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*Publication date:*
2005

*Document Version*
Publisher's PDF, also known as Version of record

WORKSHOP
ENERGY CROPS & BIOGAS/BIOENERGY
PATHWAYS TO SUCCESS?

Utrecht the 22nd of September 2005, The Netherlands

# Predicted energy crop potentials for biogas/bioenergy worldwide - regions – EU 25

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## Introduction

In the conditions of global warming and increasing release of $CO_2$, $CH_4$, $N_2O$ and other greenhouse gasses there is a tremendous need for actions to be taken. Newly tendencies of such actions have started in countries like Germany and Austria, where farmers are starting paradigm shifts from being food and feed producers towards biomass producers, at higher levels of land productivity, for the energy demands and needs, and for nearby future new biorefinery products.

In Europe renewable energy production will constantly increase due to restricted use of fossil carbon resources world-wide and a prosperous future for various renewable energy technologies among others solar power, wind power and biomass based energy systems. At the same time we do not have to forget the need for creation of new employment, as contrast to stagnation, and that EU needs developments towards advanced technology societies, in the context of decentralisation of energy recovery resources, which have to be sustainable, in contrast to the fossil fuel century we have just passed. This summer at an EU-US workshop hosted by US-DOE and EU DG TREN it was concluded that biomass will be the primary energy source for the 21st century, like the fossils in the past.

## How to produce biomass for biorefineries and examples of resource potentials

In all countries, in temperate, sub tropic and tropic climate zones, there are various medium to high potentials of producing biomass for a broad variety of demands, except in arid and semi arid clime zones, where the deserts and steps are widespread.

If good growing conditions such as sunlight, temperature above 5 ºC and sufficient water in the root zone, in the top soils, are available, besides recycling of nutrients from the societies and in some cases addition of chemical fertilisers, we have the basic conditions in place for biomass production from efficient photosynthesis. One do not have to forget the most efficient photosynthesis C-4 plants such as sugar canes, maize (corn), sorghum etc.

In table 1 and 2 a case example for Denmark is given. This is a picture of potentials and possibilities for the future European paradigm shift towards biomass production for energy and new biomass based products.
In earlier decades all efforts were concentrated on production of food and for feeding a growing population and an rising animal production, by all means increasing living standards. At the same time all energy demands and supplies were fulfilled by fossil carbon sources. Have we reached a maturity level, or is it even above in some industrialized countries?

In table 1 an example of how the entire area of Denmark is utilized, including future possible changes, is presented. The survey balances, interests of agricultural, forestry production, nature conservation as well as environmental interests.

Table 1. Utilization of the entire area of Denmark and probable future changes [10]

| **Area usage;** units in 1.000 ha | **1995** | **2005** | **2025** |
|---|---|---|---|
| Arable land | 2.290 | 2.035 | 1.770 |
| Fallow / brackish | 220 | 150 | 0 |
| Non-food, single/mutiannual | 30 | 150 | 300 |
| Permanent grassland | 200 | 325 | 450 |
| **Agriculture total** | **2.740** | **2.660** | **2.520** |
| 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** | **4.308** | **4.308** | **4.308** |

From 2005 to 2025 the tendency will be that there will be no more fallow land. Part of the arable land resources, in the range of 10-20-30 percent of the categories of arable land, fallow and non-food areas, will in the next two decades be utilized for energy farming, cultivation systems aiming at maximum energy storage in organic biomass with acceptable quantities of medium to high net yielding crops per hectare. These kinds of crops will be grown and handled much more rational than traditional food crops and as cheap as possible at the input side, to gain maximum favorable energy output and balance.

Table 2 depicts Danish gross energy consumption of present years compared with a survey of future scenarios of either light green or dark green scenarios. One scenario features how to run the society without any kind of fossil fuels. In these scenarios highly efficient utilisation of energy sources by all means as well as energy savings at all levels are included.

Table 2 displays the energy net consumption derived from biomass in the span of 119 – 137 PJ of biomass in the year 2030. In combination with 300.000 – 500.000 ha arable land dedicated for energy and biorefinery farming, in the long term it will be more than realistic to reach between 120 – 140 PJ biomass energy production, or even higher, under Danish conditions. This means that such a society can be organized and managed on conditions of between 50 – 100 pct. renewable energy sources. At the same time the dependencies of fossil carbon sources will be minimized throughout the years, as it can be seen in the statistical data from year 1992 and year 2003, where the coal dependency had been decreasing nearly to the half of the consumption in 1992.

Table 2. Comparison of Danish gross energy consumption with two future scenarios [11]

| Unit: PJ per year | 1992 *) | 2003 *) | 2030 Light green scenario | 2030 Dark green Scenario |
|---|---|---|---|---|
| Oil | 348 | 342 | 246 | 0 |
| Coal | 324 | 176 | 22 | 0 |
| Natural gas | 95 | 191 | 146 | 0 |
| Biomass | 54 | 88 | 119 | 6-7 (137) |
| Biogas | <1 | 4 | - | 45 (90) |
| Liquid biofuels | - | 2 | - | 22 (47) |
| Solar heating | <1 | <1 | 4 | 40 |
| PV (Solar cells) | - | - | 4 | 25 |
| Windpower | 3 | 20 | 32 | 90 |
| Net power import | 13 | - 31 | 0 | 0 |
| **Total** | **776** | **793** | **573** | **229 (429)** |

* ) Figures from the Danish Energy Authority

The future will be much more diversified, where regenerative carbon sources will be based on biomass sources of various kind, naturally adapted to the different growing conditions in the changing climate conditions and with a broader utilisation of biomasses for food, feed, fibres, fuels, fertilisers etc, after passing different, pre-treatment technologies before biorefining.
Table 3 contents registered data of total area of land use for 25 European Countries (EU-25). Areas of specific interests for biomass production conditions are the columns of arable land, and partly forest areas and permanent grassland areas. The fallow areas will quite soon be integrated in arable land or non-food areas.

Table3.Data of total area and areas of interest for biomass production for each member of EU25[12]

| Unit: 1 000 ha<br>Country | Total area | Agriculture area | Arable land (% of total area) | | Forest (% of total area) | | Permanent grass (% of total area) | | Fallow |
|---|---|---|---|---|---|---|---|---|---|
| **Austria** | 8 387 | 3 374 | 1 379 | 16 | 3 260 | 39 | 1 917 | 23 | 106 |
| **Belgium** | 3 053 | 1 393 | 833 | 27 | 607 | 20 | 536 | 18 | 28 |
| **Cyprus** | 925 | 137 | 87 | 9 | N/A | N/A | 1 | <1 | 7 |
| **Czech Republic** | 7 887 | 3 652 | 2 767 | 35 | 2 643 | 34 | 839 | 11 | 83 |
| **Denmark** | 4 310 | 2 676 | 2 479 | 58 | 473 | 11 | 186 | 4 | 205 |
| **Estonia** | 4 523 | 698 | 613 | 14 | 2 251 | 50 | 67 | 1 | 25 |
| **Finland** | 33 815 | 2 236 | 2 204 | 7 | 22 487 | 66 | 27 | <1 | 211 |
| **France** | 54 909 | 29 556 | 18 275 | 33 | 15 403 | 28 | 9 972 | 18 | 1 280 |
| **Germany** | 35 703 | 16 974 | 11 791 | 33 | 10 531 | 29 | 4 970 | 14 | 835 |
| **Greece** | 13 196 | 3 897 | 2 211 | 17 | N/A | N/A | 146 | 1 | 441 |
| **Hungary** | 9 303 | 5 867 | 4 516 | 49 | 1 772 | 19 | 1 063 | 11 | 195 |
| **Ireland** | 7 027 | 4 372 | 1 177 | 17 | N/A | N/A | 3 193 | 45 | 18 |
| **Italy** | 30 134 | 15 546 | 8 384 | 28 | 6 856 | 23 | 4 379 | 15 | 617 |
| **Latvia** | 6 459 | 1 596 | 973 | 15 | 2 862 | 44 | 610 | 9 | 94 |
| **Lithuania** | 6 530 | 2 903 | 1 639 | 25 | 1 997 | 31 | 1 203 | 18 | 193 |
| **Luxembourg** | 259 | 128 | 62 | 24 | 89 | 34 | 65 | 25 | 2 |
| **Malta** | 32 | 10 | 9 | 27 | N/A | N/A | N/A | N/A | 0 |
| **Netherlands** | 4 153 | 1 949 | 1 011 | 24 | 353 | 9 | 892 | 21 | 30 |
| **Poland** | 31 269 | 16 899 | 13 067 | 42 | 9 090 | 29 | 3 562 | 11 | 2 302 |
| **Portugal** | 9 191 | 3 846 | 1 589 | 17 | 3 465 | 38 | 1 468 | 16 | 539 |
| **Slovakia** | 4 903 | 2 236 | 1 377 | 28 | 2 002 | 41 | 799 | 16 | 4 |
| **Slovenia** | 2 027 | 505 | 168 | 8 | 1 283 | 63 | 307 | 15 | 1 |
| **Spain** | 50 532 | 25 289 | 13 081 | 26 | 16 493 | 33 | 7 125 | 14 | 3 195 |
| **Sweden** | 41 034 | 3 140 | 2 680 | 7 | 22 323 | 54 | 482 | 1 | 269 |
| **United Kingdom** | 24 291 | 16 352 | 6 397 | 26 | N/A | N/A | 9 906 | 41 | 33 |
| **Summary, EU-25** | 393 849 | 165 229 | 98 765 | 25 | 126 239 | 32 | 53 715 | 14 | 10 710 |

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From table 3 can be surveyed the biomass potentials for biorefinery purposes. E.g. Germany, a large central European country, has 11.8 mil. ha of arable land. Future biomass potentials in Germany for energy crops are stipulated to be up to 2.0 mil. ha or 17 pct. of the arable land in medium to long terms. From this area can be derived and produced a corresponding energy production of 40 pct. Of the fuels needed for transportation or 20 pct. of the primary energy net consumption.
As an example: if only 10 pct. of arable land is used for energy production at poorly developed yield condition, there will be 1778 PJ production for the whole EU-25. That would be more than the double of the demand for the entire Danish energy consumption for a whole year (which is $^{+}/_{-}$ 800PJ).

In the tables 3a & 3b scenarios of area utilisation of arable land from 25 EU countries for energy crop production and the potentials of energy recovery form these areas expressed as mill. tons of oil equivalent at 3 different crop yielding levels are shown.

Table 3a. Scenarios of area utilization of arable land for EU-25 in PJ

| Area used for energy prod. | 10 % of arable land in EU-25 | 20 % of arable land in EU-25 | 30 % of arable land in EU-25 |
|---|---|---|---|
| Yield pr. ha | | | |
| 10 t TS pr. ha | 1 778 PJ | 3 556 PJ | 5 333 PJ |
| 20 t TS pr. ha | 3 556 PJ | 7 111 PJ | 10 667 PJ |
| 30 t TS pr. ha | 5 333 PJ | 10 667 PJ | 16 000 PJ |

* 1 PJ equals $10^{15}$ J

Note: The total area of the arable land in the EU-25 is assumed to be in the order of 98.765.000 ha (according to Eurostat figures 2002)

Table 3b. Scenarios of area utilization of arable land for EU-25 in MTOE

| Area used for energy prod. | 10 % of arable land in EU-25 | 20 % of arable land in EU-25 | 30 % of arable land in EU-25 |
|---|---|---|---|
| Yield pr. ha | | | |
| 10 t TS pr. ha | 40 MTOE | 79 MTOE | 119 MTOE |
| 20 t TS pr. ha | 79 MTOE | 159 MTOE | 238 MTOE |
| 0 t TS pr. ha | 119 MTOE | 238 MTOE | 357 MTOE |

* MTOE: Million Ton Oil Equivalent. 1 MTOE equals 44.8 PJ

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Table 4 presents total and agriculture area as well as arable land, permanent crops, pasture, and forests and woodland expressed in hectares and as a percentage of the total area. The table contains data for the whole world, continents and the most attractive countries for biomass production.

Table 4. Total area and areas important for biomass production in the world, subdivided in continents and the most interesting countries [13]

| Unit: 1 000ha | Total area | Agriculture area | Arable land (% of total area) | | Permanent crops (% of total area) | | Permanent pasture (% of total area) | | Forests and woodland (% of total area) | |
|---|---|---|---|---|---|---|---|---|---|---|
| **World** | 13 427 880 | 5 012 266 | 1 404 130 | 10 | 136 578 | 1 | 3 471 729 | 26 | 4 172 435 | 31 |
| **Africa** | 3 030 974 | 1 110 974 | 184 905 | 6 | 25 792 | 1 | 900 448 | 30 | 712 676 | 24 |
| Algeria | 238 174 | 40 065 | 7 665 | 3 | 600 | 0 | 31 800 | 13 | 3 950 | 2 |
| Cameroon | 47 544 | 9 160 | 5 960 | 13 | 1 200 | 3 | 2 000 | 4 | 35 900 | 76 |
| Ethiopia | 110 430 | 30 671 | 9 936 | 9 | 735 | 1 | 20 000 | 18 | 13 300 | 12 |
| Morocco | 44 655 | 30 283 | 8 396 | 19 | 887 | 2 | 21 000 | 47 | 8 970 | 20 |
| Nigeria | 92 337 | 72 200 | 30 200 | 33 | 2 800 | 3 | 39 200 | 42 | 14 300 | 15 |
| South Africa | 121 909 | 99 640 | 14 753 | 12 | 959 | 1 | 83 928 | 69 | 8 200 | 7 |
| Sudan | 250 581 | 133 833 | 16 233 | 6 | 420 | 0 | 117 180 | 47 | 42 000 | 17 |
| **Asia** | 3 186 692 | 1 683 886 | 511 701 | 16 | 61 686 | 2 | 1 110 499 | 35 | 556 747 | 17 |
| China | 959 805 | 553 957 | 142 621 | 15 | 11 335 | 1 | 400 001 | 42 | 130 518 | 14 |
| India | 328 726 | 181 177 | 161 715 | 49 | 8 400 | 3 | 11 062 | 3 | 68 500 | 21 |
| Indonesia | 190 457 | 44 877 | 20 500 | 11 | 13 200 | 7 | 11 177 | 6 | 111 774 | 59 |
| Japan | 37 789 | 5 190 | 4 418 | 12 | 344 | 1 | 428 | 1 | 24 621 | 65 |
| Kazakhstan | 272 490 | 206 769 | 21 535 | 8 | 136 | 0 | 185 098 | 68 | 9 600 | 4 |
| Pakistan | 79 610 | 27 120 | 21 448 | 27 | 672 | 1 | 5 000 | 6 | 3 480 | 4 |
| Thailand | 51 312 | 20 167 | 15 867 | 31 | 3 500 | 7 | 800 | 2 | 14 500 | 28 |
| Turkey | 77 482 | 41 690 | 25 938 | 33 | 2 585 | 3 | 13 167 | 17 | 20 199 | 26 |
| **Europe** | 2 297 649 | 486 858 | 287 221 | 13 | 16 772 | 1 | 182 865 | 8 | 947 276 | 41 |
| Belarus | 20 760 | 8 924 | 5 606 | 27 | 124 | 1 | 3 194 | 15 | 7 200 | 35 |
| Bulgaria | 11 099 | 5 325 | 3 355 | 30 | 228 | 2 | 1 742 | 16 | 3 348 | 30 |
| Romania | 23 839 | 14 837 | 9 398 | 39 | 501 | 2 | 4 938 | 21 | 6 680 | 28 |
| Russia | 1 707 540 | 216 651 | 123 465 | 7 | 1 835 | 0 | 91 351 | 5 | 765 912 | 45 |
| Serbia & Mont. | 10 217 | 5 586 | 3 397 | 33 | 327 | 3 | 1 862 | 18 | 1 769 | 17 |
| Ukraine | 60 370 | 41 396 | 32 544 | 54 | 913 | 2 | 7 939 | 13 | 9 239 | 15 |
| **North& Central America** | 2 272 494 | 621 403 | 257 273 | 11 | 15 094 | 1 | 349 036 | 15 | 823 914 | 36 |
| Canada | 997 061 | 67 505 | 45 660 | 5 | 6 455 | 1 | 15 390 | 2 | 453 330 | 45 |
| Cuba | 11 086 | 6 655 | 2 668 | 24 | 1 120 | 10 | 2 867 | 26 | 2 608 | 24 |
| Mexico | 195 820 | 107 300 | 24 800 | 13 | 2 500 | 1 | 80 000 | 41 | 48 700 | 25 |
| Nicaragua | 13 000 | 6 976 | 1 925 | 15 | 236 | 2 | 4 815 | 37 | 3 200 | 25 |
| USA | 962 909 | 411 863 | 176 018 | 18 | 2 050 | 0 | 233 795 | 24 | 295 990 | 31 |
| **South America** | 1 783 361 | 642 482 | 112 642 | 6 | 13 952 | 1 | 515 888 | 29 | 931 570 | 52 |
| Argentina | 278 040 | 177 000 | 33 700 | 12 | 1 300 | 0 | 142 000 | 51 | 50 900 | 18 |
| Bolivia | 109 858 | 36 937 | 2 900 | 3 | 206 | 0 | 33 831 | 31 | 58 000 | 53 |
| Brazil | 851 488 | 263 580 | 58 980 | 7 | 7 600 | 1 | 197 000 | 23 | 555 000 | 65 |
| Paraguay | 40 675 | 24 815 | 3 020 | 7 | 95 | 0 | 21 700 | 53 | 12 850 | 32 |
| Peru | 128 522 | 31 410 | 3 700 | 3 | 610 | 0 | 27 100 | 21 | 84 800 | 66 |
| **Oceania** | 856 440 | 466 663 | 50 388 | 6 | 3 282 | 0 | 412 993 | 48 | 200 252 | 23 |
| Australia | 774 122 | 447 000 | 48 300 | 6 | 300 | 0 | 398 400 | 51 | 145 000 | 19 |
| New Zealand | 27 053 | 17 235 | 1 500 | 6 | 1 872 | 7 | 13 863 | 51 | 7 667 | 28 |

J.B. Holm-Nielsen, P.O. Popiel & M. Madsen, Department of Bioenergy, SDU, Denmark (2005)
Data from 2002 (forests and woodland – 1994)

As expected, from the above table it can be easy noticed that the highest percentage of arable land is in Asia, and than in Europe and North & Central America. Moreover, the arable land areas in Asia are over $^1/_3$ of the total world arable land. Therefore, countries like China or India are together covering around 300 000 000 ha of arable land. These countries might become the most vital biomass - and consequently bioenergy - producers.
In Africa, although the priority is food production, the need of energy is necessary as well. Biomass agriculture might significantly positively influence on the national economies of developing countries, especially in tropical and sub-tropical regions: countries like Cameroon or Nigeria in which area of arable land as well as woodland is main part of the country. Furthermore, the South Africa, which is the only one African country ranked as a developed country [13], might be also interested in energy crop production due to its high energy requirements.
In Europe, apart from EU countries, Ukraine might play a significant role in biomass production; Russia with huge potential for biomass production and of course its vast forestry area could play a major role in energy crops, forestry/agriculture industry.
USA and Brazil are already gaining profits from bioethanol production from maize and sugar cane, respectively. Other American countries, like Canada or Argentina with significant agriculture areas, might join them in the near future, with suitable well adopted crop types.

Tables 4a and 4b consist of calculated energy recovery expresses in PJ and TOE, respectively. The values for the whole world and different continents are computed for three diverse crop yielding levels and three different percentage of assumed area for energy production.

Table 4a. Scenarios of area utilization of arable land at the world and particular continents for energy crop production expressed in PJ

| | Area used for energy production | 10% of arable land | 20% of arable land | 30% of arable land |
|---|---|---|---|---|
| | Yield pr. ha | | | |
| **World** | 10 tTS/ha | 25 274 PJ | 50 549 PJ | 75 823 PJ |
| | 20 tTS/ha | 50 549 PJ | 101 097 PJ | 151 646 PJ |
| | 30 tTS/ha | 75 823 PJ | 151 646 PJ | 227 469 PJ |
| Africa | 10 tTS/ha | 3 328 PJ | 6 657 PJ | 9 985 PJ |
| | 20 tTS/ha | 6 657 PJ | 13 313 PJ | 19 970 PJ |
| | 30 tTS/ha | 9 985 PJ | 19 970 PJ | 29 955 PJ |
| Asia | 10 tTS/ha | 9 211 PJ | 18 421 PJ | 27 632 PJ |
| | 20 tTS/ha | 18 421 PJ | 36 842 PJ | 55 264 PJ |
| | 30 tTS/ha | 27 632 PJ | 55 264 PJ | 82 896 PJ |
| Europe | 10 tTS/ha | 5 170 PJ | 10 340 PJ | 15 510 PJ |
| | 20 tTS/ha | 10 340 PJ | 20 680 PJ | 31 020 PJ |
| | 30 tTS/ha | 15 510 PJ | 31 020 PJ | 46 530 PJ |
| North & Central America | 10 tTS/ha | 4 631 PJ | 9 262 PJ | 13 893 PJ |
| | 20 tTS/ha | 9 262 PJ | 18 524 PJ | 27 785 PJ |
| | 30 tTS/ha | 13 893 PJ | 27 785 PJ | 41 678 PJ |
| South America | 10 tTS/ha | 2 028 PJ | 4 055 PJ | 6 083 PJ |
| | 20 tTS/ha | 4 055 PJ | 8 110 PJ | 12 165 PJ |
| | 30 tTS/ha | 6 083 PJ | 12 165 PJ | 18 248 PJ |
| Oceania | 10 tTS/ha | 907 PJ | 1 814 PJ | 2 721 PJ |
| | 20 tTS/ha | 1 814 PJ | 3 628 PJ | 5 442 PJ |
| | 30 tTS/ha | 2 721 PJ | 5 442 PJ | 8 163 PJ |

Lower combustion energy value is 18 MJ per kg TS; 1 PJ equals $10^{15}$ J

Table 4b. Scenarios of area utilization of arable land at the world and particular continents for energy crop production expressed in MTOE

| | Area used for energy production / Yield pr. ha | 10% of arable land | 20% of arable land | 30% of arable land |
|---|---|---|---|---|
| **World** | 10 tTS/ha | 564 MTOE | 1 128 MTOE | 1 693 MTOE |
| | 20 tTS/ha | 1 128 MTOE | 2 257 MTOE | 3 385 MTOE |
| | 30 tTS/ha | 1 693 MTOE | 3 385 MTOE | 5 077 MTOE |
| Africa | 10 tTS/ha | 74 MTOE | 147 MTOE | 223 MTOE |
| | 20 tTS/ha | 149 MTOE | 297 MTOE | 446 MTOE |
| | 30 tTS/ha | 223 MTOE | 446 MTOE | 669 MTOE |
| Asia | 10 tTS/ha | 206 MTOE | 411 MTOE | 617 MTOE |
| | 20 tTS/ha | 411 MTOE | 822 MTOE | 1 234 MTOE |
| | 30 tTS/ha | 619 MTOE | 1 234 MTOE | 1 850 MTOE |
| Europe | 10 tTS/ha | 115 MTOE | 231 MTOE | 346 MTOE |
| | 20 tTS/ha | 231 MTOE | 462 MTOE | 692 MTOE |
| | 30 tTS/ha | 346 MTOE | 692 MTOE | 1 039 MTOE |
| North & Central America | 10 tTS/ha | 103 MTOE | 207 MTOE | 310 MTOE |
| | 20 tTS/ha | 207 MTOE | 414 MTOE | 620 MTOE |
| | 30 tTS/ha | 310 MTOE | 620 MTOE | 930 MTOE |
| South America | 10 tTS/ha | 45 MTOE | 91 MTOE | 136 MTOE |
| | 20 tTS/ha | 91 MTOE | 181 MTOE | 272 MTOE |
| | 30 tTS/ha | 136MTOE | 272 MTOE | 407 MTOE |
| Oceania | 10 tTS/ha | 20 MTOE | 41 MTOE | 61 MTOE |
| | 20 tTS/ha | 41 MTOE | 81 MTOE | 122 MTOE |
| | 30 tTS/ha | 61 MTOE | 122 MTOE | 182 MTOE |

MTOE: 1 million ton oil equivalent ~ 44.8 PJ
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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 pct. of arable land shifting from food and feed towards energy farming will gradually occur. Another large European country, Ukraine is rapidly developing in the same direction like the EU countries. In such a large, fertile agricultural country it is stipulated that introduction of renewable energy sources will grow as fast as in many EU countries. In the table below it is depicted that biomass will cover nearly 50 pct. of the renewable energy resources in the long term future. Energy cropping will even increase this potential when energy crops are integrated in large scale biorefinery systems in Ukraine.

Table 5. Renewable energy sources (RES) in Ukraine; Calculations and predictions until 2030 [2]

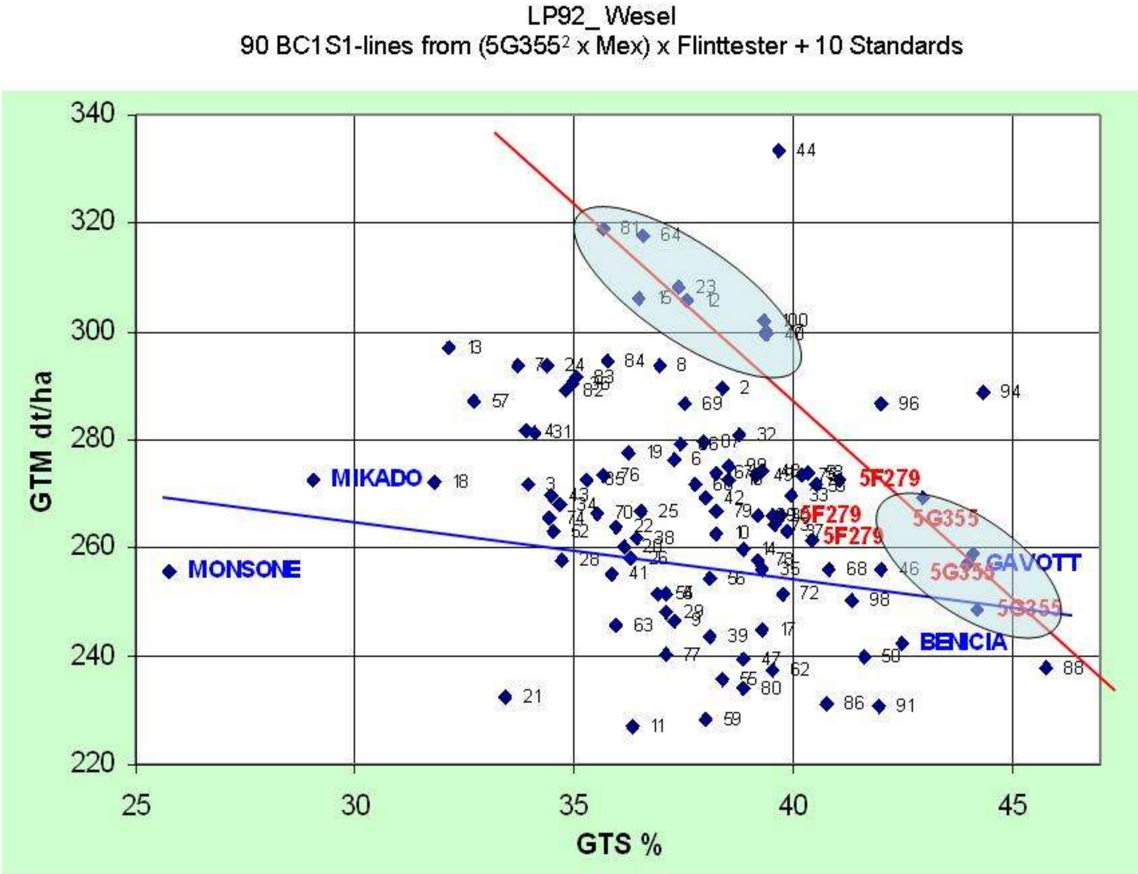
| Type | Technical potential | | Heat and electricity production from RES | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2001 | | 2010 | | 2020 | | 2030 | |
| | Mln t coal eqv | % | Mln t coal eqv | % | Mln t coal eqv | % | Mln t coal eqv | % | Mln t coal eqv | % |
| Wind energy | 15 | 23.8 | 0.01 | 0.2 | 0.22 | 3.2 | 1.0 | 7.0 | 2.15 | 10 |
| Photovoltaic | 2.0 | 3.2 | N/A | N/A | 0.001 | 0.02 | 0.01 | 0.1 | 0.03 | 0.1 |
| Small hydro | 3.0 | 4.8 | 0.17 | 3.1 | 0.15 | 2.2 | 0.48 | 3.4 | 0.65 | 3.0 |
| Big hydro | 7.0 | 11.1 | 4.36 | 78.7 | 4.8 | 68.6 | 5.6 | 39 | 6.53 | 30.2 |
| Solar heating | 4.0 | 6.4 | 0.002 | 0.04 | 0.12 | 1.7 | 0.7 | 4.9 | 1.28 | 5.9 |
| **Biomass** | **20** | **31.7** | **0.99** | **17.9** | **1.66** | **23.8** | **6.3** | **43.9** | **10.13** | **46.9** |
| Geothermal | 12 | 19 | 0.004 | 0.1 | 0.034 | 0.5 | 0.247 | 1.7 | 0.83 | 3.8 |
| Total | 63 | 100 | 5.54 | 100 | 6.99 | 100 | 14.34 | 100 | 21.6 | 100 |

1 TOE =1.43 t coal eqv.; N/A: Not Available

**Case example of plant breeding gene pool potentials exemplified by maize/corn crop varieties.**

The gen-pools are not yet developed for dedicated biomass production. For decades crop breeding was dedicated for specific tasks of optimal production yields for starch, vegetable oil, sugar, proteins and not for the total crop yield, including the interesting lignocelluloses complexes in steams and leaves and the entire crop biomass. A future perspective for biomass carbon capture includes the whole crop, with as effective and/or robust conversion into photosynthesis products, at as good rates as will be possible, due to various growing and climate conditions. Potentials are not yet very well developed in the plant breeding and cropping sectors of agriculture.

Below is a plant breeding company example of new maize varieties. The breeding incentives for energy maize varieties include **a.** short-day genes, **b**. tolerance towards cold growing conditions in late varieties, **c.** nutrient/water efficiency. Commercial energy maize varieties, as an example, will be on the market in 2007. The figure below shows how to grow not 15-20 t of TS/ha, but with an increasing trend towards 30 t of TS/ha in the future (figure 1, 2).




Source: Dr. Ernst Kesten, KWS Saatgut AG, Einbeck, (D)

Figure 1. Case example of plant breeding gene pool potentials for mazie crop [4]

Harvest of energy maize

Source: Dr. Ernst Kesten, KWS Saatgut AG, Einbeck (D)

Figure 2. Harvesting of maize crops [4]

**Future perspectives for biomass utilisation in the energy and industrial sectors.**

At present the energy supply from biomass is around 45 $^{+}/_{-}$ 10 EJ per year. Main uses consist on traditional way e.g. firing for cooking and heating. The modern technologies (e.g. production of liquid biofuels or electricity and heat – CHP) are approximated at 7EJ a year [6].
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 harvest and conversion technologies. Biofuels and fuel cells can reduce $CO_2$ emissions significantly from the transportation sector, as we have seen in stationary systems such as biomass for heat and electricity production systems [7].

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, big effort is enforced on improvement of the bioethanol production from lignocellulosic materials (forestry and straw from agriculture, the whole crops) which are the richest and renewable compounds for people. Unfortunately, the polymers are not accessible for microorganisms, therefore the material must be prior degraded to basic monomers. Different pre-treatment methods are under investigation in laboratories around the world such as acid hydrolysis, steam explosion or wet-oxidation among others [9].

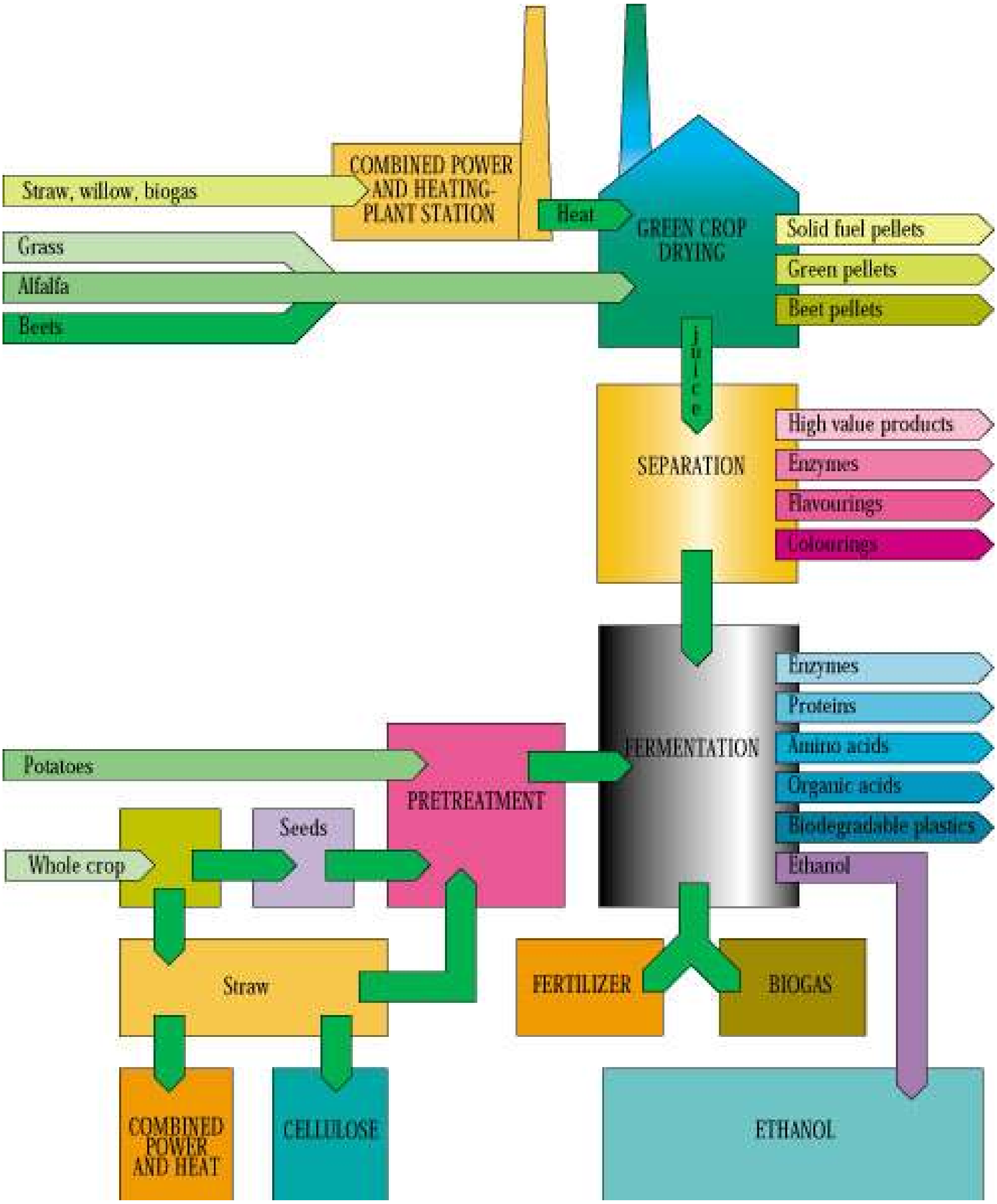
Developments and implementation of improved growing systems for the purpose of biomass production for biorefinery utilisation will get more and more into focus due to increasing demands for biofuels and a variety of biorefinery products. The commitments for making this kind of shift in the way of widespread using sustainable resources in much larger scales have grown and will grow in this and the coming decade, mainly due to increasing needs of growth in living conditions in big countries like China and India, and all over the world and because fossil fuels will be completely inadequate in the medium to long term.
However, the challenge will be to make the paradigm shift in a sustainable manner.

**What is a Biorefinery?**

According to [8] one can distinguish two types of biorefinery. Brazil, the United States, China, Southern Asia or Australia is principally “biomass-producing-country” type. Useful products are being produced from biomass such as grains, sugarcane or potatoes. Whereas, in European countries or in Japan - where due to lack of space, the significant problem with storage of huge quantity of organic waste occur – the biorefinery is often based on “waste-material-utilization” type [8]. The production of valuable bioproducts, until now, is mainly connected with organic waste handling problems.

The basic conceptual idea of Biorefinery is illustrated by the flow sheet below (figure 3), from the survey conducted by the research group – The Biomass Institute, SUC, (DK) back in the early 90’ties and after that realized in the full scale: The green juice – amino acid , Lysin plant, Agroferm Ltd., Esbjerg. Other ideas are realized as joint biogas plants in Denmark like Ribe, Linko, Lemvig, Blaabjerg and Thorsoe and Hashoej biogas plants, to mention only some examples.

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 for the transportation sector and biogas for combined heat and electricity production or the natural gas grid and biofertilizers for recycling to the arable land.




Source: Pauli Kiel et. al. Biomass Institute, SUC, 1994

Figure 3. Ethanol in the Green Biorefinery [5]

**World energy scenarios – goals for future**

Table 6 presents possible energy obtained from agriculture. In table 7 two world primary energy consumption scenarios are depicted.

Table 6. Energy scenarios

| No. | | | Source |
|---|---|---|---|
| 1. | Non collected straw (50%) | 75 000 PJ/year | Sanders J.: *Biorefinery, the bridge between Agriculture and Chemistry*. Wageningen University and Researchcenter. Workshop: Energy crops & Bioenergy. |
| 2. | Collected waste processing (50%) | 45 000 PJ/year | |
| 3. | Forest/pastures (50%) | 150 000 PJ/year | |
| 4. | 10% of arable land – World Wide (20 t TS / ha) | 50 549 PJ | Holm-Nielsen J.B., Madsen M., Popiel P.O.: *Predicted energy crop potentials for biogas/bioenergy. Worldwide – regions – EU25*. AAUE/SDU. Workshop: Energy crops & Bioenergy. |
| 5. | 20% of arable land – World Wide (20 t TS / ha) | 101 097 PJ | |
| 6. | 30% of arable land – World Wide (20 t TS / ha) | 151 646 PJ | |
| Sum: 1+2+3+5 | | 371 097 PJ | |

Table 7. World primary energy consumption for 2050

| | Predicted value | Source |
|---|---|---|
| Total energy required 2050 | 1 000 000 PJ/year | Sanders J.: *Biorefinery, the bridge between Agriculture and Chemistry*. Workshop: Energy crops & Bioenergy. |
| Total energy demand 2050 | 1 300 000 PJ/year | Shell's World Energy Scenario |

20% of arable land dedicated for energy production (20tTS/ha) would give us around 10% of total world energy required in 2050. Adding: 7.5% from non collected straw, 4.5% from collected waste processing, and 15% from forest or pasture would result in almost 40% of the whole energy needed in 2050. However, Shell predicts that energy demand in 45 years will increase even to 1300EJ/year. On the other hand, it forecasts that energy from renewable would be more than 50% of the total energy.

**Summary**

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

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 2050 it will be possible to meet the world energy demand with 75-90 percent of all energy by full integrated utilization of Bioenergy, Wind, Hydro and Solar energy sources. Bioenergy can fulfill in between 30-50 percent of the entire world energy needs and demands. 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, environmentally as well as economically speaking internationally.

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