentioned that very few centralised data sources are available which collect relevant data for the balances following the same methodology and format. Proxies and expert estimates in the field were often used to calculate estimates. Therefore it remained difficult to set-up a single accounting rule to follow across all countries.

3.2 Methodology used for GHG balance and calculation of emission savings

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 and Lesschen *et al.*, 2011). Mitterra also includes a (co)-digestion sustainability tool (Zwart et al., 2006) 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). 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[1], which deals with the harmonisation of greenhouse gas emission calculations of biofuels throughout the European Union.

MITERRA-Europe (Velthof *et al*, 2009 and Lesschen *et al.*, 2011) is an environmental 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. 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 41 crops including six second generation energy crops (*Miscanthus*, switchgrass, canary reed, poplar, willow and eucalyptus).

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 these values were not available and an average emission of 5 g CO_2-eq/MJ was assumed for processing and transport.

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).

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, less differences can be observed in the case of gas or oil based systems, either for electricity generation or heating (Fritsche et al., 2006) In this project we use GHG emission factors based on GEMIS (version 4.8)[2] which is a life-cycle analysis program and database for energy, material, and transport systems, and comprises of a database on 1) fossil fuels, renewables, nuclear, biomass and hydrogen, 2) processes for electricity and heat, 3) materials and 4) transports.

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)[3]. The fossil fuel mix for 2020 for both electricity and heat is based on the PRIMES reference scenario for 2020 (Capros *et al*., 2009).

3.3 Scenarios

To derive a picture of the most likely mid-term developments on production and use of RE in agriculture the following two scenarios 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[4] 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 scenario the NREAP targets are reached without putting in place any specific stimulation measures for farming to develop RES activities. The only

[1] http://www.biograce.net/

[2] http://www.oeko.de/service/gemis/en/

[3] http://ec.europa.eu/energy/publications/doc/statistics/part_2_energy_pocket_book_2010.pdf

[4] 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/

stimulation is that there is an increased demand for RES-energy from the market resulting from the 20% renewable energy consumption target set in the RES Directive, which will stimulate a market demand and higher prices for RE-energy. This however is the only stimulation through policy and impacts on farming in the same manner as it impacts on other sectors of the economy. 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 incentives are given other than an increased market demand for RE energy, 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[5]. 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 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. A second, “NREAP+Agri” 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, it will be assumed that in regions where certain circumstances are more optimal to develop certain on-farm RE-activities, the right incentive schemes (which include the present RES stimulation measures such as feed-in tariffs, but particularly measures in the present and future RDPs) would indeed lead to their optimal deployment by farmers, 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.

[5] Summarised in Tables 7a in the NREAPs.

4 RESULTS

4.1 RE balance

On-farm production of renewable energy for the agriculture sector in EU-27 is presented in a consolidated renewable energy balance (Table 1). This balance represents the best available estimate of the current situation of renewables on farms across Europe, based on the information presently available.

Table 1: Renewable Energy balance for EU-27 in 2008 (in ktoe)

	Import	Production	Export	Consumption on farm			
Final energy	on farm	on farm	from farm	Total	by households		Remarks:
Electricity	761.3	**8022.2**	**8019.7**	**763.8**	-		Input
from solar PV	-	25.6	25.6	0.0	0.0		Unrealistic input
from wind	-	7288.3	7288.3	0.0	0.0		**Calculation**
from solid biomass	-	17.8	17.8	0.0	0.0		No disaggregation possible
from biogas	-	689.8	687.3	1.2	-		Assumption
from…	-	0.8	0.8	0.0	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	2539.8		
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**	0.0		
Intermediate fuels							
Biogas		**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	**-**	**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	-		
….							

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 RE balance reveals that total on-farm production of final energy from renewable sources in the EU-27 amounts to 11.8 Mtoe. This is similar to a recent estimation provided by the European Commission[6]. It represents a relatively small share of total RE consumption (e.g. 80 Mtoe from biomass alone in 2008). 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 which is almost twice the total amount of electricity and over ten times the amount of heat delivered to the sector, at 4.5 Mtoe and 0.3 Mtoe[7], respectively. 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.

Wind is by far the most prevalent resource used for production of renewable electricity in agriculture,

[6] Directorate-General for Agricultre and Rural Development, 2010. Rural development in the European Union. Statistical and Economic Information. Table 2.2.4.16.1.

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

contributing around 90% of the total, all of which is exported to the electricity grid. The second largest contributor 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 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 are still small and are only taken up by farmers in two or three countries.

In terms of uptake, it is clear from Figure 3 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. In Germany the agricultural biogas sector is also significant. 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.

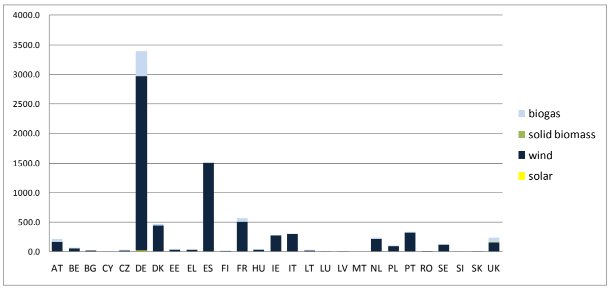

Figure 3: Renewable electricity production in the agriculture sector in 2008 per MS (in ktoe)

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. Some a-typical heat production technologies are found in the Netherlands which is recovering heat from the cooling of milk and heat pumps in Denmark. Eastern European countries with the largest number of farms also consume the largest amounts of heat from solid biomass (in absolute terms).

As to the most under used RE one can conclude that a number of regions could develop significant non-biomass related resources, especially solar energy in Southern European countries and biogas in Central and Eastern Europe.

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 by others in the power generation process, European farmers already contribute more than 10% of 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. European farmers are of course also the most important producers of feedstock for the production of biofuels.

Table 2: Renewable Energy balance for EU-27 in 2020 in NREAP sccenario (first table) and NREAP+Agri scenario (last table) (in ktoe)

NREAP scenario:

	Import on farm	Production on farm	Export from farm	Consumption on farm	
Final energy				Total	by households
Electricity	-	**35894.7**	**35885.5**	**9.2**	**0.0**
from solar PV	-	653.4	653.4	0.0	0.0
from wind	-	32692.7	32692.7	0.0	0.0
from solid biomass	-	31.5	31.5	0.0	0.0
from biogas	-	2516.2	2507.0	9.2	0.0
from…	-	0.8	0.8	0.0	0.0
Heating	-	**6127.7**	**0.8**	**6126.9**	**2539.8**
from solar	-	304.4	0.0	304.4	0.0
from solid biomass	-	5327.8	0.0	5138.1	2539.8
from biogas	-	238.3	0.8	237.2	0.0
from green gas	-	0.0	0.0	0.0	0.0
from geothermal	-	224.4	0.0	224.4	0.0
from ….	-	32.8	0.0	32.8	0.0
Cooling		0.0	0.0	0.0	0.0
Biofuels for transport	-	-	-	-	-
Biofuels for machinery	-	-	-	-	-
Intermediate fuels					
Biogas		**6456.6**	**366.7**	**6456.6**	-
Primary fuels					
Total energy crops	**0.0**	**25538.5**	**10441.2**	**2715.4**	-
Oilseeds, cereals, sugar crops	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	-	-	-	-
….					

NREAP+Agri scenario:

	Import on farm	Production on farm	Export from farm	Consumption on farm	
Final energy				Total	by households
Electricity	0.0	**62499.2**	**61424.9**	**22.8**	-
from solar PV	-	881.9	881.9	0.0	0.0
from wind	-	53797.0	53797.0	0.0	0.0
*from solid biomass**	-	43.0	43.0	0.0	0.0
from biogas	-	7777.3	6702.9	22.8	-
from…	-	0.0	0.0	0.0	0.0
Heating	0.0	**7864.8**	**1.6**	**7863.1**	2539.2
from solar	-	415.8	0.0	416.1	-
*from solid biomass**	-	6517.7	0.0	6517.7	2539.2
from biogas	-	601.0	1.6	599.1	-
from green gas	-	0.0	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**	0.0
Biofuels for transport	-	-	-	-	-
Biofuels for machinery	-	-	-	-	-
Intermediate fuels					
Biogas		19046.3	403.3	18643.0	-
Primary fuels					
Total energy crops	**0.0**	**28063.3**	**14208.9**	**3484.3**	-
Oilseeds, cereals, sugar crops	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	-	-	-	-
….					

As for 2020 on-farm RE production amounts to 42 Mtoe under the NREAP scenario, an increase of 250% as compared to 2008 (see Table 2). Under the more ambitious NREAP+Agri scenario the total could amount to even 82 Mtoe, with electricity generation expected to be 62 Mtoe and the rest coming from intermediate fuels (an eight-fold increase) (see Table 2). The agricultural RE production would amount to 30% of the total 2020 NREAP demand in the NREAP scenario and even 44% of this demand in the NREAP+Agri scenario.

In the NREAP scenario electricity production is expected to rise to almost 36 Mtoe, representing a 3-4 fold increase compared to 2008. Production of heat (6 Mtoe in 2020) is showing a more modest increase, approximately doubling in size. 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 are assumed to increase following the NREAP-based growth rates. For biofuel uses we did not make estimates for 2020 uses, 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.

4.3 GHG balances: saved and avoided GHG emissions

The total calculated GHG savings from RE on farms in 2008 is 86 Mton CO_2-eq (see Figure 5). 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. The contribution to the savings per country depends strongly on the amount and mix of RE per country (see Figure 5). Germany contributes for 25% to the total GHG savings, mainly from wind energy and biogas, followed by Spain with 15%, mainly from wind energy.

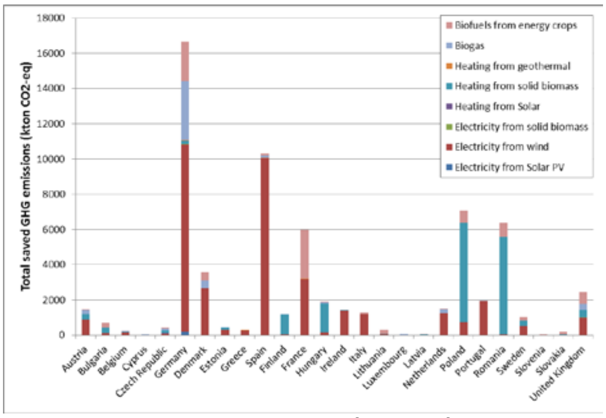

Figure 5: Saved GHG emissions from on-farm RE in 2008 (kton CO_2 equivalents)

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 3 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.

Table 3: Avoided GHG emissions and emissions from the production of biogas per country (Kton CO_2-eq)

Country	Avoided GHG emission from manure storage	Avoided GHG emission fossil fuels for electricity	Avoided GHG emission fossil fuels	GHG emissions from biogas	Net avoided GHG emissions
Austria	23.1	294.6		108.7	209
Belgium	5.9	19.6	11.7	6	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	6.9	38.1
Netherlands	126.5	173	9.9	161.4	148.1
Poland	0.5	0.5	0.3	0.2	1
Portugal	2.4	4.8		0.8	6.3
Romania	0.5	2.4		0.7	2.2
Slovenia	6.6	45.4		13	39
Spain	43.6	65.3	5.3	11.4	102.8
Sweden	0.4	1	2.3	0.6	3.1
United Kingdom	231.7	442.7		136.1	538.2
EU-27	1472.2	5194.8	113	1762.8	5017.2

For countries that have an 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 (see Figure 4).

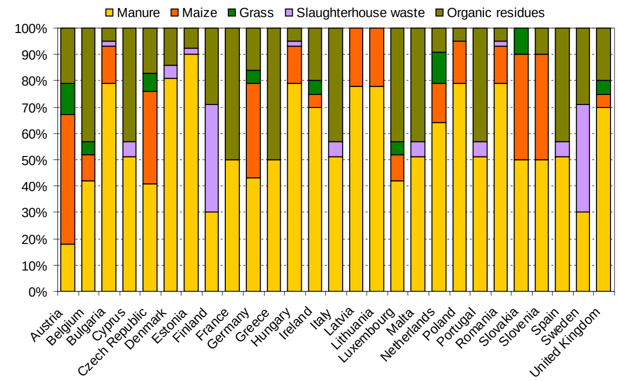

Figure 4: Average composition of the substrates per country.

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 [8], based on different EU statistics and country information. Figure 5 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).

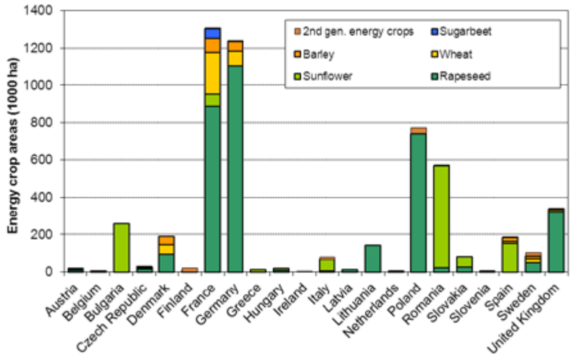

Figure 5: Energy crop areas per MS, data are based on 2006-2008, as collected in BiomassFutures project and calculated by MITERRA-Europe (**www.biomassfutures.eu**)

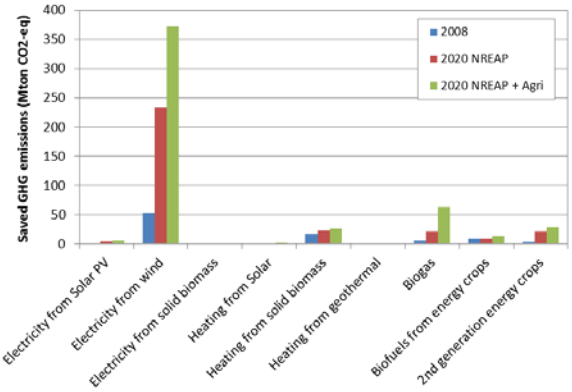

Figure 6: Saved and avoided GHG emissions from RE on farms for 2008 and the two 2020 scenarios

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 6). 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.

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

5 DISCUSSION

The substantial production of Renewable Energy (RE) on farms is a relatively recent development. This study is one of the very first to systematically analyse 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 a fivefold increase in their production of RE within eight years (2020), with an associated increase of farm income and positive effects on rural development and GHG emission reduction. But this conclusion should definitely be interpreted with caution. aking the initial farm balances was not easy given the data availability and the inconsistencies between the different data sources used. This problem lead to some inconsistencies and discrepancies for certain categories in the RE balances. Therefore total figures are not always the sum of sub-categories and should therefore be treated as indicative for the current role of RE on farms, rather than for comparison accross EU MSs.

In spite of data problems, one can cunclude that the farming sector is already contributing significantly to the RE production in the EU and that if the right incentives are taken this contribution can increase significantly. With this increase the contribution to the GHG mitigation can also become very large.

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 (NABU, 2009; FNR 2010). This will 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.

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. 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.

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).

The effect of changing the leakage 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%. 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.

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.

Finally 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.

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7 ACKNOWLEDGEMENTS

We thank ….

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8. LOGO SPACE

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