Energy Efficiency in Agriculture

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1. Introduction – One of the EU headline target indicators for Europe is "20% increase in energy efficiency" by 2020. It is anticipated that in the following decades energy use will increase significantly and will have a widespread impact on the economy, including the agricultural sector. Energy use reduction can be achieved by reduced energy input. Improved energy efficiency, however, is only achieved, if energy input per unit yield is reduced. Therefore, improved energy efficiency can be realized with either increased or decreased energy inputs depending on the input-output relationship.

Agricultural production relies very much on the use of energy from fossil resources. There is a direct consumption of fuel and electricity required to execute different crop production practices, but also an indirect use of energy required for the production of agricultural inputs, such as fertilizers or pesticides. While the discussion on energy use in agriculture is often focused on direct energy use, it needs to be stated that 50 % and more of the total energy use is related to the production of nitrogen fertilizer and other indirect energy uses (Woods et al. 2010, Pelletier et al. 2011). In fact, the energy efficiency of the feed and foodstuff production is determined by many indirect energy inputs, like manufactured inorganic fertilizers and pesticides, as well as seeds, feed and special feed supplements for livestock.

The different production systems in different climates vary substantially in their energy use and energy saving potential. This paper presents some of the results obtained in the WP2 of the KBBE.2011.4-04 project "Energy Efficiency in Agriculture - AGREE" supported by the 7th Framework Program. It gives an overview into energy use and energy efficiency of agriculture in various agro-climatic zones of Europe.

2. Methodology - Energy use in agriculture includes both direct energy use and indirect energy use associated with all kinds of inputs used to produce agricultural products. An LCA-like approach has been chosen, but the activities have been restricted to the farm gate. The energy efficiency indicator is best expressed as the ratio of energy use per cultivation area (GJ/ha) and energy use per unit of product (GJ/t). Energy use and productivity have been established for some of the agricultural products which have a decisive role in the EU foodstuff production, including arable crops, greenhouse vegetables, perennial crops and livestock production. For each type of production, the volume of inputs has been included considering Primary Energy Consumption (PEC). The parameters/energy equivalents used to convert the physical data of the input into the energy data have been preferably drawn on the BioGrace database (www.biograce.net). Some conversion factors, however, are specific for each country. For example the PEC of electricity, which depends on the national energy mix used to produce electricity. The energy indicators used were Direct Energy Inputs, Indirect Energy Inputs, Total Energy Inputs and Specific Input of Primary Energy (GJ/ha and GJ/t).

Direct Energy Inputs includes all the energy used directly in the agricultural production process, including electricity, refined petroleum products (diesel, natural gas, and others), natural gas based fuels as well as wood chips. Indirect Energy Inputs includes energy used for manufacturing of production means, including fertilizers, pesticides, farm machinery and farm buildings as well as seeding material and feed. The indirect energy associated with the construction of farm buildings and farm machinery has been excluded from our studies. The reason is that this would necessitate a very detailed level of data acquisition as farm buildings are very diverse in construction and a large variety of farm machinery is used in the field operations. Moreover, data on the energy associated with the construction of farm machinery is missing. Finally, the indirect energy from farm buildings and machinery has only a limited potential to contribute to energy savings in agriculture. Used energy has been estimated by multiplying physical units of application (kg/ha or L/ha) with the parameters expressing the energy per physical unit (MJ/kg or MJ/L) to result in the energy used per hectare.

3. Results and Discussion - The indicator of energy efficiency is the energy intensity of the economy expressed in units of energy used per unit of Gross Domestic Product (GDP). According to EUROSTAT, from 2000 to 2009 energy intensity of the EU economy continued to decline slightly from 0.187 toe/€ in 2000 to 0.165 toe/€ in 2009. The EU agricultural sector accounts for 11.0 million jobs which represent 5.1% of persons employed in the economy. At the same time the gross value added (GVA) of combined agriculture, hunting and fisheries accounted for only 1.7% in 2010. Nevertheless, there is a significant variance in GVA across Member States. In Greece and Poland the percentage share of persons employed in agriculture is relatively high, 13.0% and 12.5%, respectively, so the resulting percentage share of agriculture in GVA is also relatively high, 3.3% and 3.5%. On the other hand Germany accounts only for 1.4% of the total employment and the 0.9% share of the sector in the GVA. Portugal is in between, accounting with 7.7% of the total employment and the 2.4% share of the sector in the GVA.

According to the European energy statistics the total final energy consumption (FEC) of the EU-27 countries amounted to 49 205 PJ in 2008. The FEC of the sector "agriculture/forestry" was given as 1 071 PJ corresponding to 2.2 % of the total FEC in the EU (Table 1). However, the Eurostat data presented in Table 1 is not sufficient to describe the energy consumption of European agriculture since not all the energy required for the production of agricultural products is allocated to the "agriculture/forestry" sector in the Eurostat statistics. For example, FEC of fertilizer production is allocated to the "industry" sector.

Table 1: The total final energy consumption (FEC) and FEC of agriculture (*including forestry) for the years 1998 and 2008 according to the Eurostat data.

Country	Total FEC in PJ		FEC of agriculture* in PJ		FEC of agriculture* in % of total FEC	
	1998	2008	1998	2008	1998	2008
EU-27	46 658	49 205	1 257	1 071	2.7	2.2
Denmark	630	649	31	29	5.0	4.5
Finland	1 005	1 083	30	35	3.0	3.2
Germany	9 428	9 386	114	42	1.2	0.4
Greece	761	890	45	46	6.0	5.1
Netherlands	2 082	2 139	157	132	7.5	6.2
Poland	2 526	2 606	198	152	7.8	5.8
Portugal	2 526	2 606	25	15	1.0	0.6

The area of agricultural land and its use depends on geographical location and varies greatly across the countries. The agricultural production is specified to a great extent by the prevailing arable land in Denmark (92% in the structure of utilized agricultural area - UAA) and Finland (98%), 76% in Poland, 70% in Germany, 55% in the Netherlands, and in the southern countries, Greece and Portugal arable land occupies 52% and 31% of UAA, respectively. The structure of UAA also varies among the countries (Table 2). In most of the analysed countries, a relative big percentage of agricultural land is under permanent grassland and meadows. In Portugal it represents more than 50% of UAA, in the Netherlands 42.9%, in Germany 28.6%, and Greece and Poland more than 20%. Finland is the exception with only 1.7% of UAA. In Denmark, Germany, and Poland the largest arable land area is covered by wheat, in the Netherlands major crops are wheat, potatoes and sugar beet, in Greece olive groves dominate, and in Portugal olive groves and vineyards. The above structure of UAA is pre-conditioned naturally by the local environmental factors and determines the prevailing agricultural productions and the streams of energy use by agricultural sectors.

Concerning crop production the main indirect energy inputs are related to the accumulated energy in fertilizers and pesticides. Total consumption of nitrogen, phosphorus and potassium in the EU has been estimated at an average of 91 kg per hectare. The estimated average consumption of nitrogen in the EU has stood at 65.2 kg/ha, ranging from 21.8 kg/ha in Portugal to 136.6 kg/ha in the Netherlands. Phosphorus consumption has averaged at 8 kg/ha in the EU, ranging from 5.2 kg/ha in Denmark to 13 kg/ha in Poland, and potassium-based fertilizers averaged at 17.8 kg/ha across the EU, ranging from 7.6 kg/ha in Portugal and 9.5 kg/ha in Greece to 28.8 kg/ha in Poland, 25.0 kg/ha in Germany, and 23.1 kg/ha in Finland. Also, total use of active ingredients of pesticides per hectare of utilized agricultural area varies to a great extent across the studied European countries under consideration, ranging from 0.7 kg in Finland to 4.8 kg in Portugal, and 5.6 kg in the Netherlands.

Table 2: The percentage share of annual and perennial crops in utilized agricultural area (UAA) – 2007.

Country	Utilized Agricultural Area (UAA)	Wheat	Potato	Sugar beet	Sun-flower	Olive plantations (oil production)	Vineyards (quality wine)	Permanent grassland and meadow
	x1000 ha	%	%	%	%	%	%	%
Denmark	2 662	26.0	1.55	1.48				7.6
Germany	16 931	17.7	1.63	2.39	0.11		0.57	28.6
Greece	4 076	4.4	0.58	0.34	0.30	18.10	0.37	20.1
Netherlands	1 914	7.4	8.21	4.29				42.9
Poland	15 477	13.6	3.55	1.60				21.1
Portugal	3 472	1.6	0.58	0.07	0.43	8.19	3.05	51.3
Finland	2 292	8.9	1.20	0.70				1.7

Eurostat. Land use: Number of farms and areas of various crops by agricultural size of farm (UAA) and NUTS2 region

As an example of the various agricultural activities analysed in the AGREE project, it is presented below the results obtained for wheat production. In fact, at the European scale the highest absolute total primary energy consumption (PEC) in crop production is associated with wheat production in Germany 58.17 PJ, Greece 46.09 PJ, and Poland 42.60 PJ. In 2008, the percentage of area occupied by common and durum wheat in the countries at issue ranged from 2.4% in Portugal to 18.9% in Germany (Table 3). In the countries under study, the highest yield in tons per hectare has been recorded for the Netherlands and Germany and the lowest in the Southern countries – Greece and Portugal. The average energy input per hectare of wheat production varied greatly among the countries involved. Specific energy inputs vary from 2.1 to 4.3 GJ per ton among countries. This range results from a relatively moderate variation in energy use per ha (from 12.0 to 19.9 GJ per ha) and a relatively high variation in the yield level ranging from 3 to 8.7 tons per ha. There is a tendency for higher energy uses to be associated with higher yield which becomes clear in Figure 1.

Table 3: The energy input (PEC) in wheat production in different countries (average scenarios**,** Golaszewski et al., 2012).

Country	Production area	Share in EU-27	Yield	Specific energy inputs		Total PEC
	x 1000 ha	(%)	t ha^{-1}	$GJ \cdot ha^{-1}$	GJ t^{-1}	PJ
Finland	196.7	9.6	4.50	12.0	2.7	2.4
Germany	3087.0	18.9	7.66	18.6	2.4	57.4
Greece	2346.2	16.5	5.00	19.9	4.0	46.8
Netherlands	119.3	8.1	8.73	18.1	2.1	2.2
Poland	2346.2	14.6	5.80	15.1	2.6	35.4
Portugal	106.2	2.4	3.00	12.9	4.3	1.4

In wheat production the main energy input is associated with the use of fertilizers as can be seen in Figure 2. The energy inputs required for the use of fertilizers ranged from 6.3 GJ/ha in Portugal to 11.2 GJ/ha in Germany. The second main energy input is diesel use for field operations. The other direct and indirect energy inputs have been to a great extent specific for geographical location of countries. In the Central and Northern EU countries Germany, the Netherlands, Poland and Finland the additional energy on wheat production has been associated with drying and in the Southern countries Portugal and Greece with irrigation. Indirect energy use is a considerable part of total energy use in wheat production. It varies between 50% and 72% depending on the country. This indirect energy use is mostly associated with synthetic fertilizer use. Diesel and fertilisers are very important production factors contributing to energy use and greenhouse gas emissions (GHG). Therefore, all measures to improve the efficiency of fertilizer and diesel use will contribute to energy use efficiency to a great extent and reduction of environmental impacts.

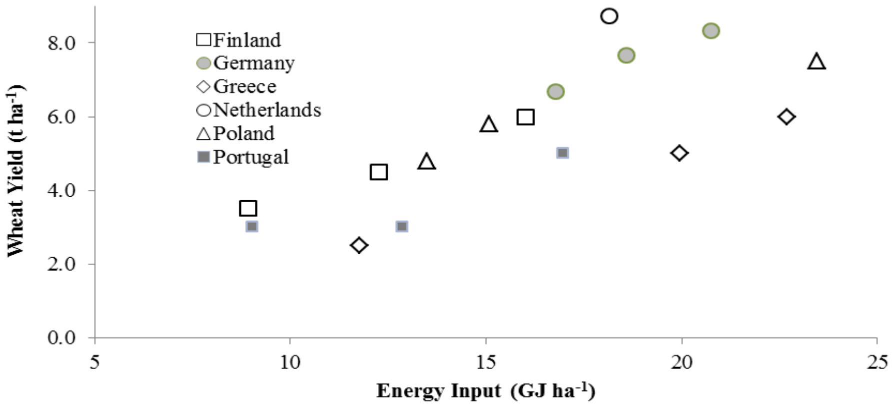

Figure 1: The relation of the total energy inputs in GJ/ha and yields in t/ha (Golaszewski et al., 2012)

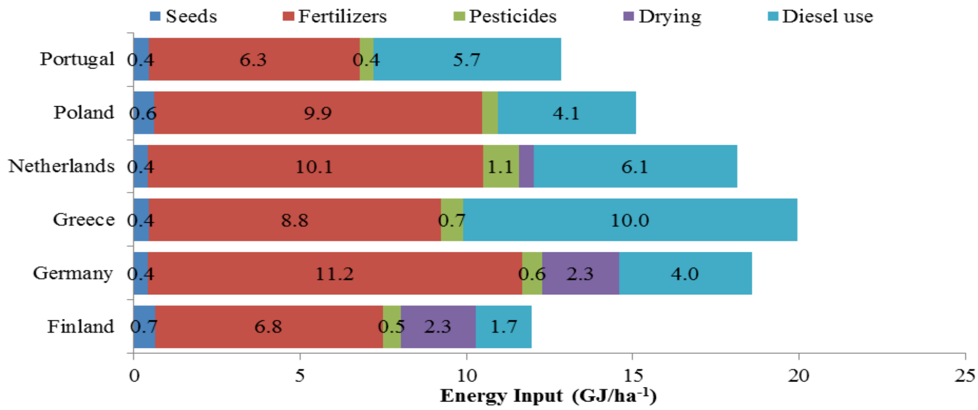

Figure 2: The structure of energy inputs in wheat production in GJ/ha (Golaszewski et al., 2012)

4. Conclusions - The actual energy consumption of the European agriculture reported in the Eurostat statistics is underestimated. The efficiency of energy use in agricultural production is specific to the EU country and geographical location. The total and specific energy consumption varies substantially for all crops considered across Europe.

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