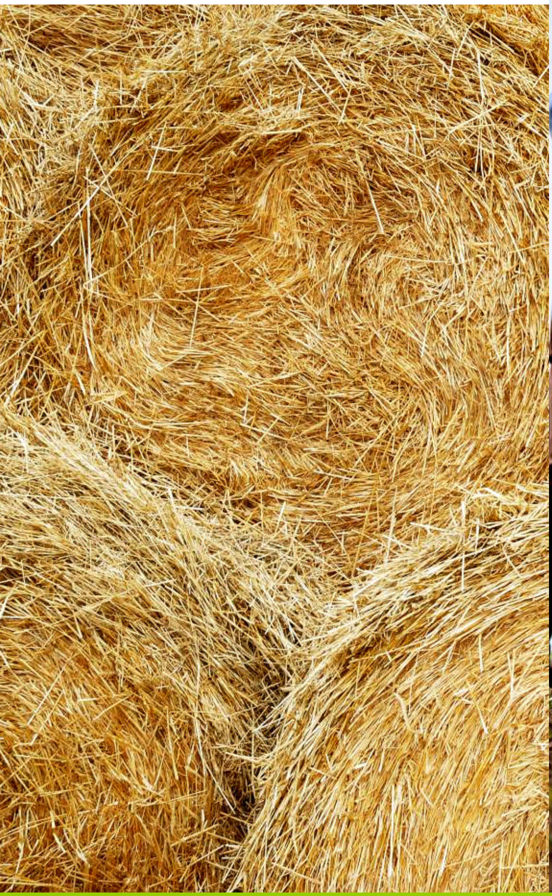

State of the Art on Energy Efficiency in Agriculture

Country data on energy consumption in different agro-production sectors in the European countries

This project is funded by the European Union

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This project was founded by the FP7 Program of the EU with the Grant Agreement Number 289139

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State of the Art on Energy Efficiency in Agriculture

Summary

Energy efficiency is the goal of efforts to reduce the amount of energy required to provide products and services. The general term "energy efficiency", when applied to agriculture, reflects changes in technology, governmental and EC policies – including the Common Agricultural Policy, climate change on a broad scale and local weather patterns, and farming management practices. There is not a single measure to describe, ensure, or improve energy efficiency. Instead, in the energy balance for a given production process, a variety of indicators may serve and support energy efficiency analysis.

The results of this study are based on the specific input of primary energy per cultivation area (GJ ha^{-1}) and on the specific input of primary energy per ton of agricultural product (GJ t^{-1}). All the measures that are suitable to reduce the specific energy input, will improve energy efficiency (the energy efficiency measures). Improving energy efficiency of agricultural production contributes directly to the reduction of greenhouse gas (GHG) emissions, particularly carbon dioxide.

This State of the Art analysis has been determined on the basis of the data provided by six countries: Finland, Germany, Greece, the Netherlands, Poland, and Portugal. The approach based on the life cycle analysis (LCA) has been chosen with the system boundary at the farm gate and have thus excluded processing into consumer goods. Specific energy input has been established for those agricultural products which have a decisive role in the EU foodstuff production, including:

- crop production: wheat, sugar beet, potatoes, cotton, and sunflower;
- greenhouse production of tomatoes, cucumber, and sweet pepper;
- production of perennial crops such as vineyards and olive trees;
- livestock production such as dairy cows (milk), pigs, and broilers.

The analysis is based on average production figures, or best estimates, (should average figures be unavailable). In several cases figures have been found for different production systems within one country and up to three scenarios have been described. In this way, low, average, and high primary energy consumption (PEC) of the various production processes have been taken into consideration.

Key Points

(1) The actual energy consumption of the European agriculture reported in the Eurostat statistics is underestimated (Table 1). The main reason is that energy which is definitely required for the production of agricultural inputs and the fuels are not allocated or not allocated entirely to the sector of "agriculture/forestry" in the Eurostat statistics, e.g. production of fertilizers, consumption of fuels is reported in transportation sector. 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. Reasons have been identified, and discussed, in terms

of various cropping practices, different agricultural machinery types, varying yields and dissimilar climates.

Table 1. Total primary energy consumption for the agricultural subsectors considered in the study in comparison with the Eurostat data (2008).

	Finland	Germany	Greece	Netherlands	Poland	Portugal
Number of subsectors considered in the study	4	10	6	9	6	7
Total PEC (PJ) for the subsectors in the study	18.8	223.9	83.0	158.4	169.6	16.9
Total FEC (PJ) in Agriculture/Forestry acc. to Eurostat (2008)	35.0	42.0	46.0	132.0	152.0	15.0

(2) The main energy input for the field crops is associated with the use of fertilizers and diesel. Often energy input for irrigation, drying and/or storage is important but it depends on geographical location and related climate, and intensity of the production systems.

(3) Greenhouse vegetable production in the Central and Northern EU countries is characterized by a very intensive direct energy input and differs significantly from the production system in the Southern EU countries. For the crops grown in the Southern countries little or even no energy input is needed when grown directly on soil; and a higher energy input is only needed in hydroponic systems.

(4) The olive grove production is limited to the Southern EU countries but the specific energy input for olives production is higher in the southwest European countries than in southeast European countries.

(5) In dairy cow (milk) and broiler production in these countries there is a highly differentiated amount of energy accumulated in feed. However, energy use for feed in pig production is very similar across the studied countries, but the specific energy input does depend on the level of direct energy inputs.

(6) The potential contribution of agricultural subsectors to energy saving measures in agriculture is country specific. The primary energy consumption in agriculture for a given country has the highest levels in the following subsectors:

Finland: dairy cows, pigs

Germany: dairy cows, wheat, pigs

Greece: wheat, cotton

Netherlands: dairy cows, pigs, potatoes, tomatoes, sweet pepper

Poland: dairy cows, wheat, pigs, potatoes

Portugal: dairy cows, olive groves, broilers

Preface

As energy prices rise against the background of severe environmental hazards associated with continued fossil energy use, the need to make agriculture more energy efficient is becoming more and more prominent. A more energy efficient agriculture will be increasingly demanded by food-chain partners and society and is also a necessity in view of competitiveness.

This report is a part of Work Package 2 of the KBBE.2011.4-04 project “Energy Efficiency in Agriculture” (AGREE) supported by the 7th Framework Program. It gives an insight into energy use and energy efficiency of agriculture in various agroclimatic zones of Europe. In the following chapters, the energy efficiency of important individual subsectors of European agricultural production i.e. crops, perennials, greenhouse vegetables, and livestock husbandry is described. The data on energy inputs, provided by participants from each of the six countries: Finland, Germany, Greece, the Netherlands, Poland, and Portugal, has been the basis of the analysis on energy efficiency

List of Abbreviations

Countries:
FI – Finland
DE – Germany
EL – Greece
NL – Netherlands
PL – Poland
PT – Portugal

Economic Indicators:
GDP in PPS – Gross Domestic Product in Purchasing Power Standard
GVA – Gross Value Added
PEC – Primary Energy Consumption
FEC – Final Energy Consumption
Agricultural production measures
UAA – Utilized Agricultural Area
LU – Livestock Unit

Units
kWh – kilowatt-hour
MJ – mega joule = 10^6 J
GJ – giga joule = 10^9 J
PJ – peta joule = 10^{15}J
kgoe – kilogram of oil equivalent
toe – ton of oil equivalent
ha - hectare
L – litre
t – metric ton

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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. This issue raises the importance of research and innovation to develop more energy efficient technologies of agricultural production. Energy efficiency is the goal of efforts to reduce the amount of energy required to provide products and services.

Agriculture plays a substantial role in the European Union economy. The Common Agricultural Policy (CAP) governs not only an adequate quantity and quality of agricultural production but also acts for economic development of rural areas and on environmental aspects. All the parallel policies relating to production, economics, and the environment interact and are related closely to energy consumption. In agricultural production the need for energy as an input can determine the profitability of farming which, in turn, impacts heavily upon the farmers’ investment in improved farming systems. Therefore, cost-effective energy measures are needed from an economic point of view and have the promise to reduce carbon emissions at the same time.

Agricultural production relies not only on the efficient use of solar energy by photosynthesis but to a great extent on the use of energy from fossil resources, either directly with the use of fuel or electricity or indirect with the use of agricultural machineries, fertilizers or pesticides. While the discussion on energy use in agriculture is often focused on direct energy use, it needs to be acknowledged 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). The different production systems in different environments vary substantially in their energy use and energy saving potential, which will be presented in this report for selected countries and relevant agricultural production systems across Europe.

Agriculture in National Economies

The indicator of energy efficiency is the energy intensity of the economy expressed in units of energy used per unit of GDP. 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 (Figure 1). In the studied countries under consideration the most energy intensive has been the Polish economy which has accounted for 0.365 toe/€, almost double the level of the indicators for the other countries (0.175-0.250 toe/€). At the same time the trend over the last 10 years showed a decrease of energy intensity in every country with the tendency of a small decrease in the economy of the Netherlands (5%) and high decrease in the economies of Greece (18%) and Poland (25%).

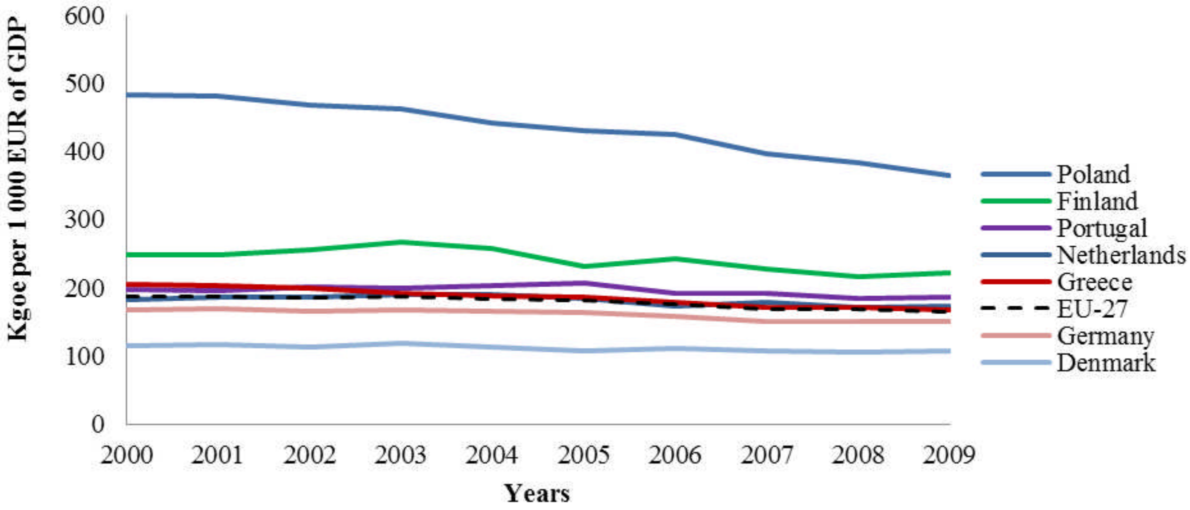

Figure 1: The energy intensity of the economy in the European Union and selected countries. Source: EUROSTAT

During 2000-2010 the contribution of agriculture, hunting and fishing to the gross value added (GVA) decreased significantly, with the greatest drop for Greece and Denmark – 50%, and the least for Finland – 17% (Figure 2).

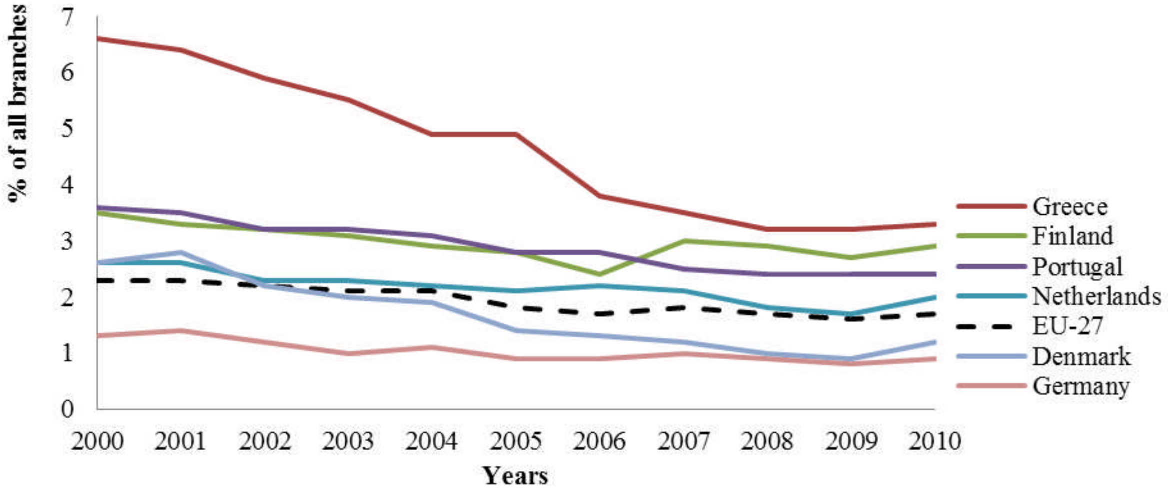

Figure 2: The gross value added by agriculture (2000-2010), hunting and fishing, % of all branches. Source: EUROSTAT

The percentage share of agriculture in the gross value added corresponds to the country's gross domestic product (GDP) and the number of persons employed in agriculture (Table 2). The EU agricultural sector accounts for 11.0 million jobs which represents 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 1.5% share of the sector in the GVA.

Table 2: The gross domestic product (GDP), percentage share of agriculture in the gross value added (GVA) and employment in agriculture (2010).

Country	Gross domestic product (GDP) in PPS[a]	Persons employed, in total[b]	Persons employed in agriculture[c]		Percentage share of agriculture, hunting and fishing in GVA[d]
		x1000	x1000	%	%
UE 27	100	216 405.4	11 028.2	5.1	1.7
Denmark	125	2 717.6	54.1	2.0	1.2
Finland	115	2 447.5	82.1	3.4	2.9
Germany	118	38 737.8	536.0	1.4	0.9
Greece	90	4 388.6	568.8	13.0	3.3
Netherlands	133	8 370.2	177.7	2.1	2.0
Poland	63	15 960.5	1 993.6	12.5	3.5
Portugal	80	4 978.2	383.0	7.7	2.4

[a] Eurostat. PPS – Power Purchasing Standard
[b] Eurostat. Employment (main characteristics and rates) – Annual averages
[c] Eurostat. Agricultural Labour Input Statistics: absolute figures (1000 annual work units)
[d] Eurostat. Gross Value Added – agriculture, hunting and fishing, % of all branches

Agriculture in National Energy Use

According to the European energy statistics[1] the total final energy consumption (FEC) of the EU-27 countries amounted to 49,205 PJ in 2008[2]. The FEC of the sector "agriculture/forestry" was given as 1,071 PJ corresponding to 2.2 % of the total FEC in the EU. On a national level, this percentage share ranged from 0.4 to 6.2 % among the seven countries listed in Table 3.

Table 3: 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

* incl. forestry

However, the Eurostat data presented in Table 3 is not sufficient to describe the energy consumption of European agriculture for various reasons.

(1) Not all the energy required for the production of agricultural products is allocated to the sector "agriculture/forestry" in the Eurostat statistics. For example, FEC of fertilizer production is allocated to the sector "industry". In 2008, FEC of the German fertilizer

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[1] http://epp.eurostat.ec.europa.eu/portal/page/portal/energy/data/main_tables
[2] Values converted from tons of oil equivalents (toe) to PJ using 1000 toe = 0.041868 PJ

production amounted to 83.7 PJ[3] which is roughly twice as much as the FEC used in total German agriculture according to the Eurostat data.

(2) The production of agricultural products requires a variety of forms of energy such as heat from biomass, electrical energy, and fossil fuel for combustion engines, for example. The energy use associated with this energy consumption is larger when the production cost of these energy carriers is taken into account. Therefore, it has been decided to use Primary Energy Consumption (PEC) as the basis for the analysis of the energy use and efficiency.

(3) In this report, the energy use by agriculture has been estimated on a production or area basis using both direct and indirect energy use. By multiplying the quantity of products produced or the area used, an estimate of total energy use associated with the main agricultural products could be established.

Energy Accumulated in Means of Agricultural Production

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. A significant percentage share of energy associated with the production of fertilizers and pesticides is consumed in production of agricultural products.

The area of agricultural land and its use depends on geographical location and varies greatly across the countries (Table 4). 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.

Table 4: 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

The structure of UAA varies among the countries at issue (Table 4). In Denmark, Germany, and Poland the largest arable land is covered by wheat, in the Netherlands there is a great

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[3] W. Bayer, Federal Statistical Office of Germany, Department E 207, personal communication, 8 Dec 2011.

percentage share of land under potatoes and sugar beet, in Greece the land with perennial crops – olive groves prevail, and in Portugal – the land with olive groves and vineyards. A very big percentage share of agricultural land which is under permanent grassland and meadow is characteristic for the agriculture of Portugal – over 50% of UAA, the Netherlands – 42.9%, and Germany 28.6%. In Finland the share is only 1.7% of UAA. In the countries at issue, 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.

Under the 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 (Table 5). 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. In some EU countries like the Netherlands, Germany and Denmark, which have high livestock densities and a high rate of manure application per hectare as a consequence, a large part of nitrogen and phosphorus balance comes from manure[4].

Table 5: The total yearly consumption of inorganic fertilizers (2007).

Country	Nitrogen[a]		Phosphorus[b]		Potassium[c]		NPK
	t of N	kg ha^{-1} of UAA	t of P	kg ha^{-1} of UAA	t of K	kg ha^{-1} of UAA	kg ha^{-1} of UAA
EU 27	9743534	65.2	797543	8.0	1686363	17.8	91.0
Denmark	190129	82.7	7444	5.2	26854	22.5	110.4
Germany	1551212	106.7	76016	8.2	148388	25.0	139.9
Greece	148840	49.4	27857	8.2	33348	9.5	67.1
Netherlands	239028	136.6	10789	9.1	24143	18.2	163.8
Poland	1094713	73.8	163642	13.0	355653	28.8	115.6
Portugal	72005	21.8	12105	5.6	20334	7.6	35.0
Finland	137977	68.8	10726	7.6	29080	23.1	99.5

[a]Eurostat

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 (Figure 3). Consumption of herbicides prevails in Finland (77%), Denmark (69%), Poland (55%), and Germany (54%). In Portugal fungicide use is more than 75% of total pesticide use and a relatively huge amount of insecticides is used in Greece (24%) while other pesticides such as growth regulators and seed treatments are used in the Netherlands (29%).

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[4] Eurostat

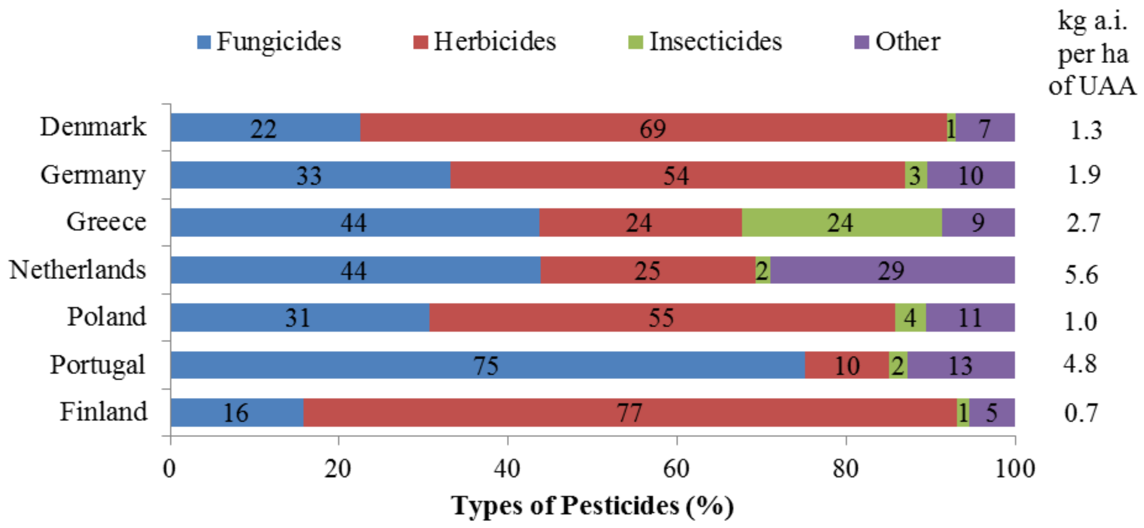

Figure 3: The percentage share of use of pesticides and total quantity of active ingredients (a.i.) of pesticides per hectare of utilized agricultural area (UAA) (Eurostat: 2008 – DK, DE, PL, PT; 2007 – NL; 2006 – FI; 2001 – EL)

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. In this report we provide an overview of the total energy use in the most important agricultural production systems. An LCA-like approach has been chosen, but the activities have been were restricted to pre-farm gate activities and have thus excluded processing into consumer goods. The energy efficiency indicator is best expressed as the ratio of energy use per cultivation area ($GJ\cdot ha^{-1}$) and energy use per unit of product ($GJ\ t^{-1}$).

Energy use and productivity have been established for those agricultural products which have a decisive role in the EU foodstuff production, including:

- arable production of wheat, potatoes, sugar beet, cotton, and sunflower;
- greenhouse production of tomatoes, sweet pepper and cucumber;
- perennial crops such as vineyard and olive trees;
- production of livestock such as dairy cows, pigs, and broilers.

Energy use has been established based on average production figures or best estimates (should the averages be unavailable). For each type of production, the volume of inputs has been included along with the FEC and PEC. The parameters/energy equivalents used to convert the physical data of the input use into the energy data have been preferably drawn on the BioGrace database (www.biograce.net). In the case of a country with a typical production system, the relevant references are given. These parameters allow converting the physical inputs into FEC and PEC figures. Some conversion factors, however, have been specific for a country, such as the PEC of electricity which depends on the national energy mix used to produce electricity.

In the case various production systems have occurred within one country and the situation has not adequately described by one average production system, more scenarios have been described with a maximum of three. In this way, low, medium, and high energy intensity of a production process could be included (for instance reduced, average and conventional tillage). Table 22 in the Annex gives an overview of these scenarios and their backgrounds.

The energy measures/indicators used have covered:

- Direct Energy Inputs – energy of fossils used in the agricultural process as the sum of consumed electricity, and solid, liquid and gaseous fuels (GJ·ha^{-1}, GJ/LU);
- Indirect Energy Inputs – energy accumulated in the means of production consumed by the agricultural process (GJ·ha^{-1}, GJ/LU);
- Total Energy Inputs – the sum of direct and indirect energy inputs for a unit of the agricultural production (GJ·ha^{-1}, GJ/LU);$E = E_D + E_I$
- Specific Input of Primary Energy– total primary energy use in the agricultural process per cultivation area (GJ·ha^{-1}) and per ton of agricultural product (GJ t^{-1}).

The data on the production processes have been scaled up to the country level to get an impression on energy use on the national level associated with a variety of processes. Energy inputs included in the calculations are as follows:

Production process	Energy inputs included in the calculations
wheat, sugar beet, potatoes, sunflower, cotton	seed use, synthetic fertilizer use (N, P, and K), transport of inorganic fertilizer, pesticides used, irrigation and water use, diesel use of machinery, drying of the product
olive groves, vineyards	synthetic fertilizer use (N, P, and K), transport of inorganic fertilizer, pesticides used, irrigation and water use, diesel use, machinery for field operations (pruning, harvesting, etc.), materials (olive cloth)
tomatoes, cucumber, sweet pepper	synthetic fertilizer use (N, P, and K), pesticides used, diesel use of machinery, greenhouse energy use (electricity, natural gas), materials (thermal screens, solarisation and LDPE films)
dairy cows, pigs, broilers	feed consumption, energy associated with maintenance of production (bed straw, water use, exploitation of buildings), diesel use, energy use

The inputs represent the direct and indirect energy uses for each of the agricultural production processes included.

Direct Energy Inputs

This includes all the energy carriers 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.

- Electricity (kWh per unit converted into MJ per unit) – consumption of electrical energy in the farm transportation and operations, lighting, electrical equipment, automation processes and farm management:
    - Grain crops: conditioning and storage of grain, electrically driven fans and/or heaters, irrigation.
    - Potatoes: conditioning, ventilation in storage rooms.
    - Cotton: irrigation.
    - Greenhouses: process control equipment, additional lighting, ventilation, irrigation.

    - Perennial crops: conditioning, ventilation in storage rooms.
    - Dairy farm: operating milking systems – feed preparation and rationing by automatic equipment, milking, milk cooling, farm management, lighting and ventilation in the cowshed and barn (hay), supplying hot water for sanitation.
    - Pig and broilers production: automatic feeding with complex rations preparation and automated rationing, controlled environment in buildings, farm management.
- Refined petroleum fuels (L per unit converted into MJ per unit) – consumption of fuels in the field operations, heating and power generation, oils and lubricants used in farm machinery:
    - Grain, root and perennial crops: field operation (tractors, self-propelled machines), heating (drying, crop stores), transportation (organic fertilizers and harvested crop), irrigation.
    - Greenhouses: heating and power generation.
    - Dairy, pig and poultry farm: transportation of feed, power generation.
- Natural gas, liquid propane – used to power facilities like crop dryers and irrigation equipment. This fuel is also used in greenhouses for heating via Combined Heat and Power units.
- Solid fuels, including biomass fuels (wood chips) – used for heating buildings, e.g. in livestock production and also in some greenhouses.

Indirect Energy Inputs

This includes energy carriers used for manufacturing of production means, including fertilizers, pesticides, farm machinery and farm buildings as well as seeding material and feed[5]. The indirect energy associated with the construction of farm buildings and farm machinery has been excluded from our studies/report. 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.

Crop Production

- Fertilizers – the energy used for production of fertilizers, transport of raw materials to processing plant (i.e. phosphate rock), packaging of final products and moving the products to retailers to be distributed to farms. The indirect energy associated with these activities have been estimated by multiplying physical units of application (i.e. kg/ha) with the parameters expressing the volume of energy per physical unit (MJ/kg) to result in the volume of energy per hectare.
- Pesticides – the energy used for production of pesticides expressed in kg of active ingredient per ha has been converted into MJ with the use of standardized parameters available in the BioGrace tool (www.biograce.net). Other inputs like seeds, organic substrates in greenhouse production or indirect energy associated with water use have also been taken into account using the required value of each input and a parameter converting this physical volume into the energy consumption figure.

Livestock Production

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[5] In some energy balance approaches the energy used in the production of seed (used as sowing material) and fodder for livestock are not included. In some other studies such indirect energy inputs are included into analysis (e.g. Stirling and Kun, 1992).

- Animal feed – the amount of energy needed to produce the feed and the raw materials (fresh and concentrated feed, feed additives). Again, the amount of energy consumed is based on the physical amount multiplied by a standardized parameter.
- Other specific indirect energy inputs needed in the production process like straw for bedding, energy associated with water availability, building use, herd replacement, hatchery, etc.

Energy output

The above mentioned inputs are defined on an hectare basis (arable, greenhouse, and perennial crops), on the basis of a kg of meat (pigs, poultry) or on the basis of the quantity of milk in t produced per livestock unit per year (dairy). Together with the total area in hectares per country or the total number of livestock units per country, this data has been used to present an estimate of the total energy consumption of the involved agricultural processes on a national level. This gives an insight into the total energy consumption involved in agricultural production processes and therefore of the potential contribution of energy saving measures in agriculture.

Energy Inputs in Subsectors of Agricultural Production

Crop production – key points

At the European scale the highest absolute total primary energy consumption in crop production is associated with wheat production in Germany 58.17 PJ, Greece 46.09 PJ, and Poland 42.60 PJ (Figure 4). The next crop is cotton cultivated in Greece – 27.19 PJ, and then potatoes in Poland 11.33 PJ and Germany 6.65 PJ, and sugar beet in Germany 4.95 PJ and Poland 4.34 PJ. Total energy consumption for sunflower production is relatively low 0.32 PJ in Germany and 0.08 PJ in Portugal.

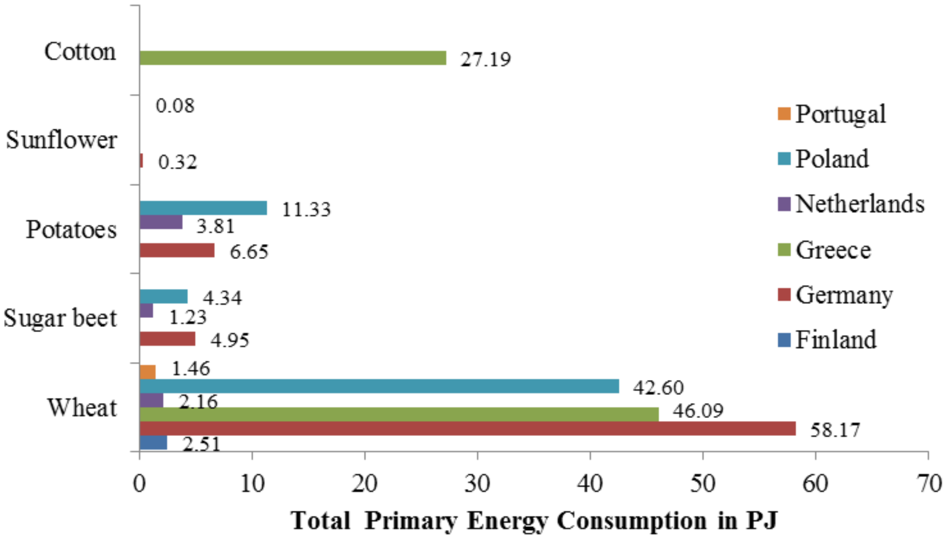

Figure 4: Total primary energy consumption (weighted means from scenarios) in crop production by country.

The specific energy use varies substantially for all crops considered across Europe (Figure 5). The ranges of specific energy input in crop production are as follows: wheat 2.08 - 4.29 GJ t^{-1};

sugar beet 0.20 - 0.29 GJ t^{-1}; potatoes 0.63 - 0.87 GJ t^{-1}; sunflower 3.98-5.06 GJ t^{-1}; and cotton 15.4 GJ t^{-1}.

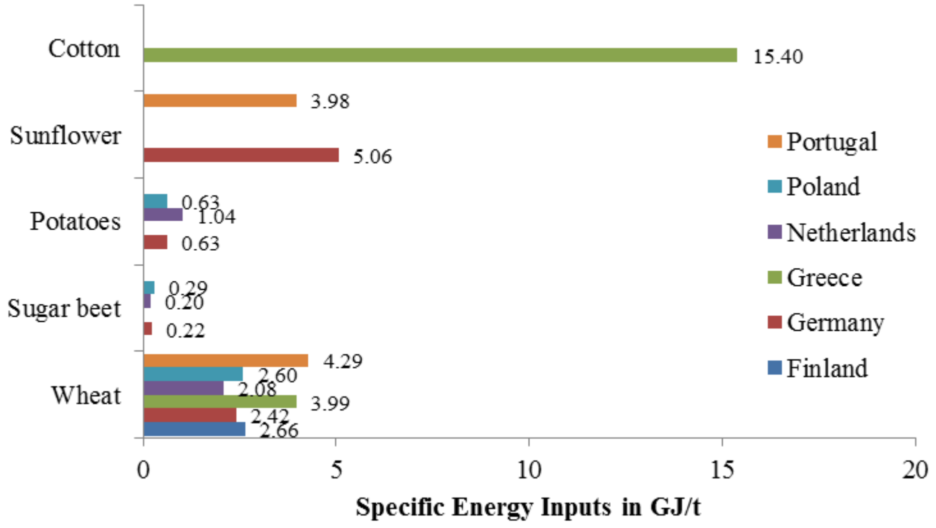

Figure 5: Specific energy input in crop production by country (average scenarios).

The structure of direct and indirect energy use may reflect the potential for energy savings. In wheat, sugar beet, and potato production, as well as in sunflower production in Germany direct energy use shares about 30 % - 50 % of the total specific energy use (Figure 6). This means that only a little higher potential for energy savings is associated with reduction of indirect energy use. The extremely high direct energy use, over 90%, is for sunflower production in Portugal and for cotton production in Greece. Thus, in these cases the inputs associated with direct energy use may contribute significantly to energy savings.

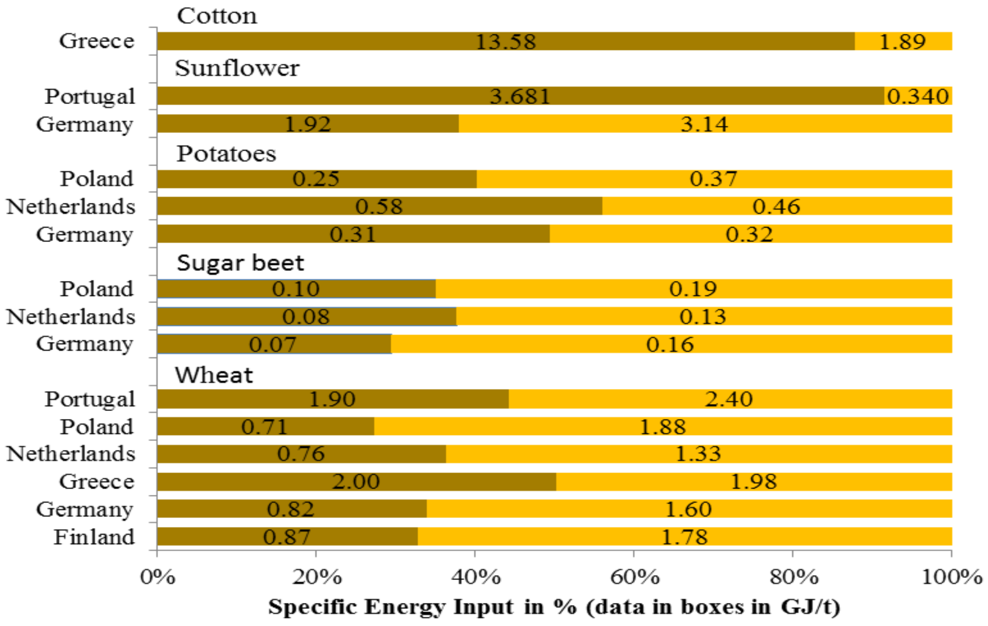

Figure 6: Direct (darker boxes) and indirect energy inputs in crop production by country (average scenarios).

Wheat. The energy efficiency indicators for wheat productions are specific for the three EU geographical areas. A relatively low specific energy input for wheat production is characteristic of the Central EU countries: the Netherlands (2.07 GJ t^{-1}) and Germany (2.43 GJ t^{-1}). Medium energy input is specific for the northeast EU countries of Finland (2.66 GJ t^{-1}) and Poland (2.60 GJ t^{-1}) and a comparatively high energy input for wheat production in the Southern EU countries Greece (3.99 GJ t^{-1}) and Portugal (4.29 GJ t^{-1}). Between 44.0 % (Greece) and 65.4 % (Poland) of the total primary energy consumption (PEC) in wheat production is used for fertilizers. Diesel use ranges between 14.1 % in Finland and 50.4 % in Greece. Drying has been found to require 18.8 % and 12.4 % of PEC, in Finland and Germany (average scenarios), respectively.

Root crops. The structure of the energy input in the production of sugar beet and potatoes in the Central and Eastern EU countries is similar but the production shows different energy efficiencies. Production of the root crops in the Eastern EU country of Poland is characterized by lower yields and lower energy input than in the Central EU countries of the Netherlands and Germany. In comparison with the highly efficient sugar beet production in the Netherlands (0.204 GJ t^{-1}) and production of potatoes in Poland (0.627 GJ t^{-1}) and Germany (0.634 GJ t^{-1}), specific energy input in Poland is 0.286 GJ t^{-1} for sugar beet and in the Netherlands it is 0.893 GJ t^{-1} for potatoes.

Sunflower. In sunflower production the level of yield, specific energy input, and the structure of energy input is distinctly different between central and southern Europe. Energy input in Germany is 5.06 GJ t^{-1} while in Portugal a lower yield of 0.72 - 0.80 t/ha is obtained at a lower energy input of 2.31 - 4.05 GJ/ha.

Cotton production takes place only in the Southern EU countries. The reported input-output energy balance is negative with a predominant energy input for irrigation. A high specific energy input of 15.4 GJ t^{-1} comes with an average yield of 4.5 t/ha.

Wheat (PEC)

Among cereals, wheat is the crop with the largest cultivated area in Europe. In 2008, the percentage share of the area occupied by common and durum wheat in the countries at issue ranged from 2.4% in Portugal to 18.9% in Germany (Table 6). In the countries at issue, 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.

Table 6: The energy input (PEC) in wheat production in different countries (average scenarios).

Country	Production area	Share in EU-27	Yield	Specific energy inputs		Total PEC
	x 1000 ha	(%)	t ha^{-1}	GJ·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

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 2.5 to 8.7 tons per ha. There is a tendency for higher energy uses to be associated with higher yields which becomes clear in Figure 7, where all the scenarios for wheat production as mentioned in Table 5 are included.

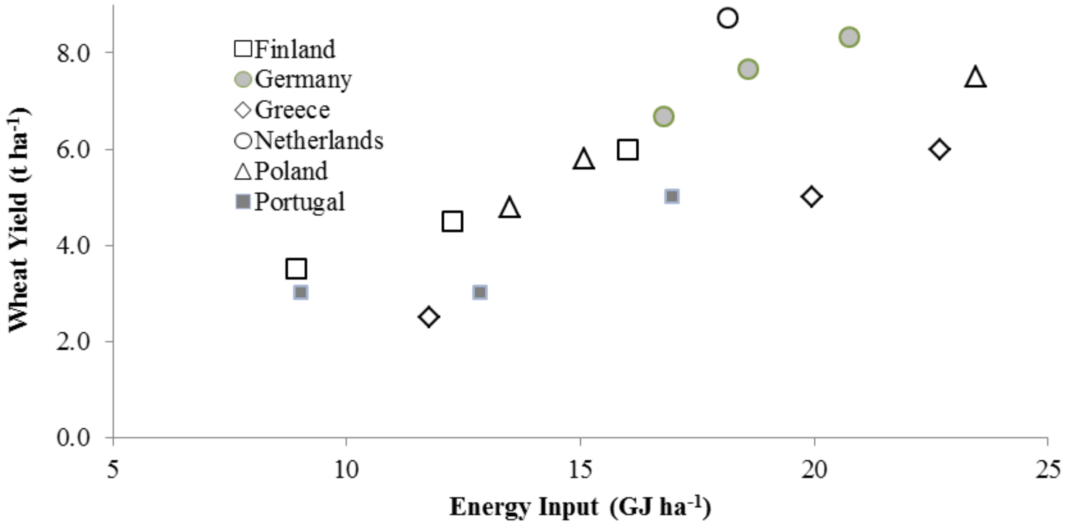

Figure 7: The relation of the total energy inputs in GJ·ha^{-1} and yields in t ha^{-1}

The results of Data Envelopment Analysis (DEA)[6] of energy efficiency for average scenarios presented in the Figure 8 shows that the six study countries may be divided into three groups. The first group is composed of the Central EU countries – the Netherlands with the highest energy efficiency (100%) and Germany (83%). The second group is composed of the North-eastern EU countries Finland and Poland with 72% and 70% of the Dutch efficiency. The third group of energy efficiencies consists of the Southern EU countries Greece (67%) and Portugal (55%).

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[6] Charnes A., Cooper W., Rhodes E. 1978. Measuring the efficiency of decision-making units. European Journal of Operational Research, 2: 429–444.

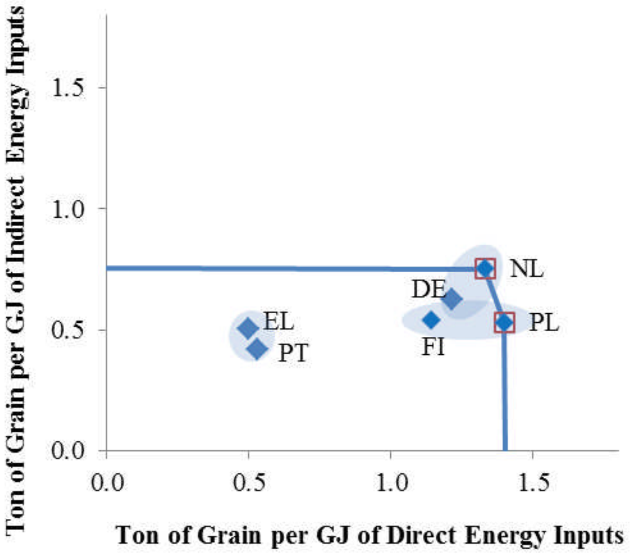

Figure 8: The efficiency of energy use in relation between ton of grain per GJ of direct and indirect energy inputs.

In wheat production the main energy input is associated with the use of fertilizers as can be seen in Figure 9. The energy inputs required for the use of fertilizers ranged from 6.3 GJ·ha^{-1} in Portugal to 11.2 GJ·ha^{-1} 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 (only in the high input scenario) and Finland the additional energy on wheat production has been associated with drying and in the Southern countries Portugal and Greece – with irrigation.

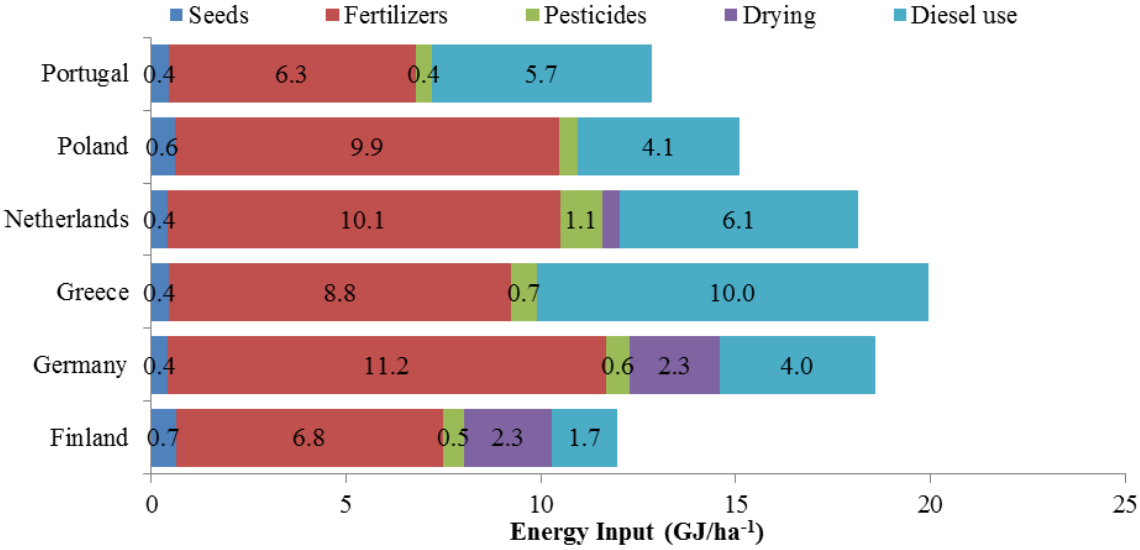

Figure 9: The structure of energy inputs in wheat production in GJ·ha^{-1}.

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.

The percentage share-based distribution of the primary energy consumption (PEC) in wheat production by process is given in Figure 10. Absolute values of energy inputs (in GJ per ha and in GJ per ton) for the various process steps can easily be calculated using data from Table 6 and Figure 9. For example, in Finland, Germany, and the Netherlands 18.8%, 12.4%, and 2.5%, respectively, of the energy inputs is required for drying. In terms of specific energy input, these figures correspond to 0.50 GJ t^{-1}, 0.30 GJ t^{-1}, and 0.05 GJ t^{-1} of marketable wheat in the three countries. The higher value in Finland results from the higher moisture content at harvest. Only in the high energy use scenario in Poland, energy inputs for drying have been assumed and in Greece and Portugal - for irrigation (Annex, Table 24).

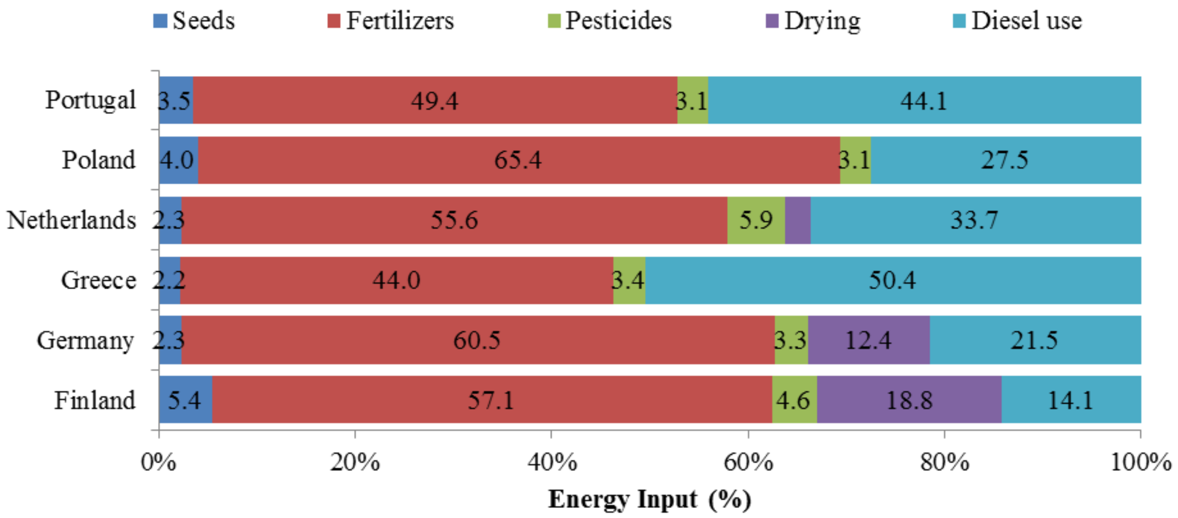

Figure 10: The percentage share-based distribution of specific energy use (PEC, in GJ t^{-1}) in wheat production by process (average scenarios).

Sugar Beet (PEC)

The land covered by sugar beet in Germany, Poland and the Netherlands has accounted for 364.7, 247.4 and 89.5 thousand hectares, respectively (Table 7). Among these countries the highest yield of roots 67.1 t·ha^{-1} is reported by the Netherlands at the lowest energy inputs per hectare 13.7 GJ·ha^{-1} and the highest energy input per ton (0.204 GJ t^{-1}). In Germany and Poland yields have been at the same level (60.3 and 60.0 t·ha^{-1}), but obtained at different energy inputs. In Germany, the total energy use has accounted for 14.0 GJ·ha^{-1} with an input of 0.235 GJ per ton of roots, while in Poland total energy use was 17.2 GJ·ha^{-1} corresponding to 0.286 GJ t^{-1}, (22% higher).

Table 7: The energy input (PEC) for sugar beet production by country (average scenarios)

Country	Production area	Yield	Specific energy inputs		Total PEC
	x 1000 ha	t·ha^{-1}	GJ·ha^{-1}	GJ·t^{-1}	PJ
Germany	364.1	60.9	14.0	0.231	5.11
Netherlands	89.5	67.1	13.7	0.204	1.23
Poland	247.4	60.0	17.2	0.286	4.25

Regardless of the country, the structure of energy inputs has only been slightly variable (Figure 11). Over 50% of the total energy use has been associated with synthetic fertilizer use: 9.0 GJ·ha^{-1}, 7.2 GJ·ha^{-1}, and 9.9 GJ·ha^{-1} in Germany, the Netherlands and Poland, respectively. Further differences among these countries have been posted by the energy input related to pesticides, that has ranged from 0.1 GJ·ha^{-1} in Germany to 1.2 GJ·ha^{-1}in the Netherlands and 1.1 GJ·ha^{-1} in Poland and diesel use has been the second main energy input ranging from 4.8 GJ·ha^{-1} in Germany, 5.2 GJ·ha^{-1} in the Netherlands and 6.1 GJ·ha^{-1} in Poland. It seems that the higher energy efficiency (lower specific energy input) in the sugar beet production in the Netherlands in comparison with the other two countries results from a relatively lower fertilizer use level.

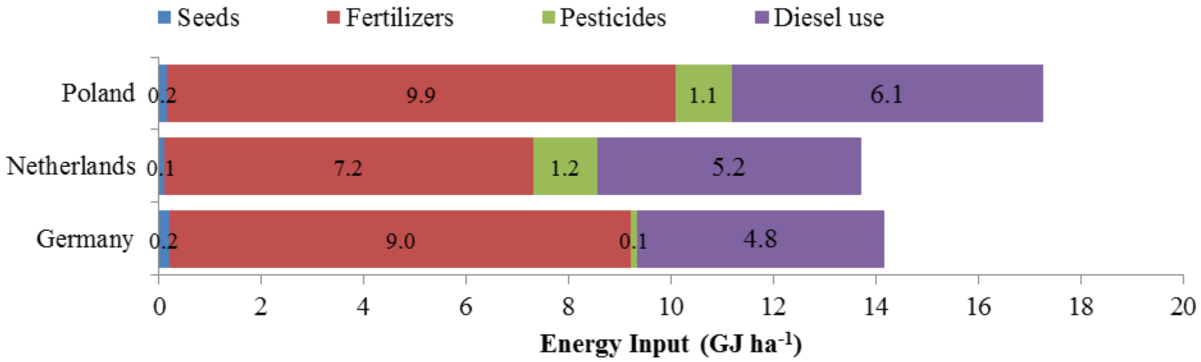

Figure 11. The structure of energy inputs in sugar beet production.

Potatoes (FEC)

Potatoes for consumption are grown in large areas in Poland, Germany, and the Netherlands (523, 244, and 73 thousand hectares, respectively) (Table 8). Similar energy efficiency production is in Poland and Germany where one ton of potatoes requires energy inputs of 0.627 GJ and 0.634 GJ, respectively. In the Netherlands the yield has been about 8 t ha^{-1} higher than in Germany but this level of production has consumed a high amount of energy, 44.8 GJ·ha^{-1}each ton in the Netherlands required 0.893 GJ of energy, a 41% higher input on average. Quite different indicators are characteristic for production of potatoes in Poland, where the yields have accounted for about 55% of the yield in the Netherlands and 66% of the yield in Germany, but energy use is only 16.9 GJ per hectare.

Table 8: The energy input (PEC) for potato production by country (average scenarios).

Country	Production area	Yield	Specific energy inputs		Total PEC
	x 1000 ha	t·ha^{-1}	GJ·ha^{-1}	GJ t^{-1}	PJ
Germany	244.400	42.4	26.9	0.634	6.57
Netherlands	73.053	50.2	44.8	0.893	3.27
Poland	529.500	27.0	16.9	0.627	8.95

The low yield of potatoes in Poland with the reported relatively low specific energy input per ton of product is obtained on light soils located in the Eastern and Central parts of Poland – the soils are commonly used for potato production and require relatively low energy inputs for cultivation. In Polish agricultural practice, energy use for storage of potatoes is done only on a small number of farms that specialize in retail potato production (the high energy inputs scenario). Similarly, in Germany, only the scenario with high energy input assumes energy consumption for storage.

The disproportion between the country data and a general tendency of close interrelationship between the level of energy inputs and resulting yield of potatoes in different energy inputs scenarios is presented in the Figure 12.

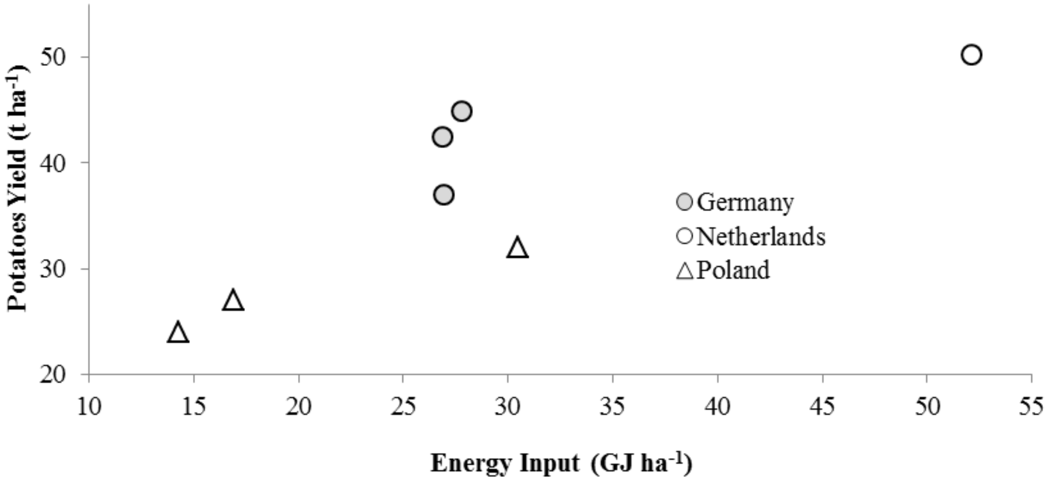

Figure 12: The relation of total energy inputs in GJ·ha^{-1} and yields in t ha^{-1}

In Figure 13 the energy use is shown for different production inputs. Remarkable differences can be witnessed among the countries:

- the absence of energy use in potato storage in Poland (the input is reported only in the high energy input scenario).
- the high diesel use in the Netherlands (222 L per ha compared to 145 L in Poland and 146 L in Germany).
- the relatively high use of fertilizers and energy for storage in the Netherlands.

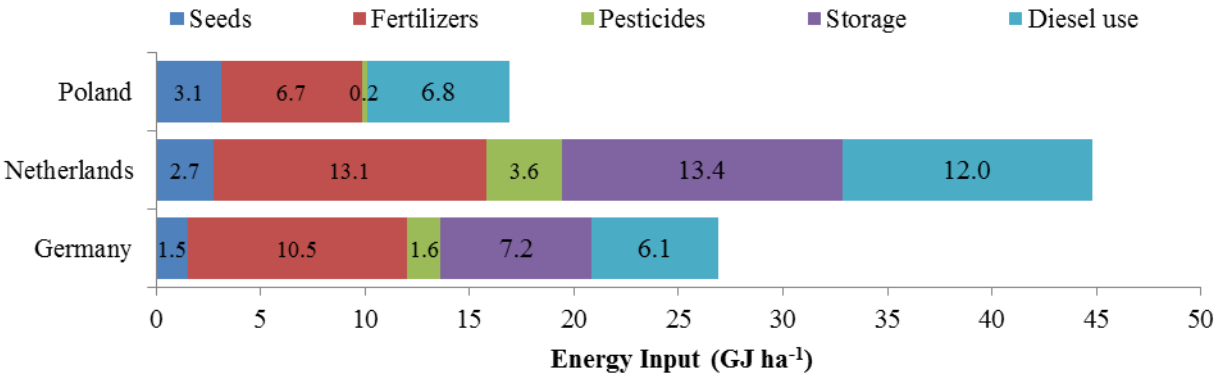

Figure 13. The structure of energy inputs for potato production (average scenarios).

Sunflower (PEC)

The energy inputs for production of sunflower seed has been reported by Germany and Portugal (Table 10). In the countries the area planted with sunflower has accounted for 26.5 and 24.9 thousand hectares, respectively. The average yield in Germany (2.31 t·ha^{-1}) requires specific energy inputs of 11.7 GJ·ha^{-1} and 5.06 GJ t^{-1}. In Portugal, two scenarios with low and high energy inputs have been assessed. They correspond to the variants without tillage and with tillage, respectively. The yields in the two scenarios have amounted to 0.72 t·ha^{-1} and 0.85 t·ha^{-1} and were three-fold lower than in Germany, but were obtained with lower specific energy inputs of 3.20 GJ t^{-1} and 4.76 GJ t^{-1}, respectively.

Table 9: The energy use (PEC) for sunflower production by country and production scenarios.

Country	Scenario	Production area	Yield	Specific energy inputs		Total PEC
		x 1000 ha	t·ha^{-1}	GJ·ha^{-1}	GJ t^{-1}	PJ
Germany	average	26.5	2.31	11.69	5.06	0.310
Portugal	low	24.0	0.72	2.31	3.20	0.056
	high		0.85	4.05	4.76	0.097

In Germany, the variable part of the inputs has been direct energy inputs (drying and diesel use) amounting in the average scenario to 3.49 GJ·ha^{-1}, while indirect energy inputs have been at a similar level. This variation has resulted from various energy inputs for drying from 0.2 to 2.0 GJ·ha^{-1} (Annex: Table 30). A great disproportion in the amount of energy use per hectare and the structure of energy inputs in Germany and Portugal are presented in Figure 14. In Portugal there is only one important energy input – diesel use, which accounts for 84% (the low energy input scenario) and 95% (high energy input scenario) of total energy inputs. In the scenarios under consideration indirect energy inputs have no significant impact on sunflower production because they are associated only with seed and herbicide application in the no–till, low energy scenario.

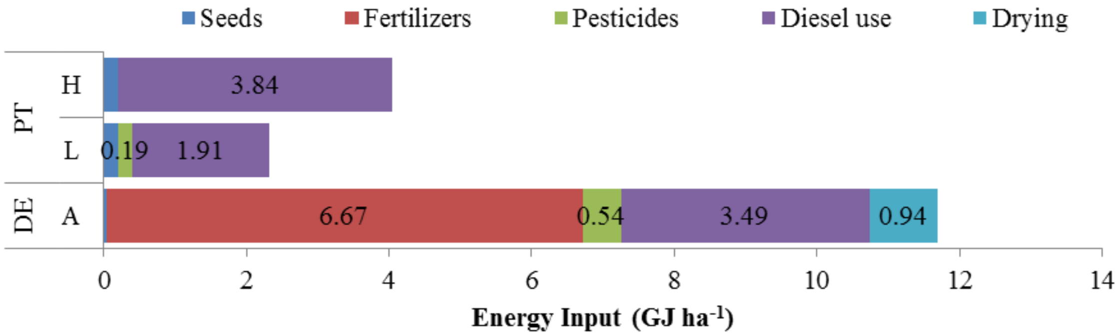

Figure 14: The structure of embodied energy inputs per hectare in sunflower production (L, A, H – Low-Average-High energy inputs scenarios).

Cotton (PEC)

In the countries of issue, cotton production takes place in Greece where the crop is cultivated on 370 thousand hectares. In the average scenario the total energy use has stood at 69.5 GJ·ha^{-1} and ranged from 68.1 GJ·ha^{-1} in the low energy input scenario to 85.8 GJ·ha^{-1} in the high energy input scenario (Table 10). In comparison to other crops, this energy use is very high. The cotton fiber yield has varied in the range from 3.2 t·ha^{-1} to 4.5 t·ha^{-1} depending on scenarios and the specific energy input has ranged from 15.4 GJ t^{-1} in the average energy input scenario to 26.8 GJ t^{-1} in the high energy input scenario. It should be noted that in the high energy input scenario, the yield is relatively low at 3.2 t·ha^{-1}.

Table 10: The energy use (PEC) for cotton production in Greece (the three energy input scenarios).

Country	Scenario	Production area	Yield	Energy inputs			Specific energy input	Total PEC
				direct	indirect	total		
		x 1000 ha	t ha^{-1}	GJ·ha^{-1}			GJ t^{-1}	PJ
Greece	low	370	4.0	61.1	7.1	68.1	17.0	25.2
	average		4.5	61.1	8.5	69.5	15.4	25.7
	high		3.2	68.5	17.4	85.8	26.8	31.8

The direct energy is consumed for irrigation 43.1-49.3 GJ·ha^{-1} and diesel use is consumed at 18.0-19.1 GJ·ha^{-1}, and the main indirect energy input is associated with fertilizers; 4.5-11.5 GJ·ha^{-1} (Table 10, Figure 15). The main variable factors of energy input in the scenarios are associated with fertilizers and irrigation, where both are about an extra 6 GJ ha^{-1}.

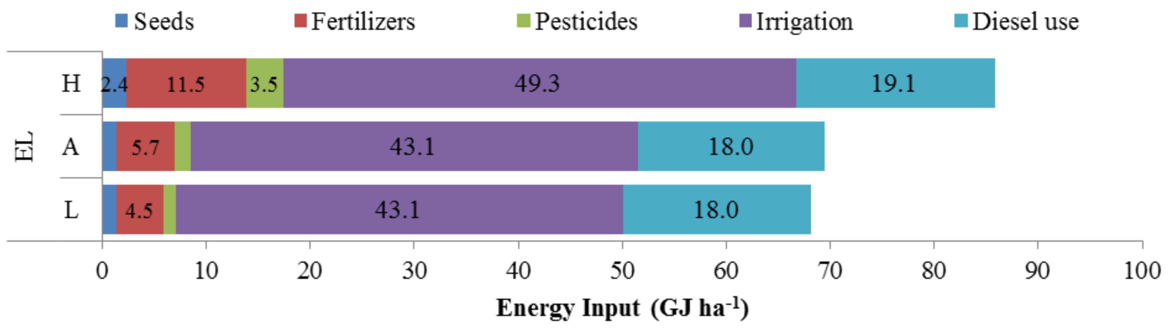

Figure 15. The structure of energy inputs in cotton production (L, A,-H – low-, average-, and high energy inputs scenarios).

The percentages shares of energy used in the production process are listed in Table 11. Regardless of the scenario the two main energy inputs are associated with irrigation (57.5-63.2%) and diesel use (22.3-26.4%). The two inputs tend to be proportionally lower when the energy inputs increase. At the same time energy inputs associated with fertilizers tends to increase significantly from 6.6% in the low inputs scenario to 13.4% in the high inputs scenario.

Table 11: The percentage share-based distribution of primary energy consumption (PEC) in cotton production by process.

Country	Scenario	Seeds	Fertilizers	Pesticides	Irrigation	Diesel use
Greece	low	1.9	6.6	1.8	63.2	26.4
	average	1.9	8.1	2.1	61.9	25.9
	high	2.8	13.4	4.1	57.5	22.3

Greenhouse production – key points

Across European study countries the highest primary energy consumption in greenhouse production is in the Netherlands (Figure 16). In the country the total primary energy consumption by tomato, sweet pepper and cucumber production account for 25.64 PJ, 15.00 PJ, and 9.44 PJ, respectively. In Germany, greenhouse production use 3.61 PJ in tomato production and 3.32 PJ in cucumber production. From the Southern EU countries, the great amount of the total primary energy use 2.15 PJ is for tomatoe production in Greece given if the production is at the relatively low specific energy use 2 GJ t^{-1}.

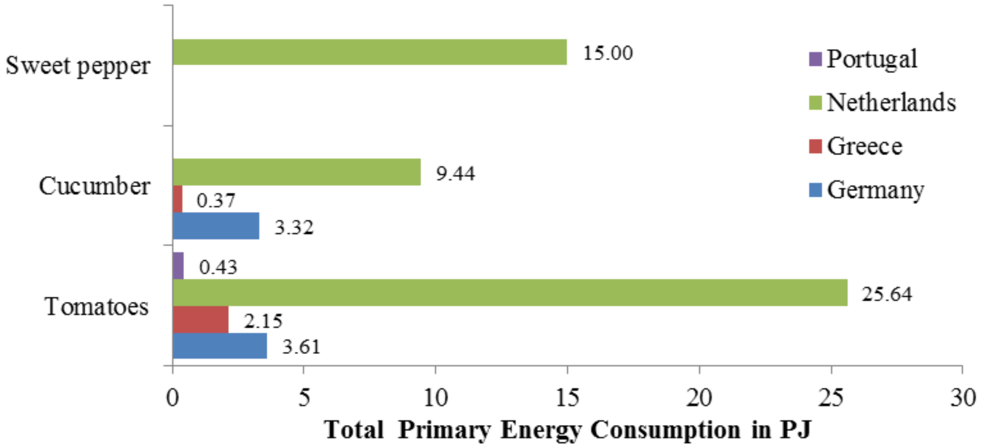

Figure 16. Total energy consumption (weighted means from scenarios) in greenhouse production by country.

Tomatoes and Cucumbers. The specific energy input for greenhouse production of tomatoes and cucumbers is specific for the two distinct regions – the central, temperate zone, countries represented by the Netherlands and Germany and the Southern European countries represented by Greece and Portugal. In Central Europe the direct energy input is predominant accounting for over 99% of the total energy input, while in the Southern countries it accounts for 10-40% of the total energy input (Figure 17).

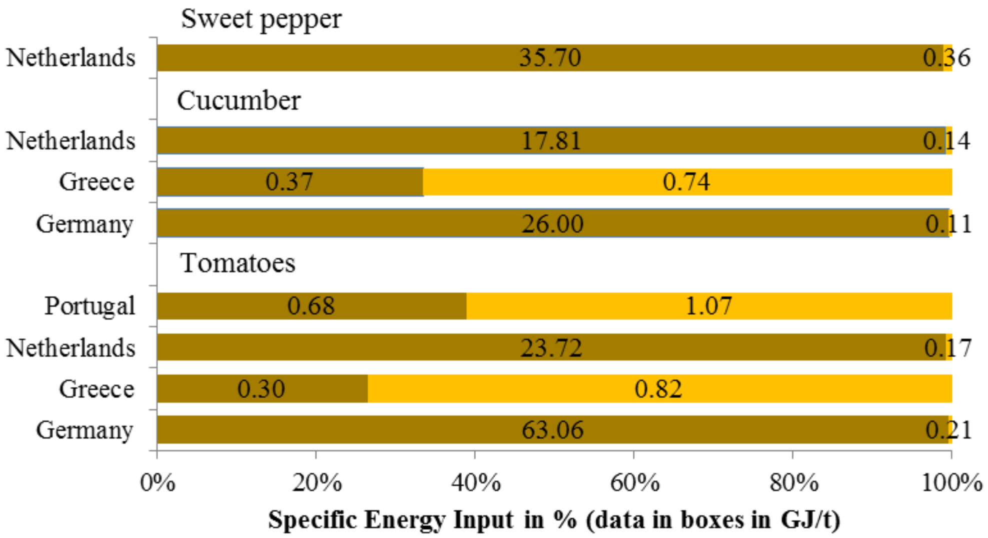

Figure 17. Direct (darker boxes) and indirect specific energy input in crop production by country (average scenarios).

In Portugal, the indirect energy input is associated with application of greenhouse materials (substrates), pesticides and irrigation, while in Greece it is associated with greenhouse materials (thermal screens, solarisation and Low Density Polyethylene, LDPE, films) and fertilizers. In the temperate zone countries, tomatoes and cucumbers are produced at a very high specific energy input of 63.3 and 26.1 GJ t^{-1} (12654 and 13053 GJ/ha) in Germany. The equivalent values for the Netherlands are 29.0 and 20.1 GJ t^{-1} (15110 and 15074 GJ/ha) for tomatoes and cucumber. In Greece and Portugal, the specific energy inputs for tomato production are 2.0 and 3.1 GJ t^{-1}, respectively. In Greece, a value of 0.9 GJ t^{-1} was determined for cucumber production.

Sweet Pepper. A high specific energy input of 36 GJ t^{-1} (11539 GJ/ha) has been determined for the production of sweet pepper at an average yield of 320 t/ha (The Netherlands).

Tomatoes (PEC)

Tomato is an important crop in the greenhouse production of many EU countries. Data has been collected in two temperate zone countries (Germany and the Netherlands) and two southern Mediterranean climate countries (Greece and Portugal). The summary data in Table 13 shows large variation in energy use between the two temperate zone countries as compared to the southern countries. In these two latter countries, tomato areas have accounted for 2.5 thousand hectares in Greece and 1.44 thousand hectares in Portugal, where the majority of the tomato production takes place in conventional soil unheated greenhouses. In Portugal, the scenarios assume low and high energy inputs when tomato is grown on soil and in hydroponics respectively. In the low energy inputs scenario, 150 ton of tomatoes per hectare require 99 GJ·ha^{-1} and typical energy use per ton is 0.66 GJ. In comparison, tomatoes grown with hydroponics require nearly four times more energy with the typical energy input at 2.23 GJ t^{-1}. In Greece the typical energy use is 257 GJ·ha^{-1} or 1.12 GJ t^{-1}.

The structure of energy inputs in these two countries has many components (Figure 18). In Portugal, the big percentage share of energy inputs is associated with application of greenhouse materials (substrates), pesticides and irrigation, while in Greece over 50% of energy has been consumed in the greenhouse aselectricity followed by materials (thermal screens, solarisation and LDPE films) and fertilizers.

The scale of tomato production and energy use in the temperate zone countries, Germany and the Netherlands, is quite different. The total greenhouse area of tomato production in Germany is 285 and in the Netherlands – 1676 hectares. The production is with the very high energy inputs of 12654 GJ·ha^{-1} in Germany and 15110 GJ·ha^{-1} in the Netherlands (Table 12). Following a large difference in the yield on a per hectare basis between both countries, 200 t·ha^{-1} in Germany and 640 t·ha^{-1} in the Netherlands, the typical energy input in Germany amounted to 65.2 GJ t^{-1} which is over two-fold higher than in the Netherlands.

Table 12: The energy input (PEC) for tomato greenhouse production by country (average scenarios).

Country	Scenario	Production area	Yield	Specific energy input		Total PEC
		x 1000 ha	t ha^{-1}	GJ·ha^{-1}	GJ t^{-1}	PJ
Germany	average	0.285	200	12654	63.3	3.6
Greece	average	2.500	230	257	1.12	0.64
Netherlands	average	1.676	640	15110	23.6	25.3
Portugal	low	1.440	150	99	0.66	0.14
	high		200	446	2.23	0.64

In Germany and the Netherlands energy inputs are dominated by the direct energy use (electricity or natural gas) while other energy inputs are marginal. The prevailing direct energy inputs for the greenhouse industry are used to provide heat to keep the right temperature in the greenhouse, ventilation and air circulation, cooling and humidification, carbon dioxide enrichment, irrigation and fertilizer application, and others.

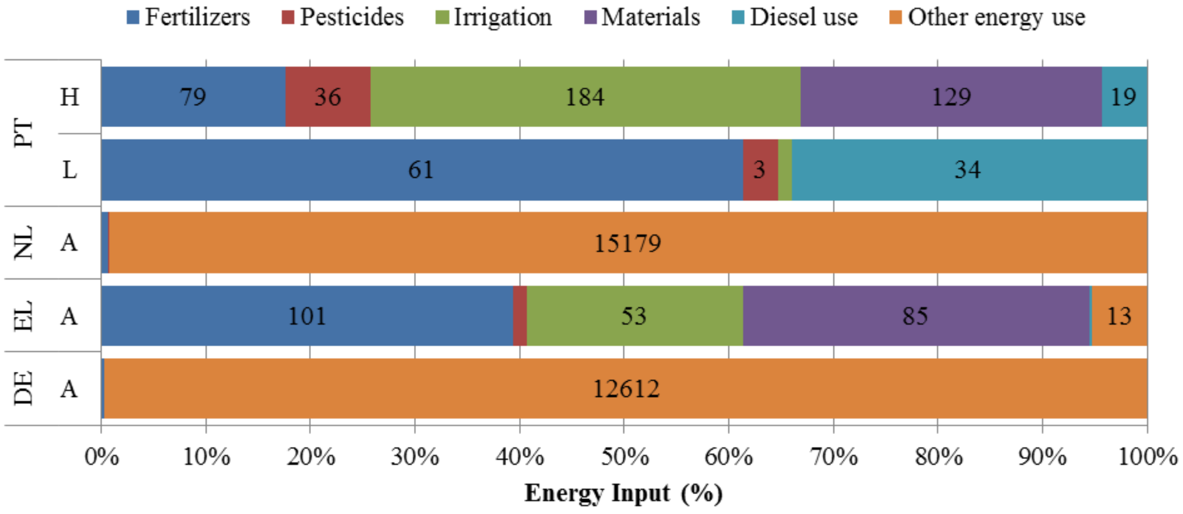

Figure 18. The structure of energy inputs in tomato production (the figures in boxes are in GJ·ha^{-1})

Cucumbers (PEC)

The production of cucumber in the countries at issue varies as far as the yield and specific energy input are concerned (Table 14). In Greece, the production has occupied 1.8 thousand hectares and in Germany and in the Netherlands the total area accounts for 254 and 626 hectares. The yield of cucumber in Greece, where two scenarios with low and high energy inputs are assumed, has accounted for 200 t·ha^{-1} and 300 t·ha^{-1}, respectively. In Germany and the Netherlands the productivity has been significantly higher with 500 t·ha^{-1} and 800 t·ha^{-1}, respectively. The total energy input for production was highest in the Netherlands, with 14360 GJ per hectare, which is comparable to the energy level of 13053 GJ·ha^{-1} in Germany. Both countries have considerably higher energy consumption for cucumber production than Greece, as the Mediterranean country. The specific energy inputs in the temperate region countries: Germany and the Netherlands are similar, whereas the specific energy input for a cucumber production in Greece is much lower.

Table 13: The energy input (PEC) for cucumber greenhouse production by country (average scenarios)

Country	Scenario	Production area	Yield	Specific energy inputs		Total PEC
		ha	t·ha^{-1}	GJ·ha^{-1}	GJ t^{-1}	PJ
Germany	average	254	500	13053	26.11	3.316
Greece	low	1800[1]	300	212	0.71	0.382
	high		200	285	1.42	0.513
Netherlands	average	626	800	14360	17.95	8.989

[1] Eurostat

The structure of energy use for the cucumber production in Germany and the Netherlands has been dominated by the direct energy use (natural gas and electricity), mostly for heating. In these countries the second main energy use component has been represented by fertilizers. In the low and high energy scenarios in Greece there have been three components – materials, i.e. solarisation and LDPE films (75 and 85 GJ·ha^{-1}), fertilizers (33 and 101 GJ·ha^{-1}) and energy use for irrigation (90 and 95 GJ·ha^{-1}) (Figure 19).

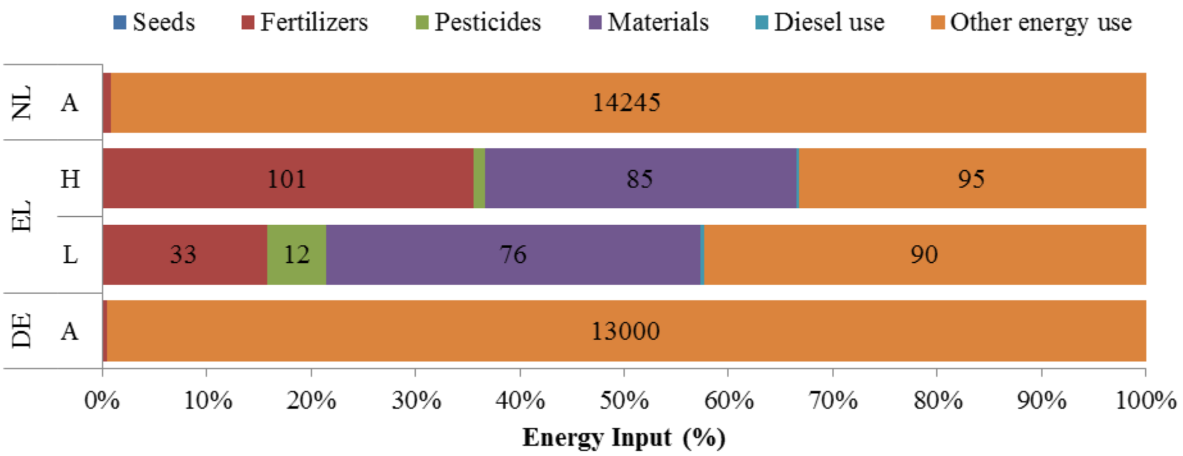

Figure 19. The structure of energy inputs in cucumber production (the figures in boxes are in GJ ha^{-1}).

Sweet pepper (PEC)

In the reported data on greenhouse sweet pepper production in the Netherlands the area under production accounted for 1330 hectares (Table 14) with 320 t·ha^{-1}, but it has been highly energy consuming (11539 GJ·ha^{-1}) meaning one ton of peppers required 36 GJ of total energy.

Table 14: The energy input (PEC) for sweet pepper greenhouse production (average scenario).

Country	Production area	Yield	Specific energy input		Total PEC
	ha	t·ha^{-1}	GJ·ha^{-1}	GJ t^{-1}	PJ
Netherlands	1330	320	11539	36.1	15.00

Direct energy inputs have accounted for 99% of the total energy inputs (Table 12). Among indirect inputs fertilizers, mostly nitrogen and potassium, accounted for the highest energy use. The percentage share occupied by other energy inputs (pesticides, CO_2 enrichment), although important for production, is marginal (Table 15).

Table 15: The structure of energy inputs in sweet pepper production, in GJ·ha^{-1}.

Energy inputs	GJ·ha^{-1}	Fertilizers	GJ·ha^{-1}	Pesticides	GJ·ha^{-1}
Seeds	0.0005	Nitrogen	89.3	Fungicides	1.6
Fertilizers	112.6	Phosphorus	5.1	Insecticides	0.8
Pesticides	2.5	Potassium	17.31		
Energy inputs	11424.0	Carbon dioxide	0.8		

Perennial production – key points

In the Southern EU countries the total primary energy consumption by perennial production contributes significantly to the total energy use in agriculture. Olives production in Greece share 5.59 PJ and in Portugal 4.03 PJ and in comparison with vineyard production the figures are two-fold higher (Figure 20). The subsector of vineyard production is present in the Central EU countries and in Germany accounts for 2.16 PJ.

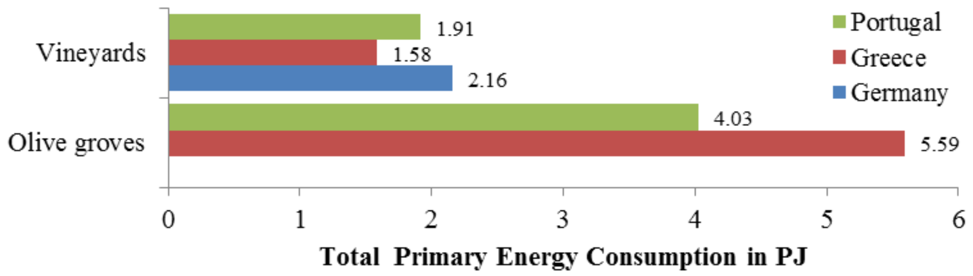

Figure 20. Total energy consumption (weighted means from scenarios) in perennial production by country.

The ratio of direct to indirect energy inputs is country specific. In the olive grove production in Greece and vineyard production in Germany the ratio of direct to indirect energy inputs is 3-4:1 while in Portugal the ratio is 2:3 for olives production and 1:1 for vineyard production (Figure 21).

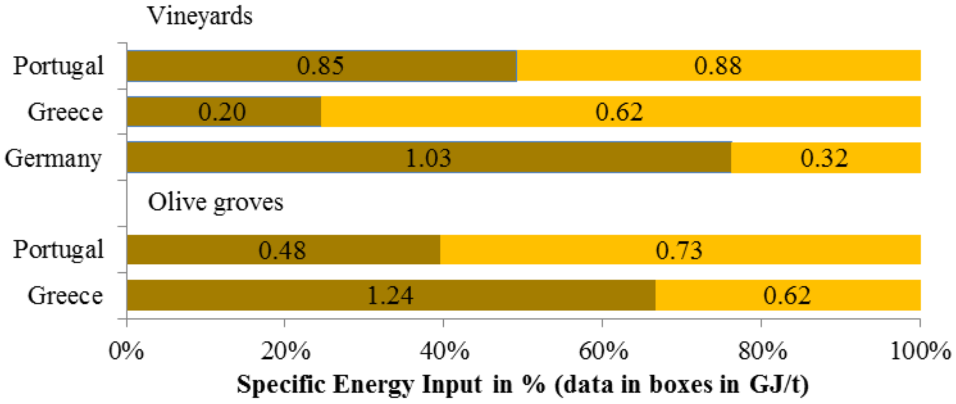

Figure 21: Direct (darker boxes) and indirect energy inputs in perennial production by country (average scenarios).

Olive Groves. In the southwest EU country (Portugal) olives are produced in significantly higher yield per hectare, but at a lower energy efficiency than in the southeast EU country (Greece). More specifically, the olive yield in Portugal amounts to 8.0 t/ha and is obtained with a specific energy input of 1.21 GJ t^{-1}. In comparison the yield in Greece is lower, reaching 5.5 t/ha (lower by 31%), but also the specific energy input is lower at 1.07 GJ t^{-1} by 11%..

Vineyards. The most energy efficient production of grapes for wine is in Greece where the yield of 20.0 t/ha is produced at a specific energy input of 0.82 GJ t^{-1}. The yield in Germany amounts to 15 t/ha with a higher energy input of 0.53 GJ t^{-1}. The production system of quality wines in Portugal assumes reduction of yield by pruning of fruits in early growth stages giving 4.5 - 7.5 t/ha at the corresponding specific energy input of 2.49 GJ t^{-1} - 1.39 GJ t^{-1}, respectively. Such production requires a high amount of energy associated with pesticides, which in Portugal accounts for between 8.7% and 70.2% of the total energy input. The similar scenario of the vineyards production system in Greece assumes a yield of 14 t/ha at an energy input of 1.08 GJ t^{-1} with high amount of energy used for irrigation (59%). In Greece and Germany fertilizers and diesel are the main energy inputs. In Greece, the main energy input stems from fertilizers (56%) whereas in Germany, energy input arising from diesel use is predominant (70-78%).

Olive groves (PEC)

The energy use for olive production has been reported by the Southern EU countries Greece and Portugal. In these countries the areas covered by olive groves, producingolives, accounted for 765.0 and 335.8 thousand hectares, respectively (Table 16). In the average scenario the olive yield per hectare in Portugal is 8.0 t·ha^{-1} where it is 2.5 t·ha^{-1} higher than in Greece, and was obtained with a higher energy input of 9.7 GJ·ha^{-1} in comparison with 5.9 GJ·ha^{-1} in Greece. Thus the specific energy input in these countries varies from 1.21 GJ t^{-1} in Portugal to 1.07 GJ t^{-1} in Greece.

Table 16: Energy input (PEC) in olive production in Greece and Portugal (average scenarios).

Country	Production area	Yield	Specific energy input		Total PEC
	x 1000 ha	t·ha^{-1}	GJ·ha^{-1}	GJ t^{-1}	PJ
Greece	765.000	5.5	5.9	1.07	4.50
Portugal	335.841	8.0	9.7	1.21	3.25

The structure of energy use for the average scenarios has varied considerably in the countries under consideration (Figure 22). Firstly, in Greece fertilizers (4.29 GJ·ha^{-1}) was followed by 1.07 GJ·ha^{-1} of diesel used for field operations and were the major energy inputs. In Portugal, three energy inputs shape the total energy use – diesel at 3.84 GJ·ha^{-1}, pesticides for 2.56 GJ·ha^{-1}, and fertilizers for 2.34 GJ·ha^{-1}. The main differences between the two countries result from:

- in Greece fertilizer use is significantly higher than in Portugal,
- in Portugal chemicals in plant protection are widely used and therefore higher energy consumption is allocated to this energy inputs,
- in Greece, there is no irrigation, when in Portugal it is applied.

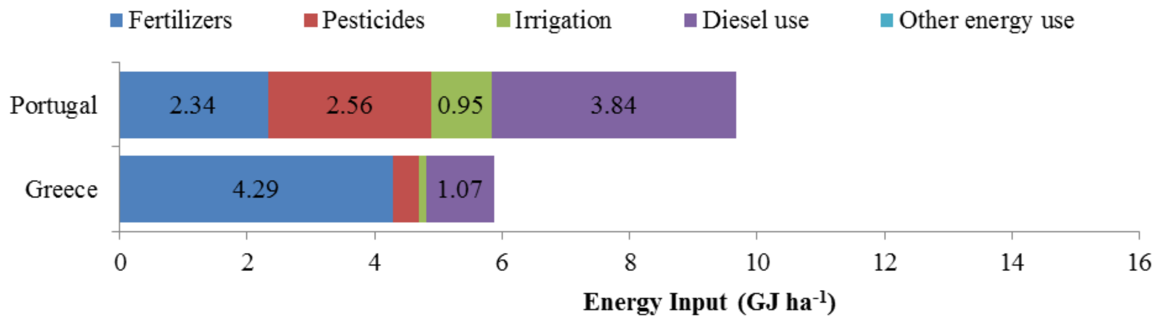

Figure 22. The structure of energy inputs in GJ per hectare for olive production (average scenarios).

Vineyards (PEC)

In the countries considered energy use in vineyards has been reported by Germany, Greece, and Portugal with areas of 102.3, 99.3, and 177.8 thousand hectares, respectively (Table 17). According to the Eurostat data (2010) the average production in Greece is 10.1 t·ha^{-1}, which is lower than the values reported here but can be explained by the Eurostat statistics also including the low intensity wine production of the Greek islands.

In the average energy input scenario for Germany the yield of grapes harvested for wine production is 15 t·ha^{-1} and associated energy inputs amounts to 20.3 GJ·ha^{-1}. In the Southern EU countries (Greece and Portugal) the yield and energy inputs vary greatly. In Greece, the yield is relatively high (20 t·ha^{-1}) and is obtained with a relatively low energy input of 16.3 GJ·ha^{-1}. In Portugal, the data has been reported only for low (lower level of machinery use) and high (higher level of machinery use) energy inputs scenarios in which the yield of 4.5 t·ha^{-1} and 7.5 t·ha^{-1} is produced with energy inputs of 11.5 GJ·ha^{-1} and 10.5 GJ·ha^{-1}, respectively. As far as grape production is concerned, it should be noted that in Portugal wine processing begins in the field. Grape production is reduced by pruning the fruit bunches in the early growth stages to decrease yields in order to give better fruit quality for the production of quality wines.

Among the three study countries the specific energy input is relatively low in Greece 0.82 GJ t^{-1}. In Germany the specific energy inputs is 1.35 GJ t^{-1} and in Portugal – 2.49 GJ t^{-1} and 1.39 GJ t^{-1} in the low and high energy inputs scenarios, respectively. The reason for the lower specific energy input in the high energy input scenario in Portugal stems from the fact that this scenario of vineyard production assumed labour-related work which was not considered in the approach[7].

Table 17: The energy input (PEC) in vineyard production (for wine) by country (average scenarios).

Country	Scenario	Production area	Yield	Specific energy input		Total PEC
		ha	t·ha^{-1}	GJ·ha^{-1}	GJ t^{-1}	PJ
Germany	average	102.340	15.0	20.3	1.35	2.08
Greece	average	99.286	20.0	16.3	0.82	1.62
Portugal	low	177.829	4.5	11.2	2.49	1.99
	high		7.5	10.5	1.39	1.86

The main energy input in Germany is diesel use which stands at 15.4 GJ·ha^{-1} (76%), in Greece – energy input associated with fertilizers stands at 9.1 GJ·ha^{-1} (56%), and in Portugal – the energy input associated with pesticides (mostly fungicides) stands at 7.9 GJ·ha^{-1} (70.2%) and 2.3 GJ·ha^{-1} (8.7%), for the low and high energy inputs scenarios, respectively (Figure 23).

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[7] The data reported by Portugal assumed two different production systems based on different topographic characteristic of the Alentejo and Douro regions. For the low input scenario it was assumed lower machinery use and higher input of labour work (Douro), For the high input scenario it was assumed higher level of mechanization (Alentejo)

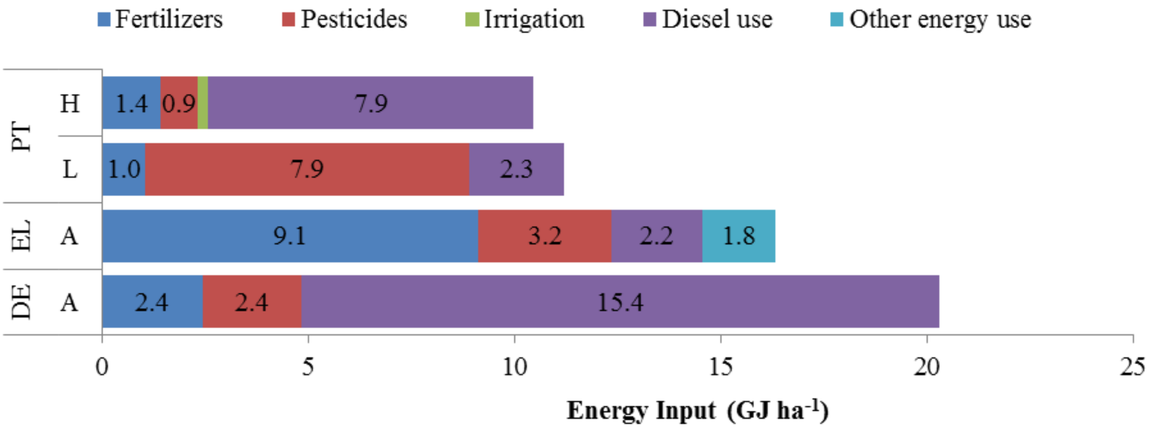

Figure 23. The structure of energy inputs in vineyard production (average scenarios).

Livestock production – key points

The livestock subsectors comprise a great share of primary energy consumption in agriculture and they are equaly important in any EU countries. The most energy consuming subsector in study countries is milk production followed by pig and broiler production (Figure 24). The scale of primary energy consumption depends on the country. The highest absolute quantity of primary energy consumption by livestock production is in Germany. In this country dairy cow, pig and broiler production account for 94.58 PJ, 43.23 PJ, and 6.93 PJ, respectively.

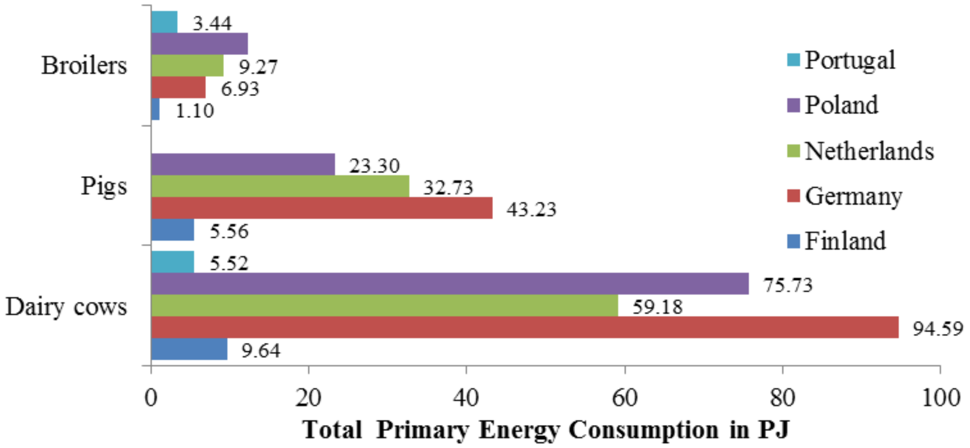

Figure 24. Total energy consumption (weighted means from scenarios) in livestock production by country.

The proportion between direct and indirect energy use in dairy cow production is very similar at the ratio of 2:3 (Figure 25). It points out that energy saving potential in milk production will result from the activity in the both groups of the inputs. In pig and broiler production the ratio is in the range from 1:5 to 2:3. Thus, the highest potential in energy savings will have reduction of indirect inputs.

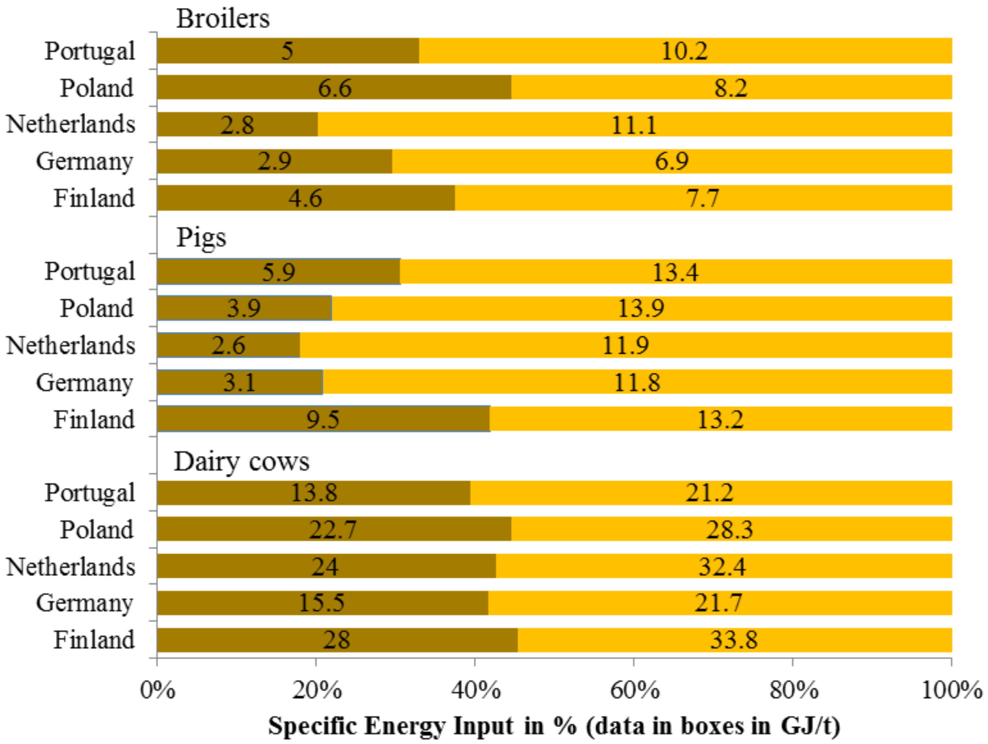

Figure 25. Direct (darker boxes) and indirect specific energy input in livestock production by country (average scenarios).

Dairy Cows (milk). Across these six EU countries the average energy input for milk production is in the range from 2.71 GJ t^{-1} (Germany) to 5.05 GJ t^{-1} (Poland). The main energy input for milk production is energy associated with feed (60-85%) and direct energy consumption. The latter varies by country, i.e. diesel use for transport and farm operations in the Netherlands, Poland and Portugal, electricity use for milk storage in Germany, and electricity and wood chips used for heating water and cowsheds (buildings) in Finland.

Pigs. The specific energy input in pork production is in the range from 14.5 GJ t^{-1} in the Netherlands to 22.6 GJ t^{-1} in Finland. The indirect energy input is associated mostly with piglet production (19-30%) and feed (38-62%). Direct energy use is, again, specific for the countries – diesel use in Poland (11.1-11.8%), wood chips in Finland (35%) and electricity use in the other countries the Netherlands 7%, Germany 10%, and Portugal 21%.

Broilers. The specific energy input in chicken meat production accounts for 9.8 GJ t^{-1} in Germany, 12.3 GJ t^{-1} in Finland, 8.9 - 12.6 GJ t^{-1} in Portugal, 14.0 GJ t^{-1} in the Netherlands, and 14.8 GJ t^{-1} in Poland. There is no clear regional difference in the energy use for broiler meat production, except for Portugal where over 90% of total energy input is associated with feed. In the other production systems energy for feed requires 53-74% of the total energy input.

Dairy Cows (PEC)

The national herd sizes in the countries considered accounted for over 4 million in Germany, 2.6 million in Poland, 1.8 million in the Netherlands, and close to 0.3 million in Portugal and Finland (Table 18). The average energy use per livestock unit (LU) ranged from 21.2 GJ/LU in Portugal to 33.8 GJ/LU in Finland. The most efficient energy use per ton of milk production was in Germany at 2.71 GJ t^{-1} and also the 3.28 GJ t^{-1} of Portugal. The most energy intensive production was in the Netherlands and Poland at 4.52 GJ t^{-1} and 5.05 GJ t^{-1} respectively.

Table 18: The energy input (PEC) for milk production by country (average scenarios).

Country	Dairy cows	Milk production	Specific energy input		Total PEC
	x 1000	t/LU	GJ/LU	GJ t^{-1}	PJ
Finland	288.800	8.8	33.8	3.86	9.75
Germany	4071.200	8.0	21.7	2.71	88.17
Netherlands	1800.000	7.2	32.4	4.52	58.28
Poland	2696.900	5.6	28.3	5.05	76.30
Portugal	278.416	6.5	21.2	3.28	5.91

The main energy inputs in dairy cow milk production were feed, accounting for 13.6 GJ/LU in Germany and Portugal and 25.0 GJ/LU in Finland (Figure 26). The other specific indirect energy inputs associated with using the buildings are reported in Germany to be 1.94 GJ/LU and 3.00 GJ/LU in Finland.

The second important input, common in all the countries under consideration, is associated with direct energy use. However the distribution of significant energy inputs in the overall energy balance vary by country, i.e. diesel use for transport and field operations in the Netherlands, Poland and Portugal, electricity use for milk storage in Germany, and in Finland wood chips used for heating water and buildings.

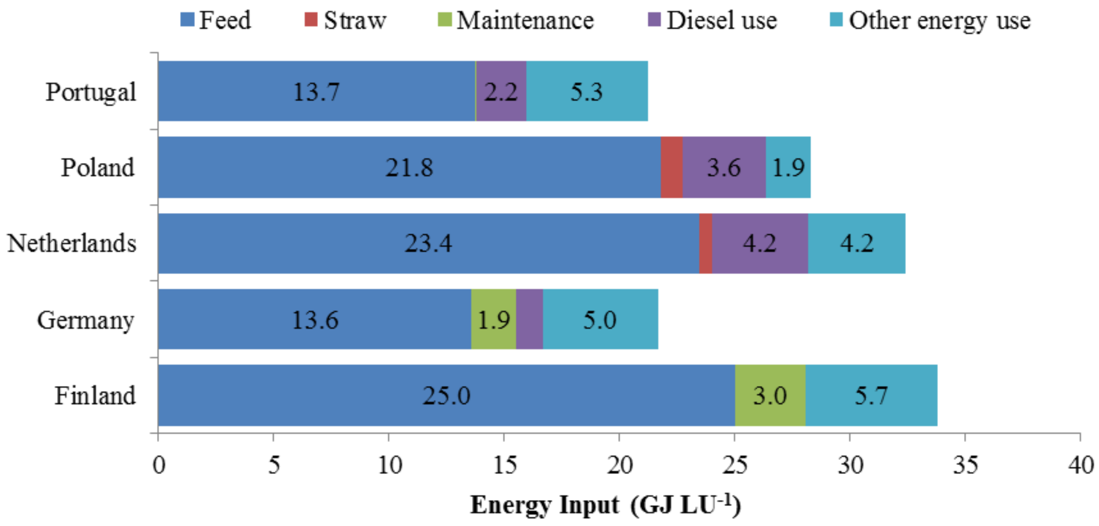

Figure 26. The structure of energy inputs in dairy cow production.

Pigs (PEC)

Among the countries considered the highest number of pigs and the highest total meat production, i.e. 27 million of pigs, is recorded for Germany (Table 19). The second largest, by population of pigs and meat production, is the Netherlands followed by Poland, amounting to 21 million and 12 million, respectively. The highest energy inputs for pork production are

22.6 GJ t^{-1} in Finland followed by 19.4 GJ t^{-1} in Portugal. On the other hand, the most energy efficient meat production is 14.5 GJ t^{-1} in the Netherlands and 14.9 GJ t^{-1} in Germany.

Table 19: The energy input (PEC) for pork production by country (average scenarios).

Country	No of pigs	Meat production[1]	Specific energy input	Total PEC
	x 1000	x 1000 t	GJ t^{-1}	PJ
Finland	2379.000	249795	22.6	5.66
Germany	27571.352	2894992	14.9	43.24
Netherlands	21500.000	2257500	14.5	32.69
Poland	12445.000	1306725	17.7	23.16
Portugal[2]	1913.161	200882	19.4	3.89

[1] the number of pigs was multiplied by 105 kg
[2] industrial production – high energy inputs

The highest energy input for pork production is associated with the energy stored in feed, ranging from 11.6 GJ t^{-1} in Finland to 13.9 GJ t^{-1} in Poland (Figure 27). Of the total energy input in Finland feed accounted for about 50%, and in the Netherlands – over 80%. Electricity and diesel use represent the important energy inputs in Poland (2.4 GJ t^{-1}, and 1.5 GJ t^{-1}) while in Portugal the second ranked energy use was electricity, 5.9 GJ t^{-1}, for ventilation and in Finland 9.5 GJ t^{-1} for heating of livestock buildings. Besides heating over 8% of the indirect energy use in Finnish pig meat production is attributed to buildings. Based on the data collected in the Netherlands the energy use associated with piglet production is estimated to be 0.46 GJ per 100 kg of meat, including 66% of energy for feed. Of the total energy use, piglet production across these countries ranges from 19% in Finland to 31% in the Netherlands (Annex: Table 42).

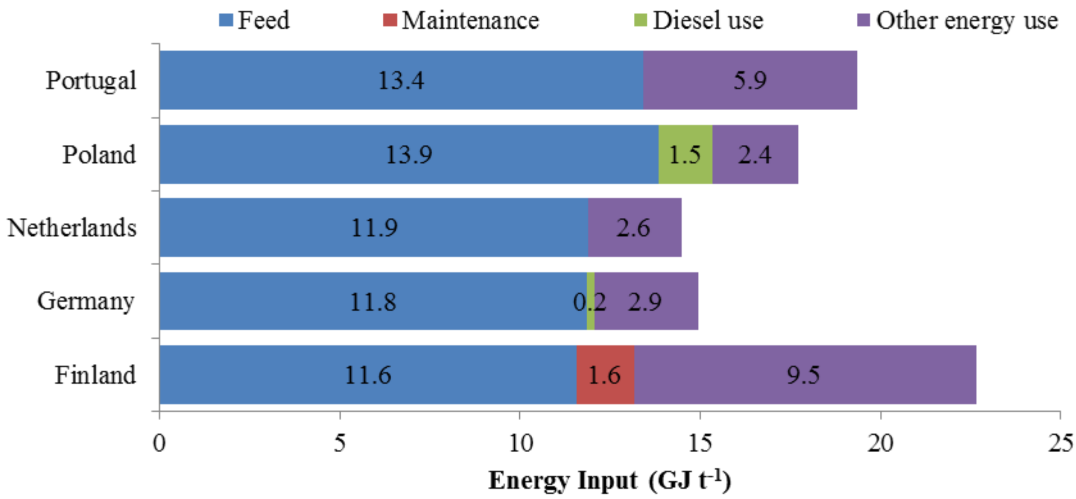

Figure 27. Structure of energy inputs in pig production (average scenarios, Portugal – high energy inputs scenario).

Broilers (PEC)

In the countries at issue the highest volume of chicken meat has been produced in Poland, Germany and the Netherlands (829.3 million tons, 706.9 million tons, and 675.1 million tons, respectively) (Table 20). The data from Finland is only for the high energy inputs scenario and from Portugal – for the low and high energy inputs. The analysis of the energy use in terms of GJ per ton of carcass weight per year showed that in the countries under consideration the most energy efficient production has been in Germany (9.8 GJ t^{-1}) and in Finland (12.3 GJ t^{-1}), as well in the high energy input scenario in Portugal 8.9 GJ t^{-1}. Broiler production in the Netherlands and Poland has similar specific energy inputs of 14.0 GJ t^{-1} and 14.8 GJ t^{-1}, respectively.

Table 20: The energy input (PEC) for broiler production by country.

Country	Scenario	Average production[a]	Specific energy input	Total PEC
		x 1000 t	GJ t^{-1}	PJ
Finland	high	89146	12.3	1.10
Germany	average	706932	9.8	6.93
Netherlands	average	675104	14.0	9.43
Poland	average	829396	14.8	12.25
Portugal	low	226038	12.6	2.85
	high		17.8	4.02

[a] Eurostat: Broilers – slaughtering (annual data – 2008), NL – 2007

Of the various energy uses, in terms of tons produced, feed is dominant . Of the total energy input it accounts for 6.5 GJ per ton (66%) of meat production in Germany, 8.2 GJ t^{-1} (55%) in Poland and 10.1 GJ t^{-1} (73%) in the Netherlands (Figure 28). In Finland for the high energy input scenario the energy use for feed is 7.3 GJ t^{-1} (59%) and in Portugal for the two scenarios, low and high, 12.1 GJ t^{-1} (96%) and 17.8 GJ t^{-1} (93%), respectively. The second main source of energy use has been diesel use in Germany (2.9 GJ t^{-1}) and Poland (2.9 GJ t^{-1}). Excluding Germany the other countries have reported quite a big amount of direct energy use in the production process, mostly for heating in the Northern EU countries Finland and Poland. These values ranged from 2.8 GJ t^{-1} in the Netherlands to 4.6 GJ t^{-1} in Finland.

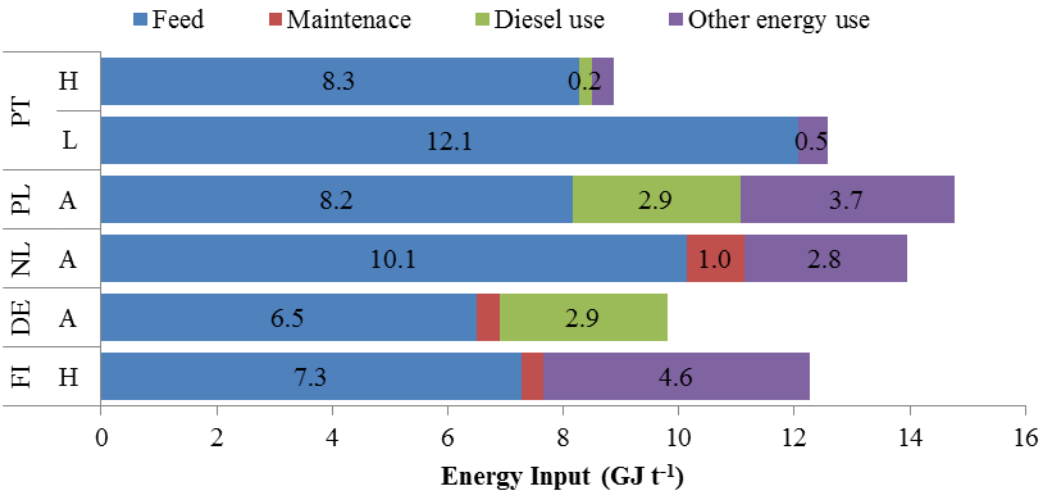

Figure 28. The structure of energy inputs in broiler production (average scenarios).

Total PEC from Agricultural Subsectors

In total, the analyzed subsectors of agricultural production in the countries under consideration consume various amount of primary energy (Table 21). The highest energy use (out of the 13 subsectors of agricultural production) is in Germany where it represents 223.93 PJ and the most energy consuming subsectors are dairy cows, wheat, and pig production. In the Netherlands and Poland the total energy use in the subsectors has similar figures 158.45 PJ and 169.57 PJ, respectively. The most energy consuming subsectors in the Netherlands are dairy cows, pigs, and tomatoes and sweet pepper production, and in Poland – dairy cows, wheat, pigs and potato production. In Finland the most energy consuming subsectors are dairy cows and pigs, in Greece – wheat and cotton, and in Portugal dairy cows, olive groves and broiler production.

Table 21. The total PEC as weighted means from scenarios for the agricultural subsectors in PJ.

Subsector	Finland	Germany	Greece	Netherlands	Poland	Portugal
Wheat	2.51	58.17	46.09	2.16	42.60	1.46
Sugar beet		4.95		1.23	4.34	
Potatoes		6.65		3.81	11.33	
Sunflower		0.32				0.08
Cotton			27.19			
Tomatoes		3.61	2.15	25.64		0.43
Cucumber		3.32	0.37	9.44		
Sweet pepper				15.00		
Olive groves			5.59			4.03
Vineyards		2.16	1.58			1.91
Dairy cows	9.64	94.59		59.18	75.73	5.52
Pigs	5.56	43.23		32.73	23.30	
Broilers	1.10	6.93		9.27	12.28	3.44
Total	18.81	223.93	82.97	158.45	169.57	16.86

Annex

Different scenarios for production systems

As indicated above, one or more scenarios have been calculated for each production process to express variations in production systems regarding energy demands. The Table 22 gives an overview of these scenarios and their backgrounds. In general we have calculated the scenarios for production systems, if major variation exists among different production systems, which may be a starting point for energy saving measures. The average energy inputs have been based on input calculations from available literature or expert opinion, which have been matched with national data on the production systems in each country.

Table 22. Scenarios of energy inputs in agricultural production.

Agriculture subsector	Country	Energy inputs		
		Low	Average	High
Wheat	Germany	Reduced tillage, low yield, little drying	Standard values	Conventional tillage, high yields, high drying
	Greece	Low fertilization, no irrigation (Central and Northern Greece)	Conventional fertilization (Central and Northern Greece)	Conventional fertilization, irrigation (Central and Northern Greece)
	Netherlands		Only one scenario is used as wheat production systems do not differ much across the Netherlands.	
	Poland	Low scale of production, low yields	Standard values	Intensive production, high yields, drying, relatively large farms
	Portugal	No tillage	Conventional	Conventional with irrigation
	Finland	Direct drilling, low nitrogen input and minimum plant protection	Reduced tillage , conventional nitrogen input and plant protection	Conventional tillage, high nitrogen input and intensive plant protection
Sugar beet	Germany	Low yield and reduced tillage	Standard values	High yields, conventional tillage
	Netherlands		Only one scenario is used as sugar beet production systems do not differ much across the Netherlands.	
	Poland	Small plantations, conventional technology	Tendency to simplification of technology, higher yielding than in conventional technology	Simplified technology, use of highly efficient machinery, high yields
Potatoes	Germany	Reduced seeding, low yield, reduced tillage	Standard values	High seeding, High yields, conventional tillage

	Netherlands		Here consumption potatoes are aimed at. For this crop type, only one scenario is used as potato production systems do not differ much across the Netherlands.	
	Poland	Small plantations, low yielding, low energy inputs on storage, relatively high amount of farmer's work	Relatively small plantations, low yields, high energy consumption on cultivation and storage	Intensive production, relatively high yields, high energy inputs for cultivation and storage
Sunflower	Germany	Less drying, reduced tillage, reduced seeding, lower yield	Standard values	More intensive drying, high seeding, high yields, conventional tillage
	Portugal	No tillage		Conventional tillage
Cotton	Greece	Low fertilization, conventional irrigation	Conventional fertilization, average irrigation	High fertilization, high irrigation
Tomatoes	Germany		Only the average scenario is used for tomatoes	
	Netherlands	Organic production of tomatoes	Bulk tomato production	Cherry tomatoes
	Greece	Soil cultivation in greenhouse, minimum equipment, no heating, low fertilization, conventional irrigation	Soil cultivation in greenhouse, standard equipment, heating with electricity, high fertilization, conventional irrigation	Hydroponics, fully equipped, heating with diesel, high fertilization, conventional irrigation
	Portugal	Grown directly on soil		Hydroponics
Cucumber	Germany		Only the average scenario is used for cucumber	
	Netherlands		Only one scenario is used for cucumber. There is not much difference across the Netherlands.	
	Greece	Soil greenhouse, minimum equipment, no heating, low fertilization, conventional irrigation.		Soil greenhouse, average equipment, heating with electricity, high fertilization, conventional irrigation
Sweet pepper	Netherlands		Only one scenario is used for sweet pepper. There is not much difference across the Netherlands.	
Olives	Greece	Low fertilization, no irrigation.	Medium fertilization, no irrigation.	No fertilization, irrigation, use of olive

				nets in all land surface.
	Portugal	Traditional, plant density – 100 trees/ha	Intensive, plant density – 400 trees/ha	Super-intensive, plant density – 2000 trees/ha
Vineyards	Germany	Reduced diesel use for field operation and lower yield	Standard values	Reduced diesel use for field operation and high yield
	Greece	Low fertilization, high irrigation	High fertilization, low irrigation, minimum pruning for high yielding	High fertilization, low irrigation, maximum pruning for high quality grapes
	Portugal	Douro region – lower machinery utilisation		Alentejo region – higher machinery utilization
Dairy cows	Germany	Low energy efforts for the production of concentrates and other feed	Medium energy efforts for the production of concentrates and other feed	High energy efforts for the production of concentrates and other feed
	Netherlands	Three scenarios are based on different levels of feed input per cow of 600 kg: 18.6, 21.1, and 23.7 of dry matter feed per cow per day.		
	Poland	Small herds, conventional technology, tied in the byre, low efficiency of milk production at the relatively high consumption of energy of feed, relatively high amount of farmer's work	Loose housing, relatively small herd, relatively small productivity, conventional way of feeding	Relatively high productivity in large herds, loose housing, rationing of feeding, high technology – milk collection
	Portugal	Based on natural pasture and complemented with concentrates and forage. Each animal eat an average of 350 g of concentrate per litre of milk. Animals stay in the field during all the year. There is no milking room. Mobile milking system is used in the field.	Feed. Variable function of the farmer's experience. Based on corn silage (42%), mixture (33%) prepared using a UNIFEED with soybean, corn gluten, corn flavour, citrus pulp, ryegrass silage, corn silage and minerals, concentrates (19%) and dried fibers (6%) Buildings. Animals remain inside the buildings during all the lactation period. Occasionally animals go to the pasture. The buildings for the cows have a mean area of 9 m^2 per animal. Milking parlour and refrigeration room.	Feed. Variable function of the farmer's experience. Based on a Mixture (42%) prepared using a UNIFEED with soybean, corn gluten, corn flavor, citrus pulp, ryegrass silage, corn silage and minerals. Corn silage (38%), concentrates (17%) and dried fibre (3%) Buildings. Animals remain inside the buildings during all the lactation period. The buildings for the cows have a mean area of 8 m^2 per animal. Milking parlour and refrigeration room. Storing buildings for food.

			Storing buildings for food.	
	Finland	A silage intensive fodder menu with a low share of energy and protein concentrate	More energy and protein concentrates than in low inputs scenario	High quality silage added with a intensive protein and energy concentrate fodder menu
Pigs	Germany	Lower meat production and low energy efforts for the production of concentrated feed	Standard values	High meat production and high energy efforts for the production of concentrated feed
	Netherlands	Different feed strategies are the basis for the three scenarios.		
	Poland	Conventional farming at small farms, feed mostly produced at farm, rearing pigs	Intensive farming, automated feeding system	Intensive farming, automated feeding system, fodders are partly produced at the farm
	Portugal			Industrial pig production is mostly conducted in one intensive production system.
	Finland		High/low feeding strategy	High/high feeding strategy
Broilers	Germany	Reduced energy efforts for feed production	Standard values	High energy efforts for feed production.
	Netherlands	Various feed strategies are the basis for the three scenarios.		
	Poland	Reared indoor on litter, high feed conversion ratio	Reared indoor on litter, efficient feed conversion ratio	Reared indoor on litter, relatively lower feed conversion ratio
	Portugal	Feeding in 78 days to 3.4 kg l.w. 0.1 m^2 per animal inside building and 2 m^2 outside.		Intensive feeding in 38 days to 1.8 kg l.w. 0.05 m^2 per animal.
	Finland			Intensive feeding in 40 days

Energy parameters

The inputs energy has been calculated on the basis of the energy parameters which have been standardized across the countries at issue. The list of the energy equivalents for the categories of inputs is presented in Table 23.

Table 23: The energy parameters for direct and indirect energy inputs in agricultural production.

Energy inputs	Unit	Energy parameters – standardized		
		FEC	PEC	References
Direct				
Electricity	MJ kWh^{-1}	3.60	9.70	BioGrace 2011
Diesel	MJ kg^{-1}	43.10	50.00	BioGrace 20112
Natural gas	MJ $(m^3)^{-1}$	31.60	35.70	BioGrace 20112
Wood chips	MJ kg^{-1} (MC 30%)	12.40	12.40	Alakangas 2000

Indirect				
Crop production				
Seeds - grains	MJ kg^{-1}	2.61	2.61	BioGrace 2011
Seeds - sugar beet	MJ kg^{-1}	36.29	36.29	BioGrace 2011
Seeds - tubers	MJ kg^{-1}	1.05	1.05	BioGrace 2011
Seeds - cotton	MJ kg^{-1}	52.60	52.60	BioGrace 2011
Mineral fertilizers				
nitrogen (N)	MJ kg^{-1}	48.99	48.99	BioGrace 2011
phosphorus (P_2O_5)	MJ kg^{-1}	15.23	15.23	BioGrace 2011
potassium (K_2O)	MJ kg^{-1}	9.68	9.68	BioGrace 2011
calcium (CaO)	MJ kg^{-1}	1.97	1.97	BioGrace 2011
magnesium (MgO)	MJ kg^{-1}	6.70	6.70	Mihov & Tringovska 2010
sulphur (S)	MJ kg^{-1}	2.10	2.10	www.stewarshipindex.org
Pesticides				
herbicides	MJ (kg a.i.)$^{-1}$	268.4	268.4	BioGrace 2011
fungicides	MJ (kg a.i.)$^{-1}$	268.4	268.4	BioGrace 2011
insecticides	MJ (kg a.i.)$^{-1}$	268.4	268.4	BioGrace 2011
nematocides	MJ (kg a.i.)$^{-1}$	268.4	268.4	BioGrace 2011
Other production means				
organics	MJ kg^{-1}	0.30	0.30	Hoefnagels
water	MJ (m^{3})$^{-1}$	0.63	0.63	Mihov & Tringovska 2010
cloth	MJ (m^{2})$^{-1}$	81.00	81.00	White et al.
GH substrate	MJ (m^{2})$^{-1}$	13.00	13.00	Mihov & Tringovska 2010
GH manual work	MJ h^{-1}	40.00	40.00	White et al. 1999
GH thermal screens	MJ (m^{2})$^{-1}$	41.00	41.00	White et al. 1999
GH solarisation film	MJ (m^{2})$^{-1}$	170.00	170.00	White et al. 1999
GH LDPE film	MJ (m^{2})$^{-1}$	69.50	69.50	BioGrace 20112
Livestock[1]				
silage, moisture content, MC 70%	MJ (kg of DM)$^{-1}$	0.90	0.90	Huhtamäki 2008
fodder from pasture, MC 80%	MJ (kg of DM)$^{-1}$	0.50	0.50	Huhtamäki 2008
dry hay, MC 15%	MJ (kg of DM)$^{-1}$	1.90	1.90	Huhtamäki 2008
concentrated feed (cereal), MC 14%	MJ (kg of DM)$^{-1}$	3.60	3.60	Huhtamäki 2008
compound feed, MC 12%	MJ (kg of DM)$^{-1}$	3.80	3.80	Huhtamäki 2008
protein concentrate, MC 12%	MJ (kg of DM)$^{-1}$	3.90	3.90	Huhtamäki 2008
half concentrate, MC 12%	MJ (kg of DM)$^{-1}$	3.90	3.90	Huhtamäki 2008
industrial feed 1, MC 12%	MJ (kg of DM)$^{-1}$	4.20	4.20	Huhtamäki 2008
soybean	MJ (kg of DM)$^{-1}$	4.25	4.25	Kraatz 2009
rapeseeds	MJ (kg of DM)$^{-1}$	5.26	5.26	Kraatz 2009
triticale	MJ (kg of DM)$^{-1}$	3.89	3.89	Kraatz 2009
straw, sawdust (bedding)	MJ (kg of DM)$^{-1}$	1.80	1.80	Wójcicki 2007
water	MJ m^{3}	0.63	0.63	Mihov & Tringovska 2010
buildings	MJ (m^{2})$^{-1}$	153.00	153.00	www.finlex.fi

[1] MC – Moisture Content; DM – Dry Matter

Energy Inputs and Structure of the Inputs

Wheat

Table 24: The energy use (PEC) in wheat production by country and production scenario.

Country	Scenario	Yield	Energy use			Specific energy input	Total PEC
			direct	indirect	total		
		t ha^{-1}	GJ·ha^{-1}			GJ t^{-1}	PJ
Finland	low	3.5	3.0	5.6	8.7	2.48	1.70
	average	4.5	3.9	8.0	12.0	2.66	2.35
	high	6.0	5.7	9.9	15.7	2.61	3.08
Germany	low	6.7	4.1	12.1	16.2	2.43	51.77
	average	7.7	6.3	12.3	18.5	2.42	57.37
	high	8.3	8.9	12.4	21.3	2.56	64.01
Greece	low	2.5	5.3	6.5	11.8	4.70	27.58
	average	5.0	10.0	9.9	19.9	3.99	46.80
	high	6.0	12.8	9.9	22.7	3.78	53.25
Netherlands	average	8.7	6.6	11.6	18.1	2.08	2.16
Poland	low	4.8	3.9	9.6	13.5	2.81	31.64
	average	5.8	4.1	10.9	15.1	2.60	35.40
	high	7.5	7.9	15.5	23.5	3.13	55.05
Portugal	low	3.0	1.6	7.4	9.0	3.01	0.96
	average	3.0	5.7	7.2	12.9	4.29	1.37
	high	5.0	6.3	10.7	17.0	3.39	1.80

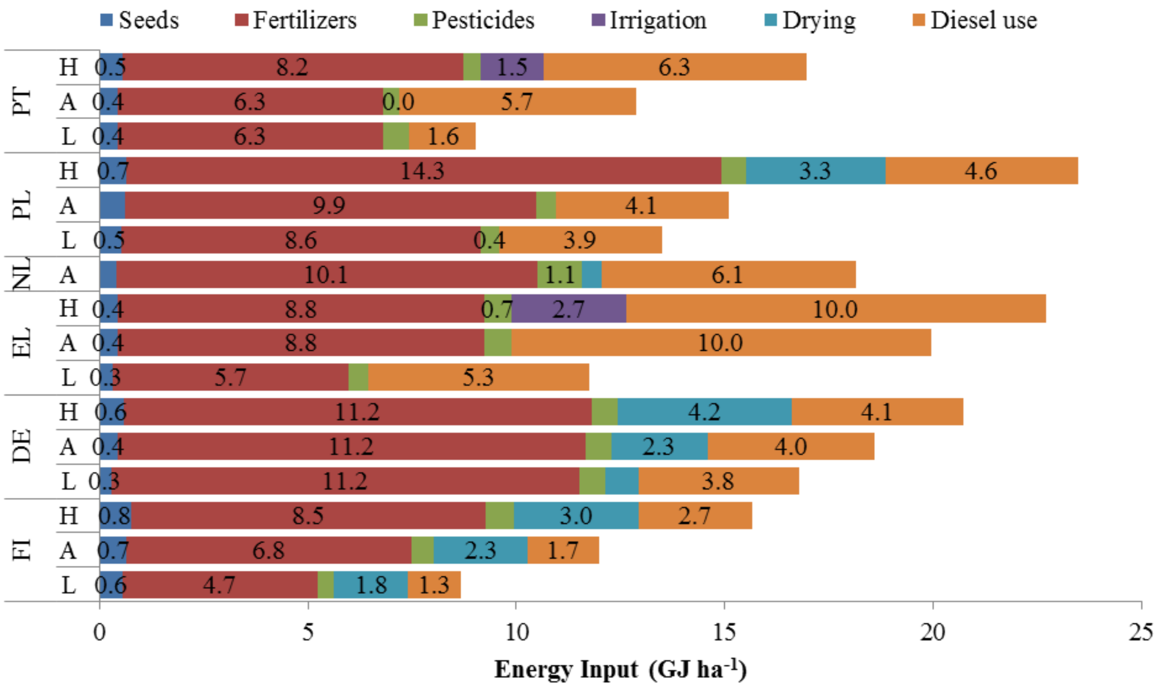

Figure 29: The structure of embodied energy inputs in GJ·ha^{-1} in different scenarios of wheat production (L, A, H – Low-Average-High energy inputs scenarios).

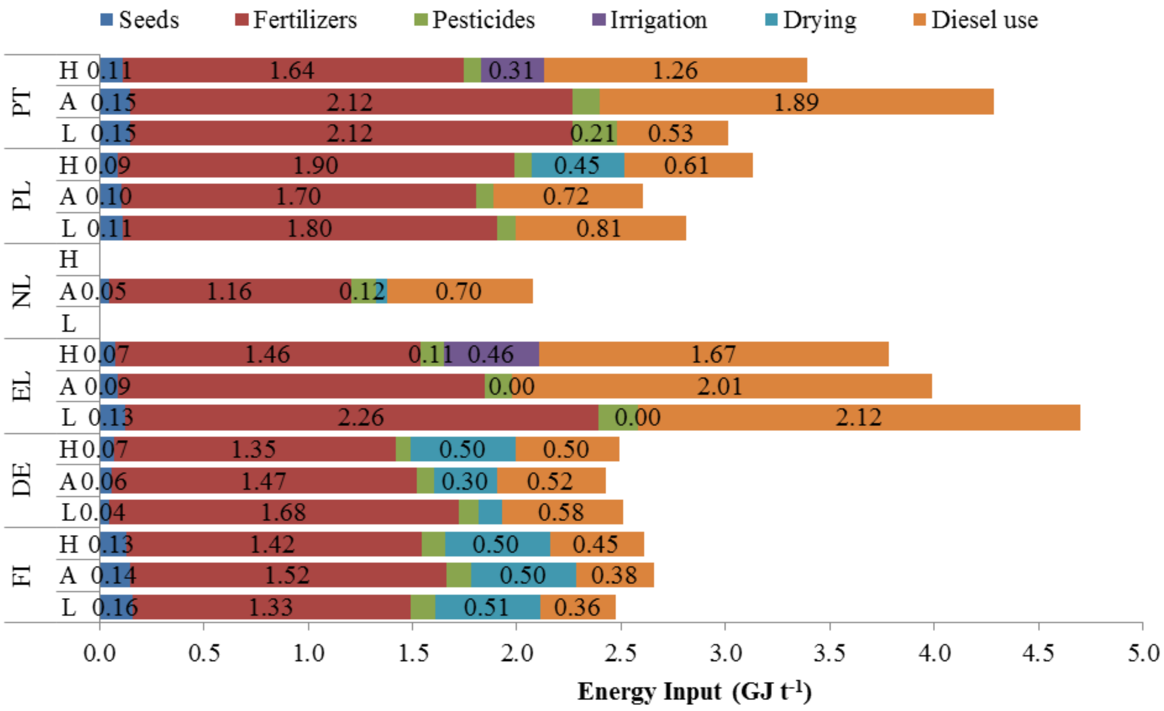

Figure 30: The structure of embodied energy inputs in GJ t^{-1} in different scenarios of wheat production (L, A, H – Low, Average, and High energy inputs scenarios).

Sugar Beet

Table 25: The energy use (PEC) in sugar beet production by country and production scenario.

Country	Scenario	Yield	Energy use direct	Energy use indirect	Energy use total	Specific energy input	Total PEC
		t ha^{-1}	GJ·ha^{-1}			GJ t^{-1}	PJ
Germany	low	57.7	3.9	9.6	13.5	0.234	5.20
	average	60.9	4.0	9.6	13.6	0.223	5.11
	high	62.4	4.1	9.6	13.7	0.219	5.15
Netherlands	average	67.1	5.2	8.6	13.7	0.204	1.23
Poland	low	50.0	5.1	10.0	15.1	0.302	3.74
	average	60.0	6.0	11.1	17.2	0.286	4.25
		70.0	7.1	12.4	19.6	0.280	4.84

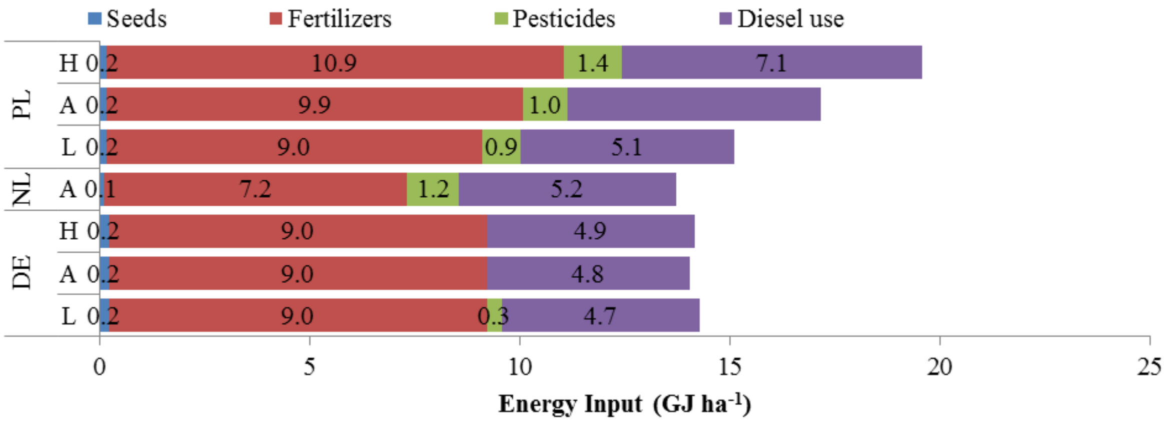

Figure 31: The structure of embodied energy inputs in GJ·ha^{-1} in different scenarios of sugar beet production (L, A, H – Low, Average, and High energy inputs scenarios).

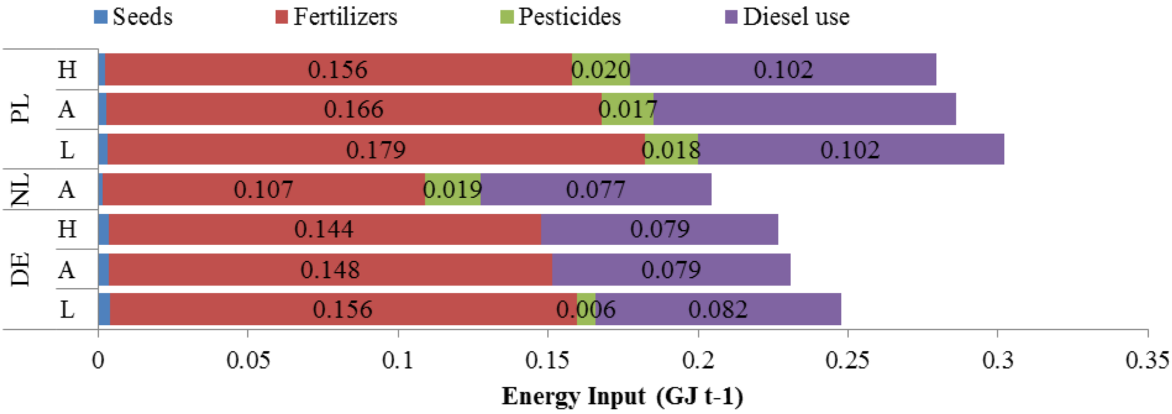

Figure 32: The structure of energy inputs in GJ t^{-1} in different scenarios of sugar beet production (L, A, H – Low, Average, and High energy inputs scenarios).

Table 26: The percentage share of specific energy use (PEC, in GJ t^{-1}) in sugar beet production by process.

Country	Scenario	Seeds	Fertilizers	Pesticides	Diesel use
		%			
Germany	low	1.5	63.0	2.4	33.0
	average	1.6	64.1	0.0	34.4
	high	1.5	63.6	0.0	34.9
Netherlands	average	0.7	52.6	9.1	37.6
Poland	low	1.0	59.4	5.8	33.8
	average	0.9	57.8	6.0	35.2
	high	0.8	55.7	7.0	36.5

Potatoes

Table 27: The energy use (PEC) in potato production by country and production scenario.

Country	Scenario	Yield	Energy use			Specific energy input	Total PEC
			direct	indirect	total		
		t ha^{-1}	GJ·ha^{-1}			GJ t^{-1}	PJ
Germany	low	37.0	13.2	13.7	26.9	0.727	6.58
	average	42.4	13.3	13.6	26.9	0.634	6.57
	high	44.9	13.4	14.4	27.8	0.619	6.79
Netherlands	average	50.2	21.9	22.9	44.8	0.893	3.27
Poland	low	24.0	5.1	9.2	14.3	0.594	7.55
	average	27.0	6.8	10.1	16.9	0.627	8.96
	high	32.0	19.6	10.9	30.5	0.954	16.16

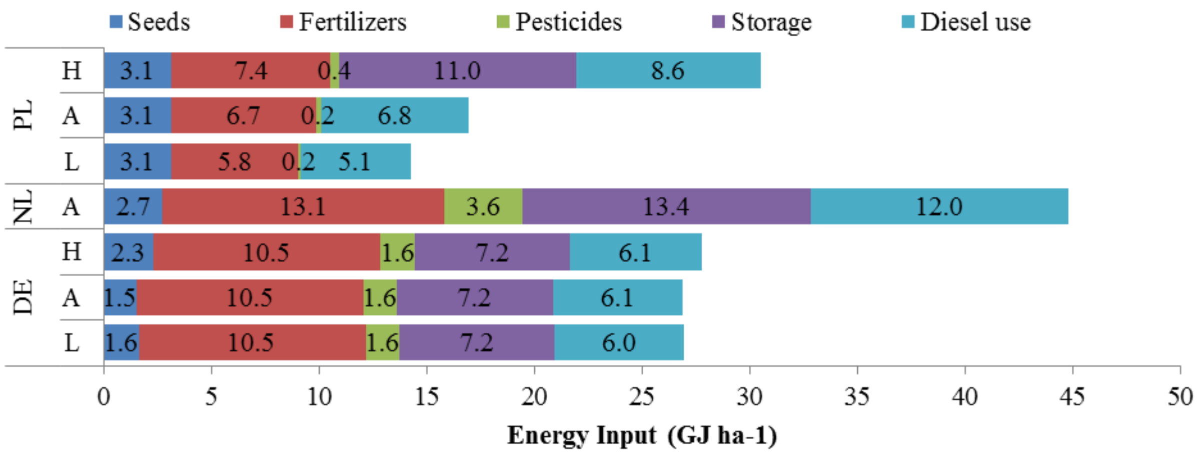

Figure 33: The structure of embodied energy inputs per hectare of potato production (L, A, H – Low-Average-High energy inputs scenarios).

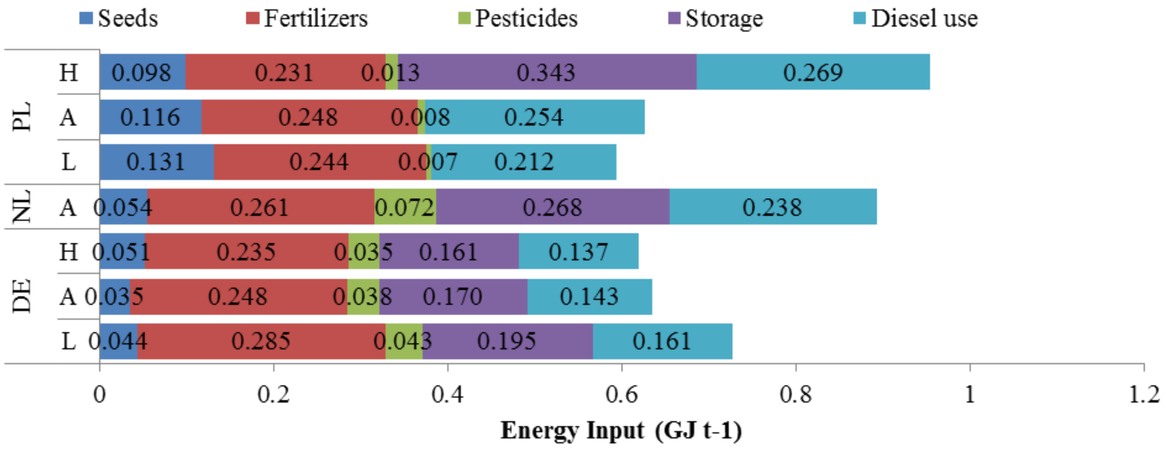

Figure 34: The structure of embodied energy inputs per ton of potato production (L, A, H – Low-Average-High energy inputs scenarios).

Table 28: The percentage share of specific energy use (PEC, in GJ t^{-1}) in potato production by process.

Country	Scenario	Seeds	Fertilizers	Pesticides	Storage	Diesel use
		%				
Germany	low	6.0	39.2	5.9	26.8	22.2
	average	5.6	39.2	5.9	26.8	22.5
	high	8.3	37.9	5.7	25.9	22.1
Netherlands	average	6.1	29.2	8.0	30.0	26.7
Poland	low	22.1	41.0	1.1	0.0	35.8
	average	18.6	39.6	1.3	0.0	40.5
	high	10.3	24.2	1.4	36.0	28.2

Sunflower

Table 29: The energy use (PEC) in sunflower production by country and production scenario.

Country	Scenario	Yield	Energy use			Specific energy input	Total PEC
			direct	indirect	total		
		t ha^{-1}	GJ·ha^{-1}			GJ t^{-1}	PJ
Germany	low	1.85	3.60	7.25	10.84	5.86	0.287
	average	2.31	4.44	7.25	11.69	5.06	0.310
	high	2.64	5.57	7.25	12.82	4.86	0.340
Portugal	low	0.72	1.91	0.40	2.31	3.20	0.056
	high	0.85	3.84	0.21	4.05	4.76	0.097

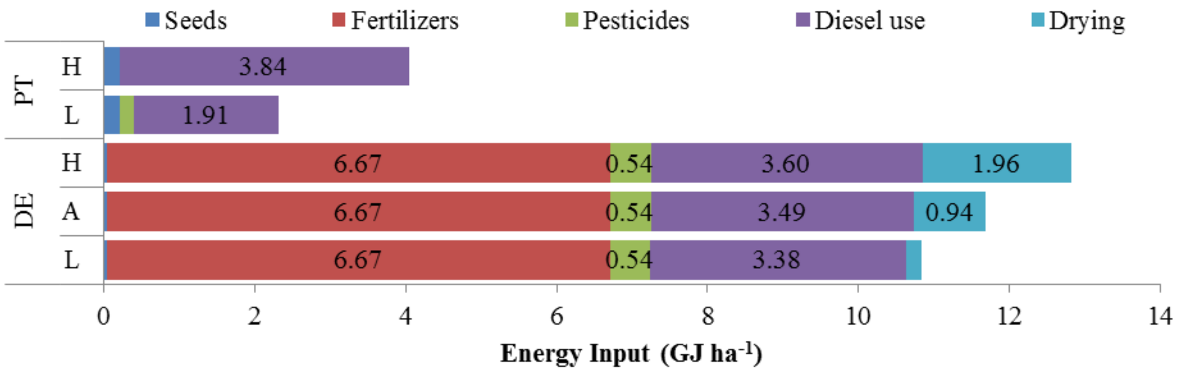

Figure 35: The structure of embodied energy inputs per hectare in sunflower production (L, A, H – Low, Average, and High energy inputs scenarios).

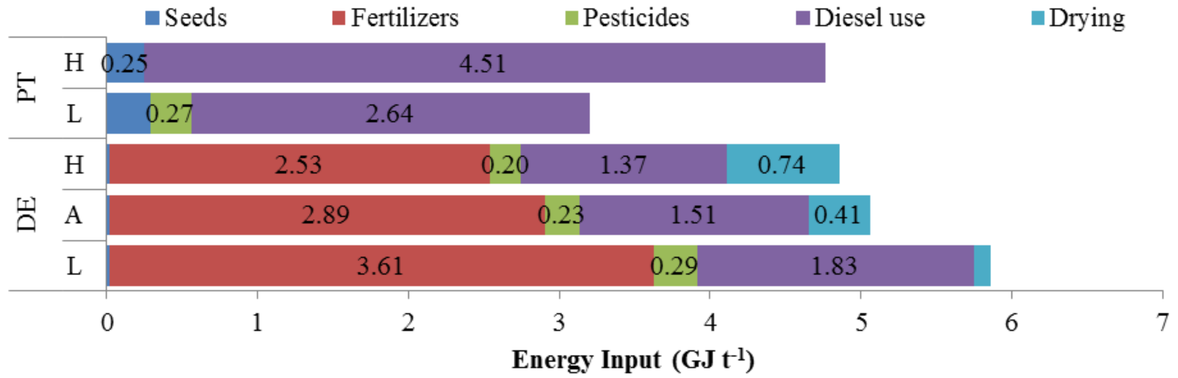

Figure 36: The structure of energy inputs in GJ t^{-1} in different scenarios in sunflower production (L, A, H – Low, Average, and High energy inputs scenarios).

Table 30: The percentage share of specific energy use (PEC, in GJ t^{-1}) in sunflower production by process.

Country	Scenario	Seeds	Fertilizers	Pesticides	Diesel use	Drying
		%				
Germany	low	0.3	61.6	5.0	31.2	1.9
	average	0.3	57.1	4.6	29.9	8.1
	high	0.3	52.1	4.2	28.1	15.3
Portugal	low	9.1	0.0	8.4	82.5	0.0
	high	5.2	0.0	0.0	94.8	0.0

Tomatoes

Table 31: The energy use (PEC) in tomato production by country and production scenario.

Country	Scenario	Yield	Energy use			Specific energy input	Total PEC
			direct	indirect	total		
		t ha^{-1}	GJ·ha^{-1}			GJ t^{-1}	PJ
Germany	average	200	12612	42	12654	63.27	3.61
Greece	low	160	49	114	163	1.02	0.41
	average	230	68	189	257	1.12	0.64
	high	380	1267	253	1520	4.00	3.80
Netherlands	low	350	14072	110	14182	40.52	23.77
	average	640	15179	110	15289	23.89	25.62
	high	700	15750	110	15860	22.66	26.58
Portugal[1]	low	150	37	62	99	0.66	0.14
	high	200	201	246	446	2.23	0.64

[1] Portugal – data for tomato production on soil (low) and hydroponics (high)

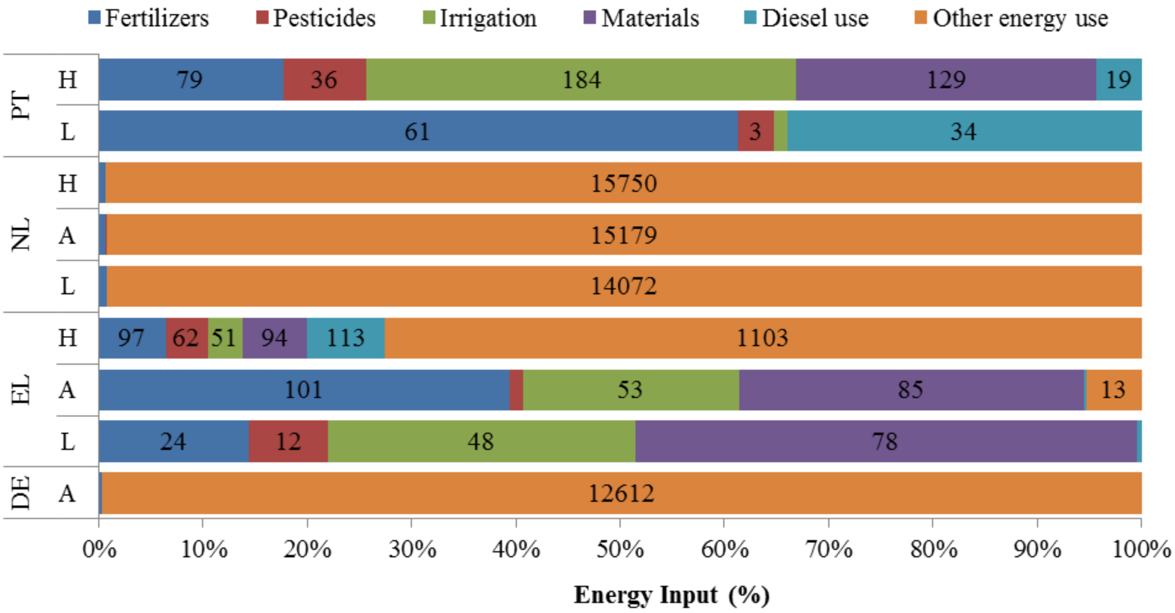

Figure 37: The structure of embodied energy inputs per hectare of tomato production (L, A, H – Low, Average, and High energy inputs scenarios).

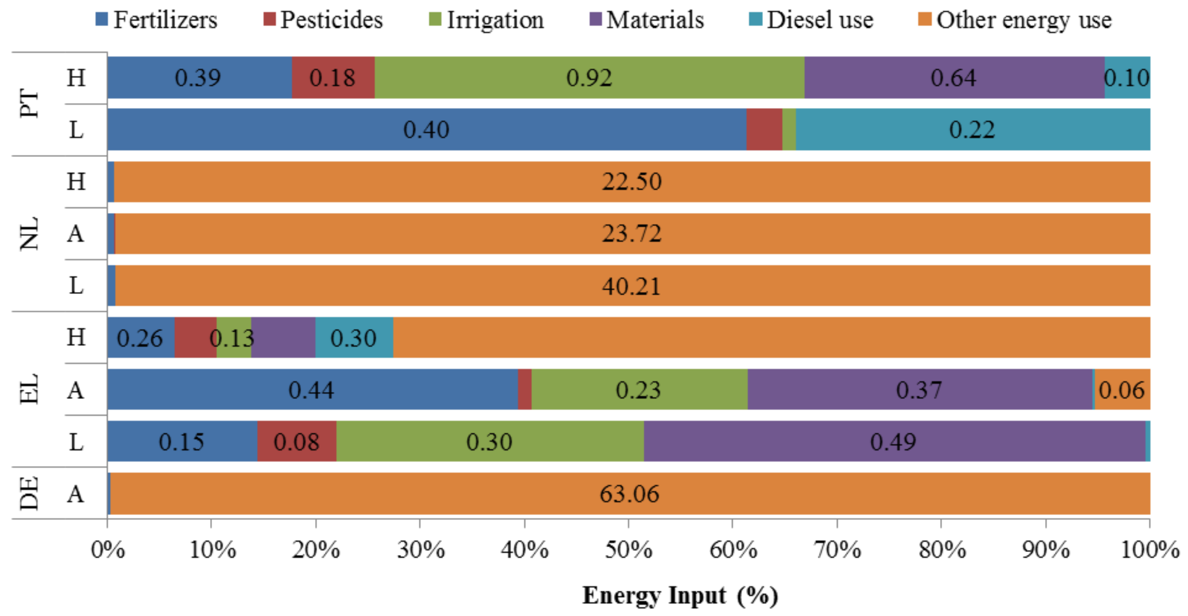

Figure 38: The structure of embodied energy inputs per ton of tomato production (L, A, H – Low, Average, and High energy inputs scenarios).

Table 32: The percentage share of specific energy use (PEC, in GJ t-1) in tomato production by process.

Country	Scenario	Fertilizers	Pesticides	Irrigation	Materials	Diesel use	Other energy
		%					
Germany	average	0.3	0.0	0.0	0.0	0.0	99.7
Greece	low	14.4	7.6	29.4	48.1	0.5	0.0
	average	39.4	1.3	20.8	33.0	0.3	5.2
	high	6.4	4.1	3.4	6.2	7.4	72.5
Netherlands	low	0.8	0.0	0.0	0.0	0.0	99.2
	average	0.7	0.0	0.0	0.0	0.0	99.3
	high	0.7	0.0	0.0	0.0	0.0	99.3
Portugal	low	61.3	3.4	1.3	0.0	34.0	0.0
	high	17.7	8.0	41.2	28.8	4.3	0.0

Cucumber

Table 33: The energy use (PEC) in cucumber production by country and production scenario.

Country	Scenario	Yield	Energy use			Specific energy input	Total PEC
			direct	indirect	total		
		t ha^{-1}	GJ·ha^{-1}			GJ t^{-1}	PJ
Germany	average	500	13000	53	13053	26.11	3.316
Greece	low	300	90	122	212	0.71	0.382
	high	200	95	189	285	1.42	0.513
Netherlands	average	800	14245	115	14360	17.95	8.989

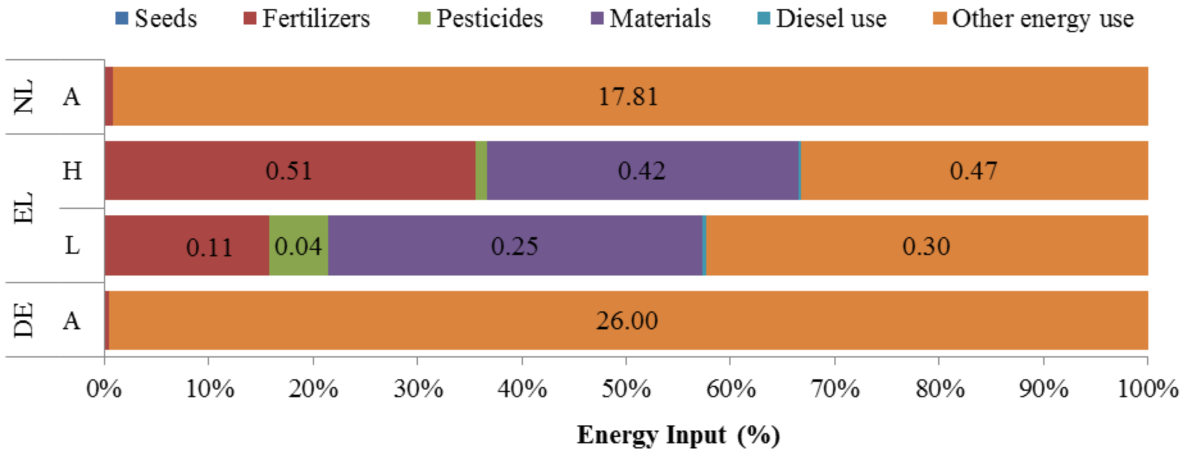

Figure 39: The structure of energy inputs in GJ t^{-1} (values in boxes) in cucumber production (L, A, H – Low, Average, and High energy inputs scenarios).

Table 34: The percentage share of specific energy use (PEC, in GJ t^{-1}) in cucumber production by process.

Country	Scenario	Seeds	Fertilizers	Pesticides	Materials	Diesel use	Other energy use
					%		
Germany	average	0.0	0.4	0.0	0.0	0.0	99.6
Greece	low	0.0	19.0	6.9	43.3	0.4	30.3
	high	0.0	40.8	1.3	34.2	0.3	23.5
Netherlands	average	0.0	0.7	0.0	0.0	0.0	99.2

Olive groves

Table 35: The energy use (PEC) in olive production by country and production scenario.

Country	Scenario	Yield	Energy use			Specific energy input	Total PEC
			direct	indirect	total		
		t ha^{-1}		GJ·ha^{-1}		GJ t^{-1}	PJ
Greece	low	3.7	4.6	2.3	6.9	1.85	5.2
	average	5.5	1.1	4.8	5.9	1.07	4.5
	high	5.5	1.7	7.2	9.0	1.63	6.9
Portugal	low	1.5	3.4	1.6	5.0	3.34	1.7
	average	8.0	3.8	5.8	9.7	1.21	3.2
	high	12.0	4.2	10.2	14.4	1.20	4.8

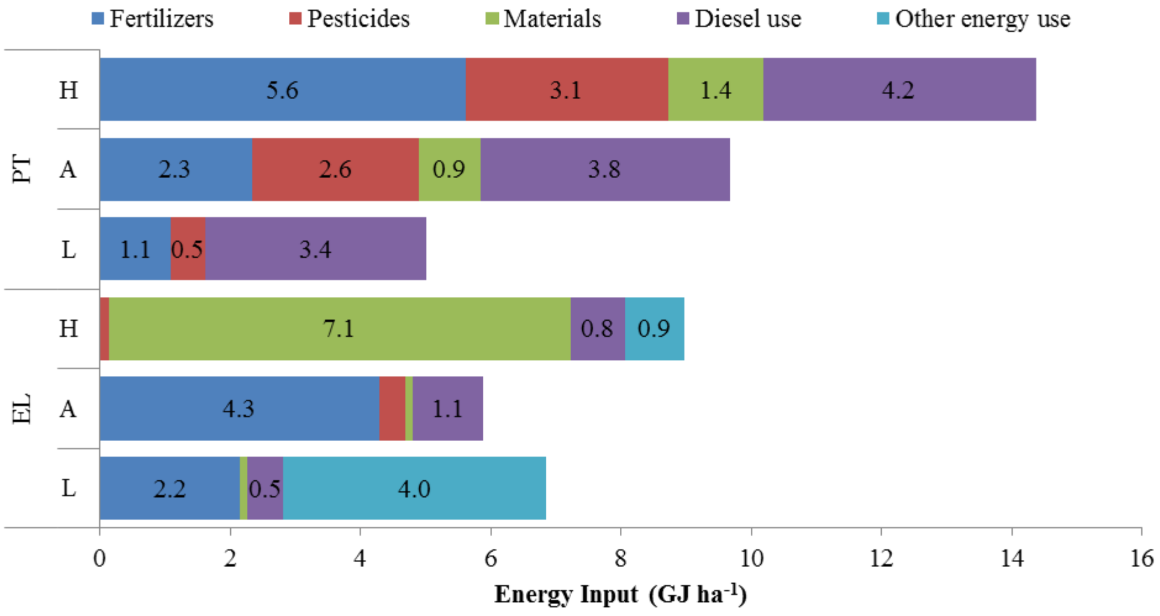

Figure 40: The structure of energy inputs in GJ per hectare for olive production (L, A, H – Low-Average-High energy inputs scenarios).

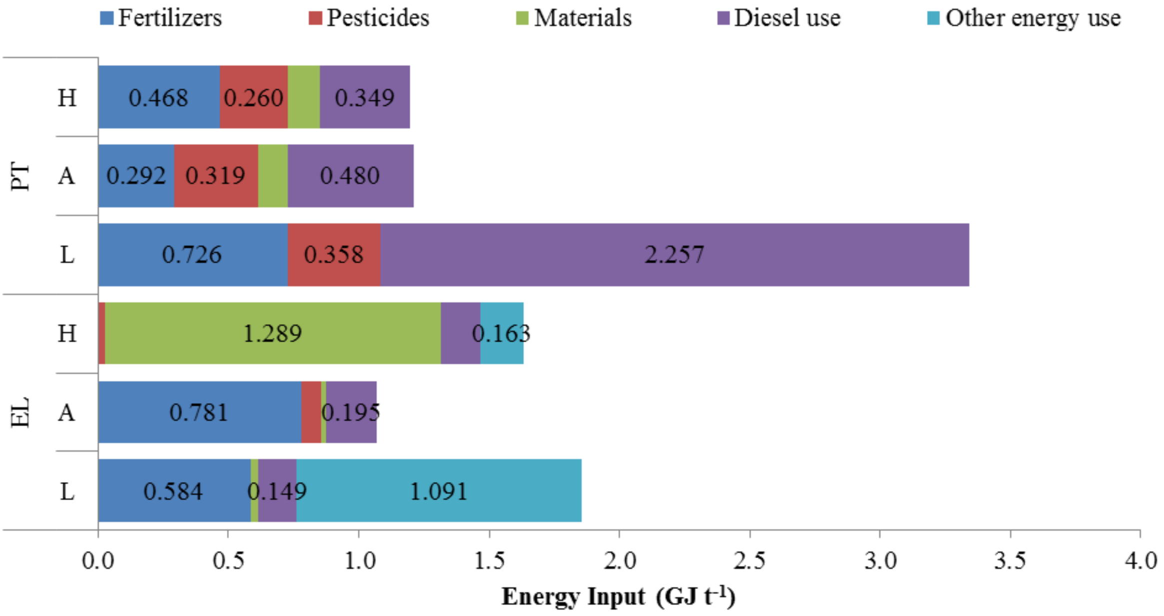

Figure 41. The structure of energy inputs in GJ per ton for olive production (L, A, H – Low-Average-High energy inputs scenarios).

Table 36: The percentage share of specific energy use (PEC, in GJ t-1) in olive production by process.

Country	Scenario	Fertilizers	Pesticides	Materials	Diesel use	Other energy use
		%				
Greece	low	31.5	0.0	1.6	8.0	58.9
	average	73.0	6.8	1.9	18.3	0.0
	high	0.0	1.5	79.0	9.5	10.0

Portugal	low	21.7	10.7	0.0	67.5	0.0
	average	24.2	26.4	9.8	39.7	0.0
	high	39.1	21.7	10.1	29.1	0.0

Vineyards

Table 37: The energy use (PEC) in vineyard production by country and production scenario.

Country	Scenario	Yield	Energy use			Specific energy input	Total PEC
			direct	indirect	total		
		t ha^{-1}	GJ·ha^{-1}			GJ t^{-1}	PJ
Germany	low	12.0	11.6	4.8	16.4	1.37	1.68
	average	15.0	15.4	4.8	20.3	1.35	2.08
	high	20.0	19.3	5.3	24.6	1.23	2.52
Greece[1]	low	14.0	11.4	3.7	15.1	1.08	1.50
	average	20.0	4.0	12.3	16.3	0.82	1.62
	high	12.0	4.0	12.3	16.3	1.36	1.62
Portugal	low	4.5	2.3	8.9	11.2	2.49	1.99
	high	7.5	7.9	2.6	10.5	1.39	1.86

[1]The data for average and maximum energy inputs scenarios in Greece has been the same due to the fact that when typical wine variety is cultivated according to “protected designation of origin” regime the pruning method does not allow high yields to keep the quality of wine above a certain quality standard. In the other case, the same agricultural practices are applied, but pruning is lighter and more fruitful buds are left to produce more inflorescence

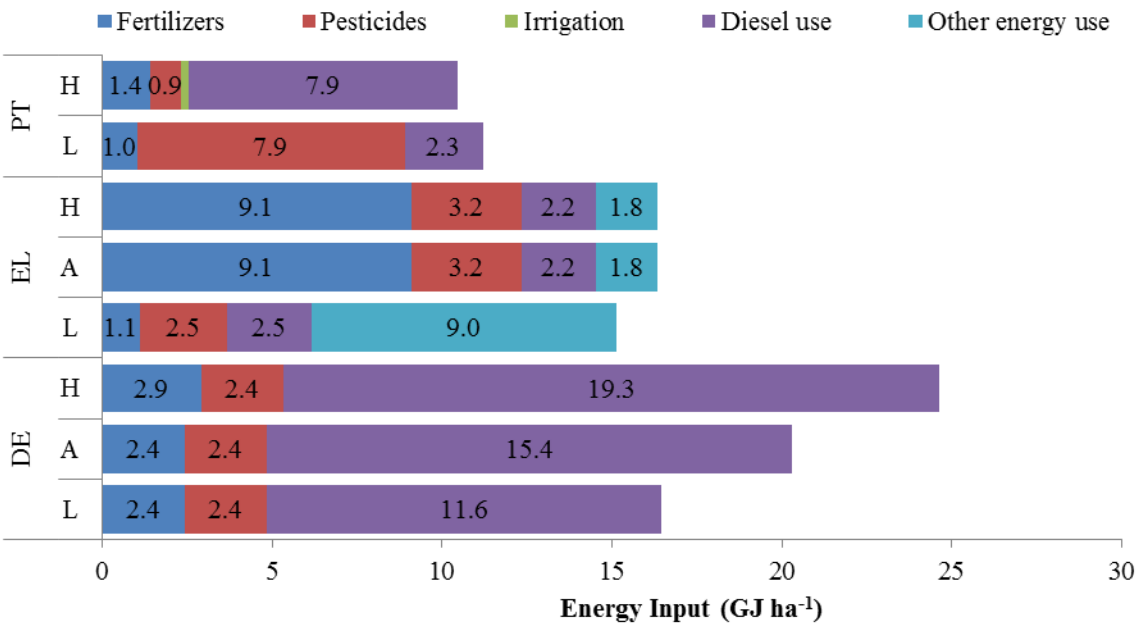

Figure 42. The structure of energy inputs in GJ·ha^{-1} for vineyard production (L, A, H – Low, Average, and High energy inputs scenarios).

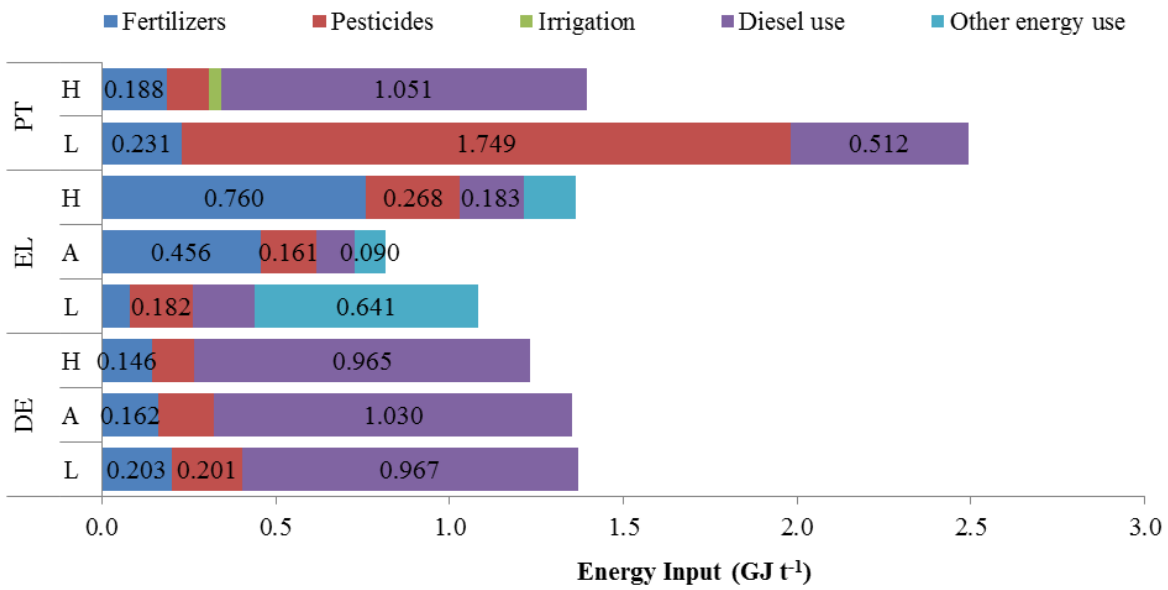

Figure 43. The structure of energy inputs in GJ t^{-1} in vineyards (for wine) production (L, A, H – Low, Average, and High energy inputs scenarios).

Table 38: The percentage share of specific energy use (PEC, in GJ t^{-1}) for vineyard production by process.

Country	Scenario	Fertilizers	Pesticides	Irrigation	Diesel use	Other energy use
				%		
Germany	low	14.8	14.7	0.0	70.5	0.0
	average	12.0	11.9	0.0	76.1	0.0
	high	11.8	9.8	0.0	78.3	0.0
Greece	low	7.5	16.8	0.0	16.4	59.3
	average	55.8	19.7	0.0	13.5	11.0
	high	55.8	19.7	0.0	13.5	11.0
Portugal	low	9.3	70.2	0.0	20.5	0.0
	high	13.5	8.7	2.4	75.4	0.0

Dairy cows

Table 39: The energy use (PEC) in dairy cows production by country and production scenario.

Country	Scenario	Energy use			Milk production	Specific energy input	Total PEC
		direct	indirect	total			
		GJ LU^{-1}			t LU^{-1}	GJ t^{-1}	PJ
Finland	low	5.7	24.3	30.0	6.8	4.39	2.2
	average	5.7	28.0	33.8	8.8	3.86	4.9
	high	5.5	29.8	35.3	10.1	3.49	2.5
Germany	low	6.1	14.2	20.3	8.0	2.54	82.8
	average	6.1	15.5	21.7	8.0	2.71	88.2
	high	7.8	19.9	27.7	8.0	3.46	112.8
Netherlands	low	8.4	19.9	28.3	5.1	5.57	50.9
	average	8.4	24.0	32.4	7.2	4.52	58.3

	high	8.4	27.2	35.5	10.2	3.50	64.0
Poland	low	4.6	19.1	23.7	4.7	5.05	63.9
	average	5.6	22.7	28.3	5.6	5.05	76.3
	high	6.2	25.0	31.2	6.2	5.05	84.2
Portugal	low	2.2	12.6	14.8	6.3	2.35	4.1
	average	7.5	13.8	21.2	6.5	3.28	5.9
	high	7.9	15.2	23.1	7.0	3.30	6.4

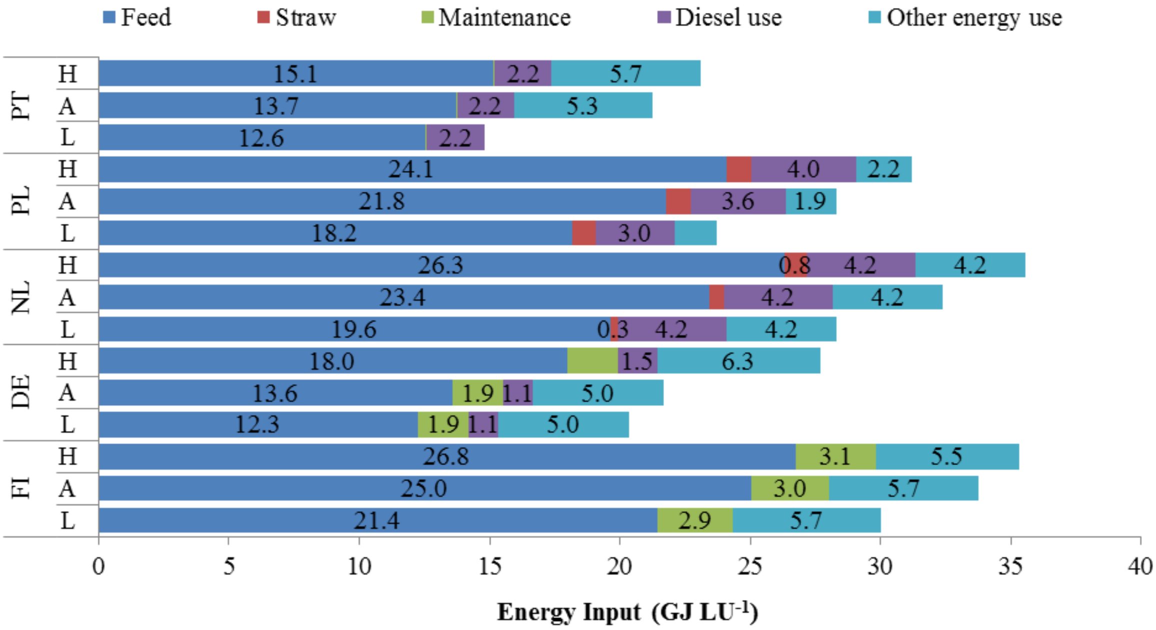

Figure 43. The structure of energy inputs in GJ per large animal unit (LU) per year in dairy cow production (L, A, H – Low-Average-High energy inputs scenarios).

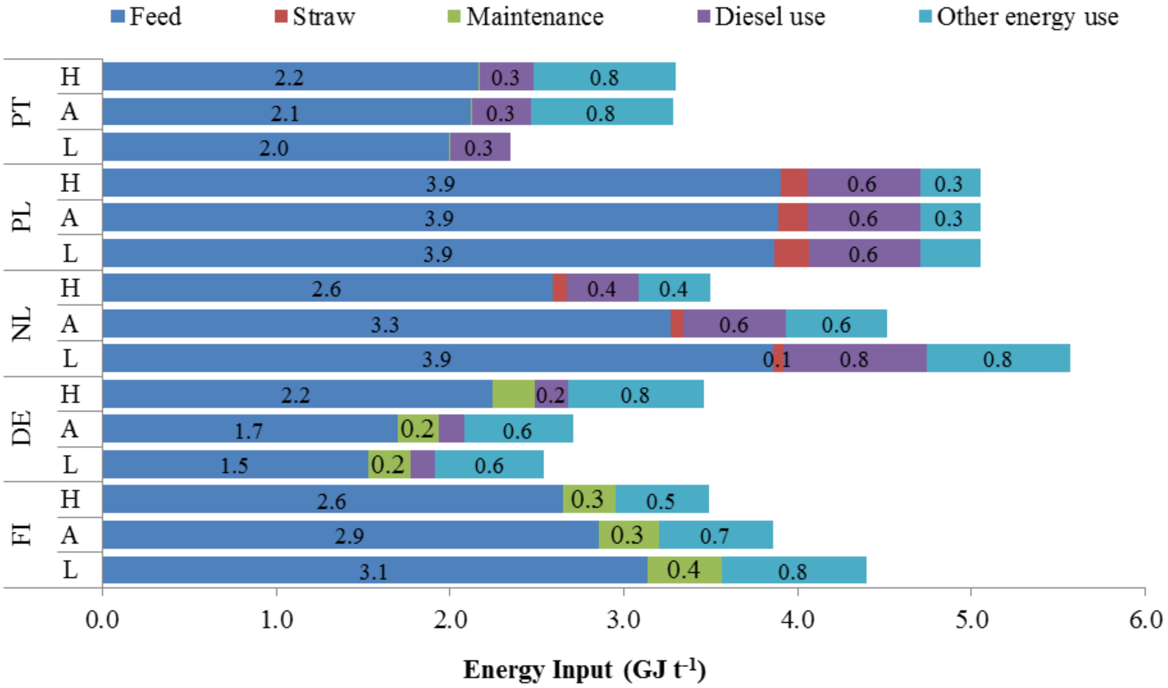

Figure 44. The ton of milk per GJ of energy inputs in dairy cow production (L, A, H – Low, Average, and High energy inputs scenarios).

Table 40: The percentage share of specific energy use (PEC, in GJ t^{-1}) in dairy cow production by process.

Country	Scenario	Feed	Straw/ Sawdust	Maintenance	Diesel use	Other energy use
		%				
Finland	low	71.5	0.0	9.7	0.0	18.9
	average	74.1	0.0	8.9	0.0	16.9
	high	75.8	0.0	8.7	0.0	15.5
Germany	low	60.3	0.0	9.5	5.6	24.6
	average	62.7	0.0	8.9	5.3	23.1
	high	64.9	0.0	7.0	5.5	22.7
Netherlands	low	69.4	1.0	0.0	14.8	14.8
	average	72.4	1.7	0.0	13.0	13.0
	high	74.1	2.3	0.0	11.8	11.8
Poland	low	76.6	3.9	0.0	12.8	6.7
	average	77.0	3.3	0.0	12.8	6.9
	high	77.2	3.0	0.0	12.9	6.9
Portugal	low	84.8	0.0	0.4	14.8	0.0
	average	64.6	0.0	0.2	10.3	24.9
	high	65.5	0.0	0.2	9.5	24.7

Pigs

Table 41: The energy use (PEC) in pig production by country and production scenario.

Country	Scenario	Energy use			Pork production[1]	Total PEC
		direct	indirect	total		
			GJ t^{-1}		x 1000 t	PJ
Finland	average	9.5	13.2	22.6	249795	5.66
	high	9.1	12.9	21.9	249795	5.48
Germany	low	3.4	12.6	16.0	2894992	46.23
	average	3.1	11.8	14.9	2894992	43.24
	high	2.8	11.0	13.9	2894992	40.21
Netherlands	average	2.6	11.9	14.5	2257500	32.69
Poland	low	5.0	12.7	17.7	1306725	23.16
	average	3.9	13.9	17.7	1306725	23.16
	high	4.4	13.7	18.1	1306725	23.61
Portugal	high	5.9	13.4	19.4	200882	3.89

[1] the number of animals was multiplied by average weight 105 kg

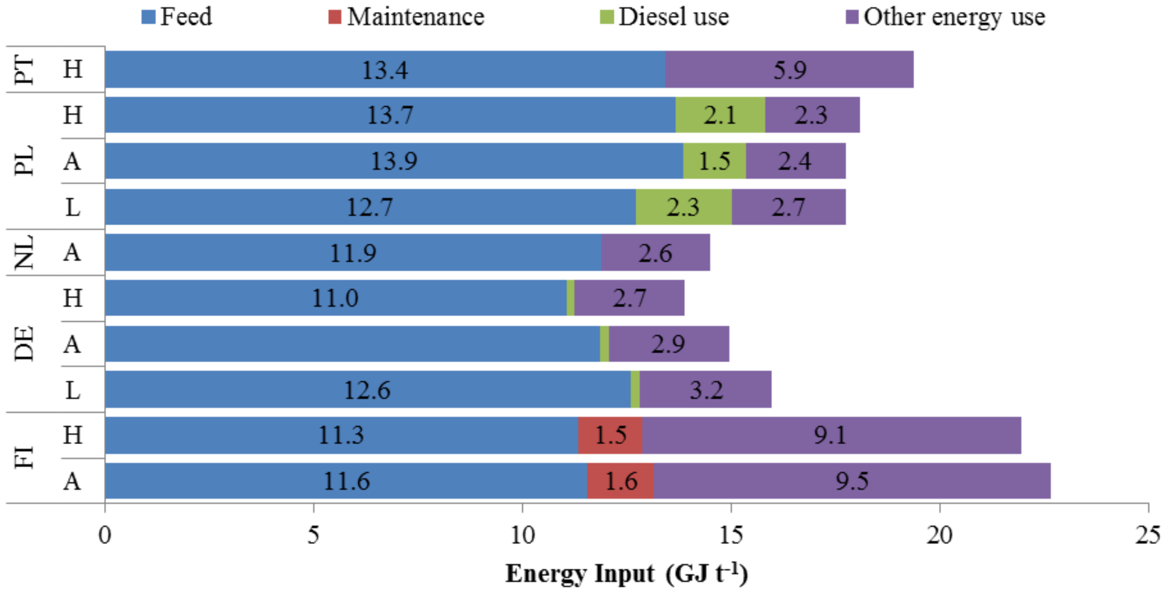

Figure 45. The structure of energy inputs in GJ t^{-1} in pig production (L, A, H – Low-Average-High energy inputs).

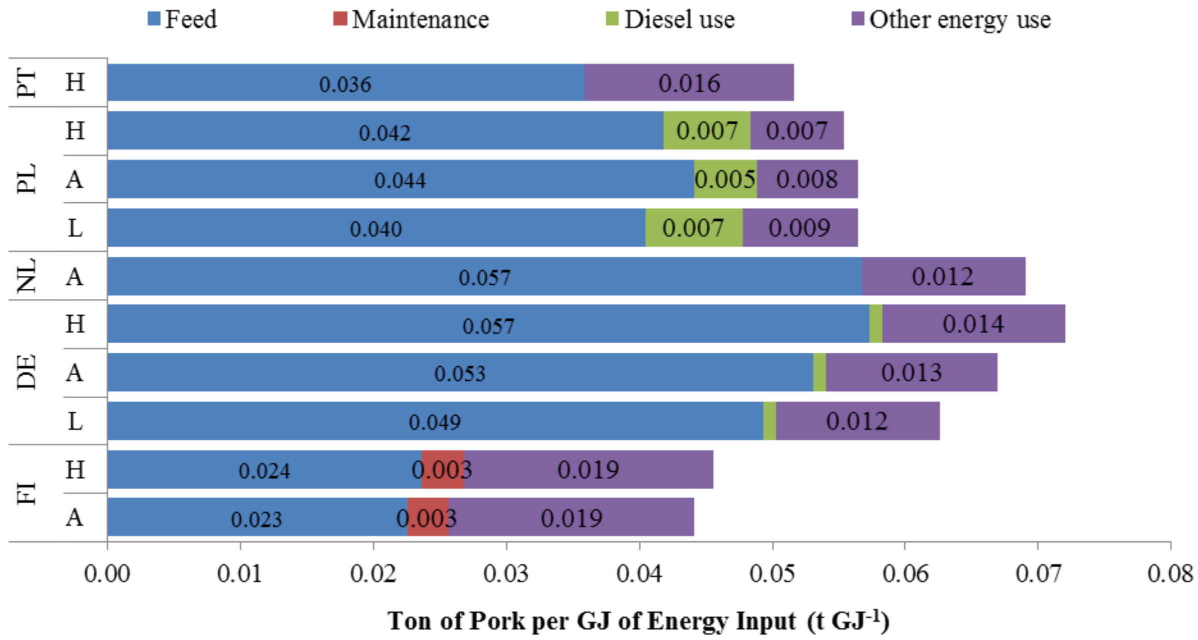

Figure 46. The ton of pork per GJ of energy inputs in pig production (L, A, H – Low-Average-High energy inputs).

Table 42: The percentage share of specific energy use (PEC, in GJ t^{-1}) of pig production by process.

Country	Scenario	Piglets	Feed	Maintenance	Diesel use	Other energy use
				%		
Finland	average	19.3	38.2	7.1	0.0	35.4
	high	19.1	39.1	7.0	0.0	34.9
Germany	low	27.4	60.7	0.0	1.4	10.5
	average	26.8	61.6	0.0	1.4	10.2
	high	26.5	62.0	0.0	1.4	10.1
Netherlands	average	25.9	54.5	0.0	13.0	6.5
Poland	low	25.5	58.8	0.0	11.8	3.9
	average	23.8	53.6	0.0	0.0	22.6
	high	30.1	55.1	0.0	11.1	3.7
Portugal	high	28.3	50.5	0.0	0.0	21.2

Broilers

Table 43: The energy use (PEC) in broiler production by country and production scenario.

Country	Scenario	Energy use			Meat production	Total PEC
		direct	indirect	total		
		GJ t^{-1}			t	PJ
Finland	high	4.6	7.7	12.3	89146	1.09
Germany	low	2.9	6.0	8.9	706932	6.28
	average	2.9	6.9	9.8		6.93
	high	2.9	7.8	10.7		7.59
Netherlands	low	2.8	9.8	12.6	675104	8.53
	average	2.8	11.1	14.0		9.43

	high	2.8	11.7	14.6		9.84
Poland	low	6.6	7.6	14.2	829396	11.76
	average	6.6	8.2	14.8		12.25
	high	6.6	8.8	15.4		12.77
Portugal	low	0.5	12.1	12.6	226038	2.84
	high	9.5	8.3	17.8		4.02

[a] Eurostat: Broilers – slaughtering (annual data) – NL - 2007

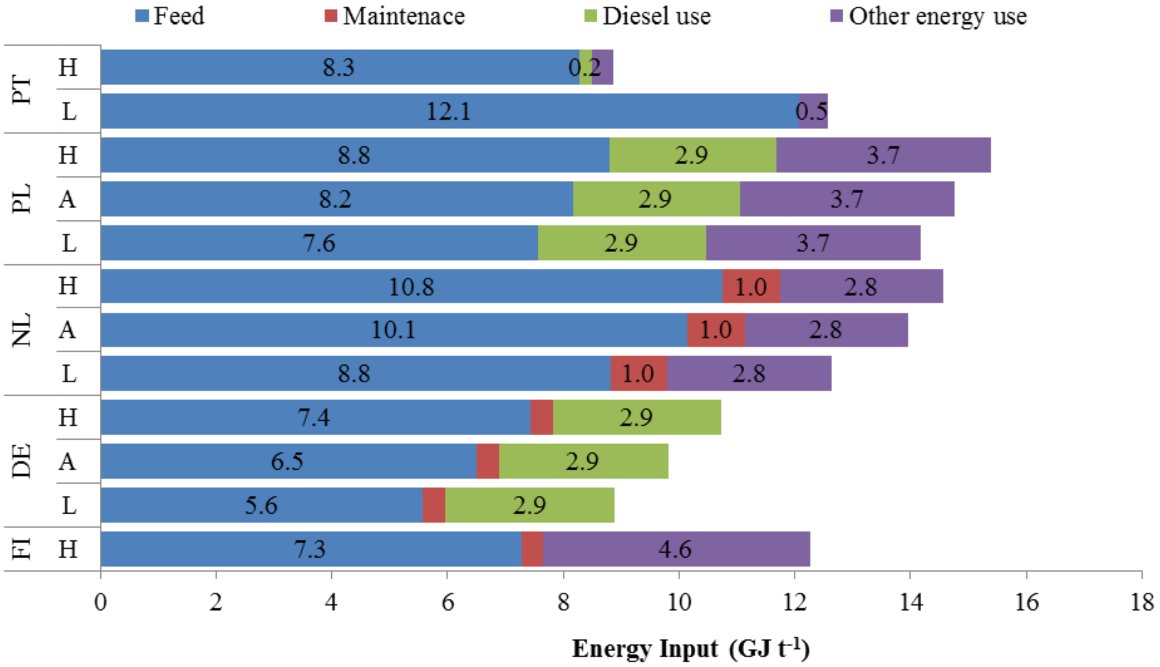

Figure 47. The structure of energy inputs in GJ t^{-1} in broiler production (L, A, H – Low-Average-High energy inputs).

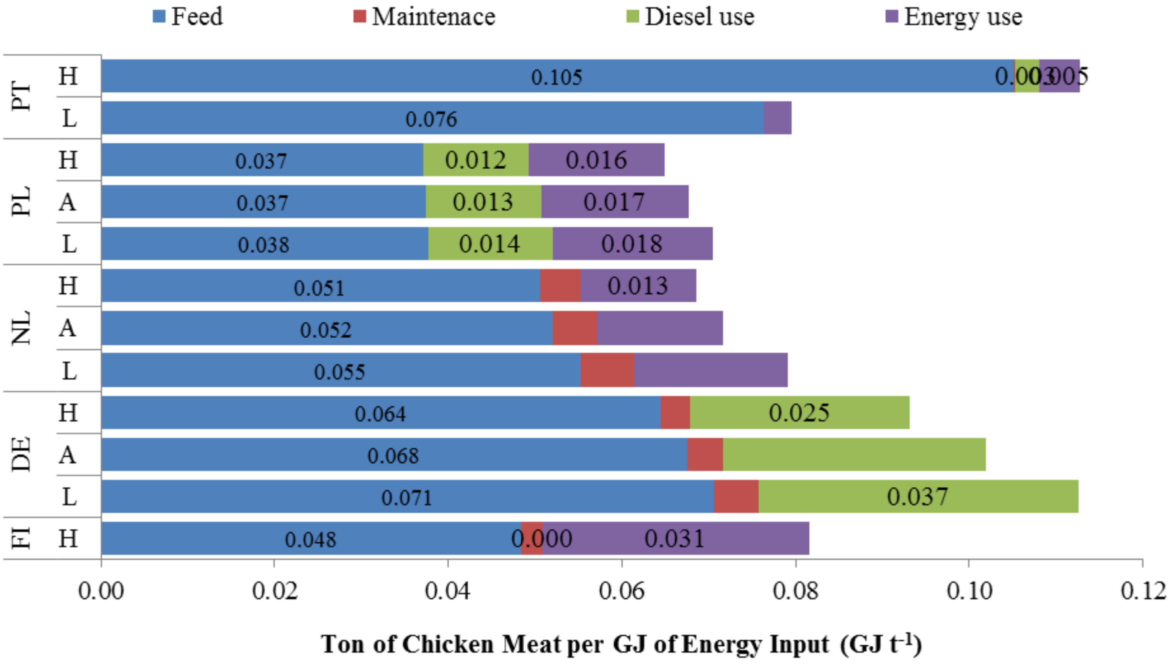

Figure 48. The ton of chicken meat per GJ of energy inputs in broiler production (L, A, H – Low-Average-High energy inputs).

Table 44: The percentage share of specific energy use (PEC, in GJ t^{-1}) in broiler production by process.

Country	Scenario	Feed	Maintenance	Diesel use	Other energy use
		%			
Finland	high	59.3	3.1	0.0	37.6
Germany	low	62.8	4.4	32.8	0.0
	average	66.3	4.0	29.7	0.0
	high	69.2	3.7	27.1	0.0
Netherlands	low	69.8	7.8	0.0	22.4
	average	72.6	7.1	0.0	20.3
	high	73.8	6.8	0.0	19.4
Poland	low	53.4	0.0	20.5	26.1
	average	55.3	0.0	19.6	25.1
	high	57.1	0.0	18.8	24.1
Portugal	low	96.0	0.0	0.0	4.0
	high	93.3	0.0	2.5	4.2

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