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### ENERGY CROP POTENTIALS FOR BIOENERGY IN EU-27


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**ABSTRACT**: Bioenergy gives Europe the best opportunity to reduce GHG emission and secure its energy supply. However, the biomass production should not create additional pressure on the environment. Therefore, for presented calculations, biomass for energy utilization originates from the cropland of the agricultural areas. Permanent grassland, areas of agro-forestry and pasture have not been taken into account. The energy crops potential for the whole EU-27 and for particular countries is presented. Only 10 % of arable land with poor yield conditions would result in almost 50 Mtoe of bioenergy production. With improved yield and increased percentage of the arable land dedicated for energy production up to 20 % of cropland, more than 180 Mtoe can be achieved. The computed results are compared with EU energy demand in 2030. As an example, this would be equal to almost 50 % of the transport fuel needs in 2030.

By integrating biomass, wind, hydro, and solar, these energy sources can guarantee even 75% of the world energy consumption in the near future (2025-2030). Moreover, diversity in energy supply would bring greater economic security and stability for the environment and the society.



**Keywords**: energy crops, land use, resource potential,

**Additional Keywords**: environment, sustainability, security of energy supply


## 1 INTRODUCTION

In order to accomplish the Kyoto greenhouse gas (GHG) reduction targets, the modern utilisation of biomass has to increase rapidly. Nowadays, world energy supply is dominated by fossil fuels. Biomass covers around 10 – 15% (app. 45 EJ) of the energy demand. However, most of it is used in developing countries for cooking or heating, very often in inefficient and not sustainable way. Modern bioenergy – commercial energy production for industrials purposes, power generation or transportation fuels – is estimated for around 7 EJ/yr in 2000 [8], [21].

An increase in the worldwide average air and ocean temperatures, prevalent snow and ice melting and rising levels of sea waters have been attributable to anthropogenic GHG's emission, with biomass resource sectors such as agriculture and wastes playing a very significant contributing role. The recently released IPCC WGI fourth assessment report is illustrating human influence in warming effect on the global climate [18].

It is evident that global climate change is one of the serious problems facing humans in the 21st century. Human activities have contributed significantly to the build up of concentration of harmful emissions in the atmosphere, with activities like fossil fuel combustion for energy, deforestation, livestock production and paddy rice farming.
Atmospheric concentrations of $CO_2$ have increased by 35% from a pre-industrial revolution value of 280ppm to 377ppm in 2005. The concentrations of methane and nitrous oxide in the atmosphere has also increased from pre-industrial levels of 715ppb and 270ppb to about 1774ppb and 319ppb, respectively in 2005 [18]. The concentrations of methane increased more than double within the time period.
The primary source of $CO_2$ since the pre-industrial period can be connected to fossil fuel use and land use changes, However, for methane and nitrous oxide which have a more damaging potential than $CO_2$, emissions have being principally from biomass sources, with agriculture accounting for a major percentage.
These increases have led to a 0.6$^o$C rise in the global average surface temperature since 1900, and this is expected to rise further. It is most likely to be detrimental to a large portion of the world population, especially in developing countries and it is expected to affect sectors such as water supply and food production.
It can be seen that activities such as agriculture, deforestation and waste play a major role in anthropogenic GHG's emission, accounting for about 37% of the total atmospheric emissions. Agricultural practices like the use of inorganic fertilizers and livestock production can lead to emissions of environmentally damaging substances such as ammonia which contributes significantly to acid rain and acidification of ecosystems, and further damaging effects on land.
In addition to the environmental impacts of land degradation and climate affecting atmospheric emissions, the problem of loss of biodiversity is also encountered. This is as a result of the use of natural habitats for the cultivation of energy crops or by the overgrazing activities of livestock.

Producing energy from biomass is one of the best ways to reduce GHG emissions. The GHG emission during all the phases of the biofuels production can be even reduced to near zero [15], when some combinations of biofuel feedstock and conversion processes is applied, i.e. enzymatic hydrolysis of cellulose to produce ethanol and using biomass as the process fuel. Once the biomass fields can replace part of the agricultural area, it can contribute to improvement of biodiversity. Moreover, it can have positive influence of the soil conditions by adding humus and reducing the erosion [16].

It is estimated that around three-fourths of the biomass which is used for production of food, feed, industrial round wood and traditional wood fuel is lost at some point in processing, harvesting and transport [29]. That recovered biomass could be easily applied for bioenergy, moreover if better efficiency of production of food/feed, industrial round wood and traditional wood fuel was developed, there would be more available biomass for modern bioenergy production. But it has to be remembered that the demand for food/feed and industrials round wood must have priority, otherwise bioenergy production cannot be sustainable.
The potential to upgrade biomass for biofuels is evident, and can be converted in conventional used technologies, as example fermentation processes for fuels to the transportation sector. At the same time the developments are well on the track for new harvesting and conversion technologies. Biofuels and fuel cells can reduce $CO_2$ emissions significantly from the transportation sector [22]. Biofuels are today the best way to direct substitute the oil for transport in the European energy market. Even though the technologies like hydrogen have

great potential, these technologies are still far behind large industrial scale. Biofules can be applied in today's ordinary car engines (only with minor modifications for high blends, and without any in low blends).

Ethanol obtained from biomass is one of the most promising sustainable transportation fuels. This compound can be produced from any simple sugar or starchy material. However, great effort is enforced on improvement of the bioethanol production from lignocellulosic materials from forestry and straw the whole crops from agriculture. Unfortunately, the lignocellulosic polymers are not accessible for microorganisms; therefore the material must be prior degraded to basic monomers. Different pre-treatment methods such as acid hydrolysis, steam explosion or wet-oxidation among others [3], [23], [27], [31], [35] are under investigation in laboratories around the world.

According to World Energy Outlook, energy supply for Europe is based mostly on fossil fuels – 79%, and nuclear – 15% (for EU in 2002, [15]). Whereas, the transport sector accounts for app. 30% of the total energy consumption, it dependency on fossils is equal to 98% [1], which most of it originate from unstable parts of the world. Introducing energy from biomass would significantly increase energy independency of the EU-27. "Oil is the energy source that represents the most severe security of supply challenge for Europe" [2].

New tendencies of such actions have started in countries like Germany and Austria, where the percentage of renewable energy is constantly increasing. Many farmers from these countries are starting paradigm shifts from being food and feed producers towards biomass producers.
The European Commission set up a vision to replace up to one-forth of the EU's transport fuels by $CO_2$ neutral sources. This ambitious goal can be easily achieved by introducing the second generation biofuels from energy crops. At the same time it could fulfil the need for creation of new employment and development of advanced technology and more sustainable society.
Biomass yield and its potential differs from country to country, from medium yields in temperate to high level yielding in sub-tropic and tropic countries. However, the temperature above 5 ºC, sufficient water supply in the root zone and top soils assure good growing conditions and efficient photosynthesis. High biomass yield can be achieved from the most efficient photosynthesis C-4 plants such as sugar canes, maize (corn) or sorghum.
Development of the gene-pools for dedicated biomass production has a great potential. For decades, the crop breeding was focused for increasing yields for starch, vegetable oil, sugar or protein, but not for the total crop biomass yield. Several investigations are running in breeding companies. As an example, the breeding incentives for energy maize varieties includes: short-day genes, tolerance towards cold growing conditions in late varieties, and nutrient/water efficiency. Such an improvement can result in increasing the yield from 10-15 tTS/ha to 20-30 tTS/ha. Potentials are not yet very well developed for the diversity of growing and climate conditions [20].

Table I and II illustrate example for Denmark as a picture of potentials and possibilities for the future European paradigm shift towards biomass production for energy and new biomass based products. Table I presents shift towards non-food agricultural production. The survey balances interests of agriculture, forestry production, nature conservation as well as environmental interests.

**Table I:** Utilisation of the area of Denmark and probable future changes [32]

| | 1995 [1000ha] | 2005 [1000ha] | 2025 [1000ha] |
|---|---|---|---|
| Arable land | 2290 | 2035 | 1770 |
| Fallow / brackish | 220 | 150 | 0 |
| Non-food, single/multi annual | 30 | 150 | 300 |
| Permanent grassland | 200 | 325 | 450 |
| **Total Agriculture total** | **2740** | **2660** | **2520** |
| Forestry / woods | 500 | 550 | 650 |
| Fences, ditches, field roads | 113 | 123 | 133 |
| Heath, dune, bog | 200 | 205 | 210 |
| Lakes, streams | 65 | 75 | 95 |
| Buildings in rural areas | 230 | 230 | 230 |
| Cities, roads, holiday cottages | 460 | 465 | 470 |
| **Total area** | **4308** | **4308** | **4308** |

The tendency is to minimize the area of fallow lands and increase the energy farming. It can be performed on the 10-30% of the arable land, fallow and non-food area. There will be cultivation systems aiming at maximum energy storage in organic biomass with medium to high net yielding crops per hectare. The energy crops fields will be grown and handled much more rational than traditional food crops in order to achieve maximum favourable energy output balance.

According to [33] two future energy scenarios are presented in table II. The dark green scenario indicates possibility of non-fossils society. The realistic view lies between those two scenarios; however the goal should be to significantly decrease the fossil fuels supply and to get as close as possible to the dark green scenario. In both scenarios highly efficient utilisation of energy sources as well as significant energy savings are included. Table II displays the energy net consumption derived from biomass in the span of 119 – 137 PJ of biomass, in the year 2030.

**Table II:** Danish gross energy consumption and two future scenarios [33]

| Unit: PJ per year | 1992 *) [PJ] | 2003 *) [PJ] | 2030 [PJ] Light green scenario | 2030 [PJ] Dark green Scenario |
|---|---|---|---|---|
| Oil | 348 | 342 | 246 | 0 |
| Coal | 324 | 176 | 22 | 0 |
| Natural gas | 95 | 191 | 146 | 0 |
| Biomass | 54 | 88 | 119 | 67 (137) |
| Biogas | <1 | 4 | - | 45 (90) |
| Liquid biofuels | - | 2 | - | 22 (47) |
| Solar heating | <1 | <1 | 4 | 40 |
| PV (Solar cells) | - | - | 4 | 25 |
| Wind power | 3 | 20 | 32 | 90 |
| Net power import | 13 | - 31 | 0 | 0 |
| **Total** | **776** | **793** | **573** | **229 (292)** |

* ) Figures from the Danish Energy Authority

Several studies concerning biomass potential have been conducted [9], [10], [12], [13], [40]. Results shown within this paper are the theoretical energy crop potential. Additionally, table summarising the annual amount of manure from pigs and cows production in EU-27 is presented. The aim of the article is to indicate that significant shift into renewable energy system is possible without harming the environment. Future scenarios for bioenergy consumption increase in Denmark are depicted. Moreover, the actual increase of bioenergy production from biomass in Germany is presented as a good example for the other EU countries. Summarizing table with the energy crop potential for the whole world is shown as well.

## 2 RESULTS AND DISCUSSION

In the presented predicted energy crops potential, general units of energy are used. It is not indicated, whether the biomass will be converted into fuel, electricity, or any other form. For simplifying the calculations, it was assumed, that the heating value of 1 kg dry matter biomass is equal to 18 MJ. For further recalculations, 1 Mtoe (mill ton of oil equivalent) was equal to 44.8 PJ.
All the data concerning total area, agricultural and arable land are taken from the FAO database (2003) [14]. The eventually changes in land use (decrease or increase of arable land) are not taken into consideration. All the potential calculations are based on the "today's" arable area.

### 2.1 Energy crop potential

Table IV contents registered data of total area of land use for 27 European countries (EU-27). Data shown for the areas of specific interests for biomass production conditions are the total agricultural area and arable land. It is important to underline that forest and permanent grassland might be partly interesting for future energy farming, specifically the forestry areas. The fallow areas might also soon be integrated in arable land or non-food areas. However, for presented potential only arable land was taken into consideration.

Based on the data from the table III, the possible energy crops potential was calculated. The results in PJ and Mtoe are presented in table IV. The countries with good potential to produce bioenergy are the one with high ratio hectares of agricultural land per capita. The new member states: Bulgaria and Romania with high hectares of agricultural land per capita (both almost 0.7) will make easier the development and implementation of EU bioenergy policies. The average of the EU-27 is 0.4 hectare/capita.

In the coming 10-20 years it will not be unrealistic to see an increasing utilisation of crops for energy and industrial purposes. Scenarios of 10 -20 -30% of arable land shifting from food and feed towards energy farming will gradually occur. Large European countries, with significant fertile agricultural area of cropland, might play a major role in bioenergy production. The average crop yield of around 20t TS/ha is considered as feasible in the near future. According to Perlack et al. [26] the average yields for switchgrass clones, tested in several places in the US, varied from a low 10 total solids per hectare to a high 25 total solids per hectare with most locations having average from 13 to 20 tTS/ha. These results indicated that future yields could be estimated as 20 tTS/ha.

**Table III**: Data of total area and areas of interest for biomass production for each member of EU-27; area data in millions of hectares [11]

| | **Total area ($10^6$ Ha)** | **Agricultural area ($10^6$ Ha)** | **Arable land ($10^6$ Ha) (% of total area)** | | **Hectares of agricultural land per capita** |
|---|---|---|---|---|---|
| Austria | 8.4 | 3.4 | 1.4 | 17 | 0.42 |
| Belgium | 3.1 | 1.4 | 0.8 | 27 | 0.13 |
| Bulgaria | 11.1 | 5.3 | 3.3 | 30 | 0.68 |
| Cyprus | 0.9 | 0.1 | 0.1 | 11 | 0.18 |
| Czech Republic | 7.9 | 4.3 | 3.1 | 39 | 0.42 |
| Denmark | 4.3 | 2.7 | 2.3 | 53 | 0.49 |
| Estonia | 4.5 | 0.8 | 0.5 | 12 | 0.63 |
| Finland | 33.8 | 2.2 | 2.2 | 7 | 0.43 |
| France | 55.2 | 29.7 | 18.5 | 33 | 0.49 |
| Germany | 35.7 | 17.0 | 11.8 | 33 | 0.21 |
| Greece | 13.2 | 8.4 | 2.7 | 20 | 0.77 |
| Hungary | 9.3 | 5.9 | 4.6 | 50 | 0.60 |
| Ireland | 7.0 | 4.4 | 1.2 | 17 | 1.09 |
| Italy | 30.1 | 15.1 | 8.0 | 26 | 0.26 |
| Latvia | 6.5 | 2.5 | 1.8 | 28 | 1.08 |
| Lithuania | 6.5 | 3.5 | 2.9 | 45 | 1.02 |
| Luxemburg | 0.3 | 0.1 | 0.06 | 24 | 0.28 |
| Malta | 0.03 | 0.01 | 0.01 | 31 | 0.03 |
| Netherlands | 4.2 | 1.9 | 0.9 | 22 | 0.12 |
| Poland | 31.3 | 16.2 | 12.6 | 40 | 0.42 |
| Portugal | 9.2 | 3.7 | 1.6 | 17 | 0.37 |
| Romania | 23.8 | 14.7 | 9.4 | 39 | 0.66 |
| Slovakia | 4.9 | 2.4 | 1.4 | 29 | 0.45 |
| Slovenia | 2.0 | 0.5 | 0.2 | 9 | 0.26 |
| Spain | 50.5 | 30.2 | 13.7 | 27 | 0.73 |
| Sweden | 45.0 | 3.2 | 2.7 | 6 | 0.36 |
| U. K. | 24.4 | 17.0 | 5.7 | 23 | 0.28 |
| **EU-27** | **433.1** | **196.6** | **113.5** | **26** | **0.41** |

**Table IV:** Energy crop potential in EU-27, depending on percentage of utilized arable land and achieved crop yield

| Yield | 10% arable land in EU-27 | | 20% arable land in EU-27 | | 30% arable land in EU-27 | |
|---|---|---|---|---|---|---|
| 10 t TS/ha | 2,042 PJ | 46 Mtoe | 4,084 PJ | 91 Mtoe | 6,127 PJ | 137 Mtoe |
| 20 t TS/ha | 4,084 PJ | 91 Mtoe | 8,169 PJ | 182 Mtoe | 12,253 PJ | 274 Mtoe |
| 30 t TS/ha | 6,127 PJ | 137 Mtoe | 12,253 PJ | 274 Mtoe | 18,380 PJ | 410 Mtoe |

## 2.2 Denmark as a case example

In combination with 10% of the regular rotational farmland, exemplified by year 2005 area data, summing up to 230 000 ha, or 20% - 470 000 ha, or 30% - 700 000 ha, dedicated for energy and biorefining farming it will give the following energy figures. Under Danish conditions by the year 2030 it will be more than realistic to reach between 130-170-250 PJ by adding 10, 20 or 30% of the bioenergy from active farming to the existing 90PJ biomass consumption in the year 2003. By combing different renewable energy technologies, Lund [24] presented the possibility of converting the present Danish energy system into a 100% renewable energy system. Such a shift is possible in every EU country, when three main technological changes are taken into account: savings on the energy demand side, efficiency improvements in the energy production, and replacement of fossil fuels by various sources of renewable energy.

The biomass potential specified for Denmark is summarized below.

**Table V:** Case example of Danish rotational farmland dedicated to bioenergy and biorefining farming year 2030

| % of available farmland | PJ | | Mtoe | |
|---|---|---|---|---|
| | 10t TS/ha | 20t TS/ha | 10t TS/ha | 20t TS/ha |
| 10 | 42 | 84 | 0.8 | 1.9 |
| 20 | 84 | 168 | 1.9 | 3.8 |
| 30 | 126 | 252 | 2.4 | 4.7 |

Available land (AL) equals the sum of arable land, fallow, and non-food land: arable land = 2 035 000 ha, fallow = 150 000 ha, non-food = 150 000 ha, AL = 2 335 000 ha. 10 % of AL approximates 230 000 ha, 20 % approximates 470 000 ha, and 30 % approximates 700 000 ha.

## 2.3 Manure resources

Biogas through anaerobic digestion process can be produced from a variety of biomass types. The primary source, which delivers the necessary microorganisms for biomass biodegradation and as well, one of the largest single source of biomass from food/feed industry, is manure from animal production, mainly from cows and pig farms. In the EU-27 more than 1500 mill tons is produced every year. When untreated or managed poorly, manure becomes a major source of ground and fresh water pollution, pathogen emission, nutrient leaching, and ammonia release. If handled properly, it turns out to be renewable energy feedstock and an efficient source of nutrients for crop cultivation. Table VI depicts the amount of cattle and pig manure produced every year in the European Union.

The livestock sector is responsible for 18% of the green house gas emission, measured in $CO_2$ equivalent. It is responsible for 37% of the anthropogenic methane, which has 23 times the global warming potential of $CO_2$. Besides, it is responsible for 65% of anthropogenic nitrous oxide and 64% of anthropogenic ammonia emission [30].

The table below shows the biogas and energy potential of pig and cattle manure in EU-27 (table VII).

**Table VI:** Estimated amounts of animal manure in EU-27 (based on Faostat, 2003 [14])

| **Country** | **Cattle** | **Pigs** | **Cattle** | **Pigs** | **Cattle manure** | **Pig manure** | **Total manure** |
|---|---|---|---|---|---|---|---|
| | [1000Heads] | [1000Heads] | 1000livestock units | 1000livestock units | [$10^6$ tons] | [$10^6$ tons] | [$10^6$ tons] |
| Austria | 2051 | 3125 | 1310 | 261 | 29 | 6 | 35 |
| Belgium | 2695 | 6332 | 1721 | 529 | 38 | 12 | 49 |
| Bulgaria | 672 | 931 | 429 | 78 | 9 | 2 | 11 |
| Cyprus | 57 | 498 | 36 | 42 | 1 | 1 | 2 |
| Czech R. | 1397 | 2877 | 892 | 240 | 20 | 5 | 25 |
| Denmark | 1544 | 13466 | 986 | 1124 | 22 | 25 | 46 |
| Estonia | 250 | 340 | 160 | 28 | 4 | 1 | 4 |
| Finland | 950 | 1365 | 607 | 114 | 13 | 3 | 16 |
| France | 19383 | 15020 | 12379 | 1254 | 272 | 28 | 300 |
| Germany | 13035 | 26858 | 8324 | 2242 | 183 | 49 | 232 |
| Greece | 600 | 1000 | 383 | 83 | 8 | 2 | 10 |
| Hungary | 723 | 4059 | 462 | 339 | 10 | 7 | 18 |
| Ireland | 7000 | 1758 | 4470 | 147 | 98 | 3 | 102 |
| Italy | 6314 | 9272 | 4032 | 774 | 89 | 17 | 106 |
| Latvia | 371 | 436 | 237 | 36 | 5 | 1 | 6 |
| Lithuania | 792 | 1073 | 506 | 90 | 11 | 2 | 13 |
| Luxembourg | 184 | 85 | 118 | 7 | 3 | 0 | 3 |
| Malta | 18 | 73 | 11 | 6 | 0 | 0 | 0 |
| Netherlands | 3862 | 11153 | 2466 | 931 | 54 | 20 | 75 |
| Poland | 5483 | 18112 | 3502 | 1512 | 77 | 33 | 110 |
| Portugal | 1443 | 2348 | 922 | 196 | 20 | 4 | 25 |
| Romania | 2812 | 6589 | 1796 | 550 | 40 | 12 | 52 |
| Slovakia | 580 | 1300 | 370 | 109 | 8 | 2 | 11 |
| Slovenia | 451 | 534 | 288 | 45 | 6 | 1 | 7 |
| Spain | 6700 | 25250 | 4279 | 2107 | 94 | 46 | 140 |
| Sweden | 1619 | 1823 | 1034 | 152 | 23 | 3 | 26 |
| U.K. | 10378 | 4851 | 6628 | 405 | 146 | 9 | 155 |
| **EU-27** | **91364** | **160530** | **58348** | **13399** | **1284** | **295** | **1578** |

**Table VII:** Energy potential of pig and cattle manure in EU-27

| Total manure | Biogas | Methane | Potential | Potential |
|---|---|---|---|---|
| [$10^6$ tons] | [$10^6$ $m^3$] | [$10^6$ $m^3$] | [PJ] | [Mtoe] |
| 1,578 | 31,568 | 20,519 | 827 | 18.5 |

Methane heat of combustion: 40.3 MJ/$m^3$; 1 Mtoe = 44.8 PJ
Assumed methane content in biogas: 65%

The fermentation of manure alone does not result in high biogas yield, but its high buffer capacity and content of diverse elements has a positive impact on the process stability. Besides, huge amount of animal manure is available in Europe. Biogas production through anaerobic fermentation from animal manure is an effective way to reduce greenhouse gas emission, especially ammonia and methane release from manure storage facilities. High methane yield can be achieved through co-digestion of manure with energy crops. The digestate after the process can be further refined and serves as organic fertilizer, rich in nitrogen, phosphorous, and potassium as well as in other macro- and micro-nutrients necessary for plants growth. Usage of large amount of animal manure for bioenergy purpose will reduce the nutrients runoff and diminish the contamination of surface- and ground- water resources by closing and optimizing the recalculation loop of biogas production.

**2.4 Germany as a positive example of successful application of large amount biomass into biofuels**

There is significant increase in biomass cultivation for bioenergy purpose in Germany. The biggest production is focused on biodiesel. The oil seed crop cover already over 1,100,000 ha, which is almost 10% of the arable land (table VIII). Germany as a large central European country has 11.8 mill. ha of arable land. Future biomass potentials in Germany for energy crops are stipulated to be even up to 2 mill. ha or 17% of the arable land on medium to long terms. From this area it can be derived and produced a corresponding energy production of 40% of the fuels needed for transportation or 20% of the primary energy net consumption.

Rapid growth in interest in biogas has been noticed recently in Germany. Between 2004 and 2005 the area dedicated for biogas energy crops increased over six times (table IX). Around 80% of the applied crops is maize, harvested for maize silage. Further growth is expected. Right now Germany has the highest number of biogas plants in Europe (around 3000) [36]. Biogas is produced from manure, industrial organic waste but especially from cultivated energy crops. Energy crops state for over 46% of the substrates. Share of animal manure is around 24% of feedstock applied for biogas in Germany. The biogas potential in Germany was calculated as 24 bill. $m^3$ biogas per year. The amount will increase rapidly and boost the number of biogas plants [36].

**Table VIII:** Cultivation of non-food crops in Germany in 2006 [28]

| Raw materials | Surface area in ha | | | Total |
|---|---|---|---|---|
| | Base areas* | | Set aside | |
| | without energy crop premium | with energy crop premium | | |
| Rapeseed | 610,000 | 172,000 | 318,000 | 1,100,000 |
| Oilseed lin | 3,000 | | | 3,000 |
| Sunflower | 4,000 | | 1,000 | 5,000 |
| Other energy crops(incl.maize) | 30,000 | 188,000 | 77,000 | 295,000 |
| Starch | 128,000 | | | 128,000 |
| Sugar | 18,000 | | | 18,000 |
| Fibres | 2,000 | | | 2,000 |
| Pharmaceutical crops | 10,000 | | | 10,000 |
| Total | 805,000 | 360,000 | 396,000 | 1,561,000 |

*estimate, as no detailed data and trade statistics available

**Table IX:** Increasing biomass cultivation for biogas production [28]

| | 2004 [ha] | 2005 [ha] |
|---|---|---|
| Maize crop | 10,628 | 66,988 |
| Total crop cultivation for biogas | 13,603 | 86,912 |

When more and more arable area is dedicated for energy crops, the biodiversity has to be preserved. The solution to avoid monoculture can be rotational cropping or growing different crop types as double cropping system, and develop diversified multi annual cropping system.
Rotational and sustainable cropping systems are developing through projects managed by the Agency of Renewable Resources (FNR). The crops are harvested green and kept ensiled, which gives opportunity of all year long storage. The goal is to use all energy potential of the feedstock – which means, to utilize the whole crop including stalk and leaves. Only when harvested prematurely, the plants contain enough amount of humidity necessary for ensilage. One more advantage of cultivating diverse crops and early harvesting is tolerating even higher pressure of weeds in the fields. Weeds are only disadvantageous, when they are spreading the seeds. Because of the early harvest, the seeds are collected together with the plant. Consequently, the amount of pesticides can be significantly reduced. In addition, weeds are also organic substances, so they can be used for energy production as well [37].
Due to early harvesting, there is possibility for cultivating a second crop. The late crops can consist e.g. of maize and sunflower. However, it can be also wild plants, which would stabilize the agricultural ecosystem.

### 2.5 Environmental and nature conservation considerations

Development and implementation of improved growing systems for the purpose of biomass production for biorefinery utilisation will get more and more into focus due to increasing demands for biofuels and a variety of biorefinery products. The commitments of making this kind of shift in using sustainable resources in much larger scales have grown and will grow in this and in the coming decade. Increasing needs of growth in living conditions in the new EU countries will cause higher energy demand. Such a tendency is common all over the world in fast developing countries, especially in China or India. On the other hand, in many poorly developed countries in Africa and Asia, the biomass as an energy source is the only way to provide the heat and electricity to the society.
However, the challenge will be to make the paradigm shift from fossil fuels to renewable resources in a sustainable manner. So, how will nature be influenced, and will the environment be harmed by increasing biomass production for the world wide energy sectors?
As stipulated by this survey it has to be remarked that the biomass for energy and industrial utilization originate from the arable land of the agricultural areas. Permanent grassland areas and the areas of permanent crops and permanent pasture have not been taken into account. For such areas value of the nature has the highest priority. If necessary, small amounts of biomass can possibly be harvested from extensive grassland areas to produce limited amounts of bioenergy [6]. At the same time, it would support the management of species-rich grasslands that maintain their biodiversity value only when mown occasionally/temporarily after the flowering and birds nesting season.
Crop residues might be significant for bioenergy potential. Removal of large quantities of residues from cropland has to be consistent with research based guidelines in order to do it in a sustainable manner. In some cases removing any residues can cause loss of soil carbon, whereas on other soils some level of removal can be sustainable and even beneficial. Residue removal should not result in increased artificial fertilizer application, in this case the environmental and economy can be negative [26]. Increased cropping can be positive if for example - energy crop plantations will replace degraded pasture land, largely neutral – when higher crop yield due to shift in cultivation practice from already cultivated area or severely negative when energy crop cultivation replaces environmentally important areas like rain forest in Brazil or i.e. areas under protection of “Natura 2000” in European Union [2].

Another aspect is that introduction of new biomass cropping systems can combine high yields with little fertilizer and pesticide input. For example double cropping systems consists of several crops on the same field [6]. They add to the structural diversity in the field, reduce nutrient leaching and can be harvested more than once a year as green crops.

The increase hectares of perennial crops relative to annual crops can avoid nutrients runoff problem. Moreover, less soil disturbance caused of perennial crops result in less soil erosion and less soil compaction. They also provide better environment for many bird and mammals compare to annual crops.

It will be more profitable to replace annual crops with perennial crops, if bioenergy and other bioproduct markets increase the values of biomass. It would increase environmental benefits: i.e. substitution of maize production with perennial trees and grasses would decrease fertilizer use and improve the soil carbon [26].

From an environmental point of view, indication of significant biomass availability seems likely including co-benefits for biomass production and nature conservation. At the same time to safeguard biodiversity, soil and water resources require environmental guidelines to become an integrated part of future cropping systems and area planning.

According to [2] the recent increase in biofuel crop production from using around 1% of EU25 arable land in 2003 to about 3% of arable land in 2005 did not result in major land use change or significant environmental impacts. Furthermore, the general farm business profitability might be improved by crop production for biofuels.

It was also mentioned that the species adapted for energy purposes might have lower environmental pressure than food/feed crops. Mostly due to the fact, that they are grown for their energy content and not for their nutrients value. To be profitable for farmers, biofuels crops need lower levels of input costs than conventional crops [2].

## 2.6 Future perspectives

Apart from biofuels, many other valuable products like amino acids, enzymes and antibiotics can be produced from organic by-products via fermentation. Co-products may be extremely important for overall renewable fuels production. High quality valuable materials might help to realize commercial success in introduction biofuels on the market. In the biorefinery concept diverse renewable feedstock can be converted into fuels, food and feed, and other different chemical compounds [34], [39]. The significant advantage of fermentation processes is that useful products can be produced from biomass such as grains, sugarcane or potatoes but also from any agricultural by-products/wastes containing organic compounds [25].

In this decade, interesting ideas are under development in new concepts like energy crop biorefineries for gaseous and/or liquid biofuels. A new integration is under R&D&D realisation, for conversion of lignocelluloses products like straw, wood chips and whole crop silage for conversion into biofuels, biogas and new products. All initial products will be used for either bioethanol or biodiesel for the transportation sector, biogas for combined heat and electricity production or into the natural gas grid, and biofertilisers for recycling to the arable land.

## 2.7 Energy demand

According to the International Energy Agency [15], the world energy demand will expand by 60% from 2002 till 2030 and it will reach 16.5 billion toe. It was predicted that fossil fuels will continue to dominate global energy use (around 80%). The total energy demand for Europe in 2030 is estimated for around 2000 Mtoe.

Comparing the prediction with the results, the sustainable energy crop potential can replace (30% of arable land dedicated for energy crops, table V) up to 20% of total energy demand under high yielding conditions.
However, with yield equal to 20tTS per hectare and 20% of arable land intended for energy, the biomass from energy crops may provide almost 50% of European transport fuels needs.
The energy demand for transport in Europe is presented in table below [1].

**Table X:** Energy demand for transport in EU [1]

| | 2000 [Mtoe] | 2030 [Mtoe] |
|---|---|---|
| Gasoline | 129.8 | 141.6 |
| Kerosene | 45.1 | 72.0 |
| Diesel oil | 147.7 | 223.6 |
| Total | 322.6 | 437.2 |

The largest increase in renewable energy use, in the coming years, will take place in the EU countries driven by strong governmental support. Building the new energy structure based on different bioenergy and RES sources should be the main target, where biomass, wind, solar and hydro become integrated part of the overall energy strategies with an important sustainable role for bioenergy and biorefineries to play. Diversifying energy sources would increase the security of supply. In the transport sector the choice is rather limited. Biofuels can be made from diverse feedstocks. Keeping a wide range of the raw materials will assure the greatest security of supply. Introducing the second generation biofuels will even more increase the variety of available raw materials for biofuels production. The type of the raw material will strongly depend of the country of origin e.g. in Brazil sugar cane will be the most popular raw material, whereas in Malaysia and Indonesia – palm oil [2]. A diversification of biomass resources is needed and can be foreseen in the medium long term.

### 2.8 Food and feed demand

There are many advantages from utilizing bioenergy, but there is also a great challenge, concern and responsibility, that cultivation of energy crops might reduce land availability for feed and food production. Below, the land requirement for food/feed production is calculated to indicate that there should not be any competition between cultivation of energy and traditional crops.

Due to aging of the society in the developed countries the future meat demand will probably decline. Additionally, trend for healthier diet might cause smaller meat demand, especially in the industrialized world [26]. On the other hand, the consumption of animal products is projected to increase in developing countries due to enrichment of the societies. The world consumption of food is estimated to reach 3302 kcal $cap^{-1}$ $day^{-1}$ in 2050, (in 1998 the average was equal to 2739 kcal $cap^{-1}$ $day^{-1}$). It has to be underlined that the food production and food security must have priority above energy crop production. However, the cultivation of dedicated energy crops should not be banned in the region where under nourishment exists. Very often, the insecurity in food access is caused by diverse number of factors like: wars, unequal distribution of income, and not always by lack of cropland [29].
Animal products consumption have significant influence on land use, it is much more land demanding than crop production per 1 kg of product. Animal product consumption is around 15% of the total calorie intake, but its production occupies more than 70% of the global

agriculture land [29]. The increase of efficiency in animal production system would generate extra land, which could be used for cultivation of energy crops. The demand for feed per kg animal vary from 3 kg dry weight biomass per kg poultry meat in a industrialized production system, to more than 100 kg dry weight biomass per kg bovine meat in a pastoral system with low technological level [29]. The studies indicated that there is potential to increase efficiency of food production, and the obtained surplus of the agriculture area can be easily applied for bioenergy production. Additionally, the diverse biofuels production co-products can serve as a valuable protein supplement for livestock feeding. Table XI presents average food requirement for diverse diets. The food demand was recalculated for grain equivalents. The data were adapted from Wolf et al.[38]. Tables XII and XIII shows calculated land requirement for food production world-wide and in the EU-27.

**Table XI:** Global food requirement for three diets: **vegetarian**: 2388 kcal $cap^{-1}$ $day^{-1}$ of which 166 kcal $cap^{-1}$ $day^{-1}$ from animal products; **moderate**: 2388 kcal $cap^{-1}$ $day^{-1}$ of which 554 kcal $cap^{-1}$ $day^{-1}$ from animal products; and an **affluent**: 2746 kcal $cap^{-1}$ $day^{-1}$ of which 1160 kcal $cap^{-1}$ $day^{-1}$ from animal products. The actual population size in 1998 ($5.9 \cdot 10^9$ people) and the estimated population size in year 2050 ($9.37 \cdot 10^9$ people), as expressed in grain equivalents $10^9$ tons dry weight per year. Adapted from Wolf et al. [38].

| Diet type | Vegetarian diet | | Moderate diet | | Affluent diet | |
|---|---|---|---|---|---|---|
| Year | 1998 | 2050 | 1998 | 2050 | 1998 | 2050 |
| Food requirement [$10^9$tTS $\cdot year^{-1}$] | 2.80 | 4.45 | 5.17 | 8.21 | 9.05 | 14.36 |

**Table XII:** Land requirement for moderate diet with population size equal to $5.9 \cdot 10^9$ people and the crop yield 6tTS grain $ha^{-1}$ $\cdot year^{-1}$

| Moderate diet | | |
|---|---|---|
| [$tTS \cdot year^{-1}$] | [$ha \cdot year^{-1}$] | [$ha \cdot person^{-1} \cdot year^{-1}$] |
| $5.17 \cdot 10^9$ | $5.17 \cdot 10^8$ | 0.146 |

**Table XIII:** Percentage of present agriculture and arable land required for food production under moderate diet with crop yielding equal to 6 tTS $grain \cdot year^{-1}$

| | EU-27 | World |
|---|---|---|
| Population [people] | $4.9 \cdot 10^8$ | $5.9 \cdot 10^9$ |
| Agricultural area [1000 ha] | $19.7 \cdot 10^7$ | $50.1 \cdot 10^8$ |
| Arable land [1000 ha] | $11.3 \cdot 10^7$ | $14.0 \cdot 10^8$ |
| Land requirement [$ha \cdot year^{-1}$] | $7.1 \cdot 10^7$ | $8.6 \cdot 10^8$ |
| Percentage of agricultural area [%] | 36.0 | 17.2 |
| Percentage of arable land [%] | 62.4 | 61.4 |

Roughly estimating little more than 60% of the arable land is needed for food production under low crop yield conditions. Of course, with rising population, the land demand for food production will also increase. Additionally, there might be change in diet in developing countries due to enrichment of the societies, especially in China and India. But based on the numbers from table XIII, there is sufficient of land which can be dedicated for energy crops. In addition, the crop yield and efficiency in harvesting is constantly increasing. So, if managed in a sustainable way, there will be no competition between food/feed and energy production in the future but challenges of integrating the systems to develop symbiotic systems.

The increasing non-sustainability in the last decades in agriculture, human nutrition, waste and waste management was noticed in the developed countries. According to Isermann and Isermann [19] the production and consumption of food and feed is more than 50% higher than necessary for nutritive energy, fat and protein basic needs for the inhabitants. In Germany the consumption of energy, fat, and animal protein exceeded the requirements by 68, 83, and 100%, respectively, in years 1985-1989 [19]. "Sustainable land management combines technologies, policies and activities aimed at integrating socio-economic principles with environmental concerns so as to simultaneously maintain or enhance production and services; reduce the level of production risks, achieve environmental stability by preserving soil, water quality, and be economically viable and socially acceptable".[4], [19]

### 2.9 Regulatory mechanisms

During intensified studies, consultations and discussions with politicians, academics, organisations and technology providers, ideas have emerged and crystallized. It is without doubt necessary to implement internationally regulatory mechanisms to protect the natural resource areas world-wide, and, at the same time, to increase the sustainable production on the commercial agricultural and forestry areas. These mechanisms have to regulate the intensification and optimisation of the recovered biomass resources on the existing agricultural and forestry areas, utilized in sustainable manners, for the purpose of production of food – feed – fuels, and their symbiotic integration in the contextual approach of biorefineries.

**Table XIV:** Suggestions of regulations of biomass production for food – feed – fuels, in a framework of environmental sustainable and climate protection restoring conditions.

| | **Suggestions of regulations of biomass production for food – feed – fuels** |
|---|---|
| 1. | Reduction of $CO_2$ emissions targets have to be minimum 70% of the $CO_2$ reduction obtained by utilizing CHP conversion of biomass, in comparison with fossil fuel utilisation for the process energy. |
| 2. | Biofuels production facilities have to be equipped with the best energy saving and energy efficient technologies (Best Available Technology - BAT standard). |
| 3. | Biomass must only originate from the existing environmentally sustainable commercial agricultural and forestry areas; |
| 4. | The natural resource areas must not be involved in commercial biomass production (e.g. environmental sensitive areas in Europe, natural rainforest areas and all the other nature sensitive areas around the world). |

**Table XV:** Suggestions for international cooperation in the frame of EU, UN, FAO or other organisations, for implementing regulatory mechanisms and framework conditions.

| | International CODEX of Biomass production for FOOD – FEED – FUELS |
|---|---|
| a. | Environmentally and economically sustainable biomass production conditions at commercial farming and forestry areas. |
| b. | Sustainable rural development, paradigm change, new ways of rural economy. |
| c. | Acting as a tool for restoring climate and preventing further climate change. |
| d. | Prohibit any involvement of the nature resource areas in commercial biomass production activities. |

## 3 CONCLUSIONS

A terminology as biomass for food, feed, fibres, fuels, and future industrial applications is going to be realized and implemented at increasing speed in this and the coming decades. A full paradigm shift has started in this decade going from fossil fuel dependencies towards biomass and accompanying renewable energy recourses based economies for the societies. Biorefineries are symbiotic integrated thinking and utilization of biomasses of any kind for new products, for industrial and energy use at sustainable conditions and terms are challenging.

Optimal utilization of biomass converted to valuable industrial and energy products, as high valuable replacements for fossil fuel products, are highly prioritized at the agenda. At year 2030 it will be possible to meet the EU-27 energy demand up to 20% percent of all energy by biomass and biogenic waste, without harming the environment and without competition with food/feed production. Full integrated utilization of Bioenergy, Wind, Hydro and Solar may significantly raise that number. In the most environmentally friendly scenario renewables could fulfil up to 75% of the entire world energy needs in long term. The world is getting greener and more sustainable if we are doing a more progressive and faster effort, bearing a more balanced future in mind, climatically, environmentally as well as socio-economically.

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