# Biomass Utilization - Next Industrial Revolution

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# Biomass statistics

- Globally the official figures for the use of biomass as an energy resource shows that it is approximately 13 % of all primary energy used. This is according to the World Bank figures.
- If we go back 30 years the official figure was almost 0 %. The reason for the difference is that in 1980 only material that was traded was registered and accounted for.
- As it was obvious that bioenergy was very important in many countries although not being traded, the new figures were estimated.
- The figure 13 % then has principally been kept for 25 years, although the total global energy use has increased by 30-40%.
- In reality much more is used indirectly as food, building materials etc, but then not considered “for energy use”.

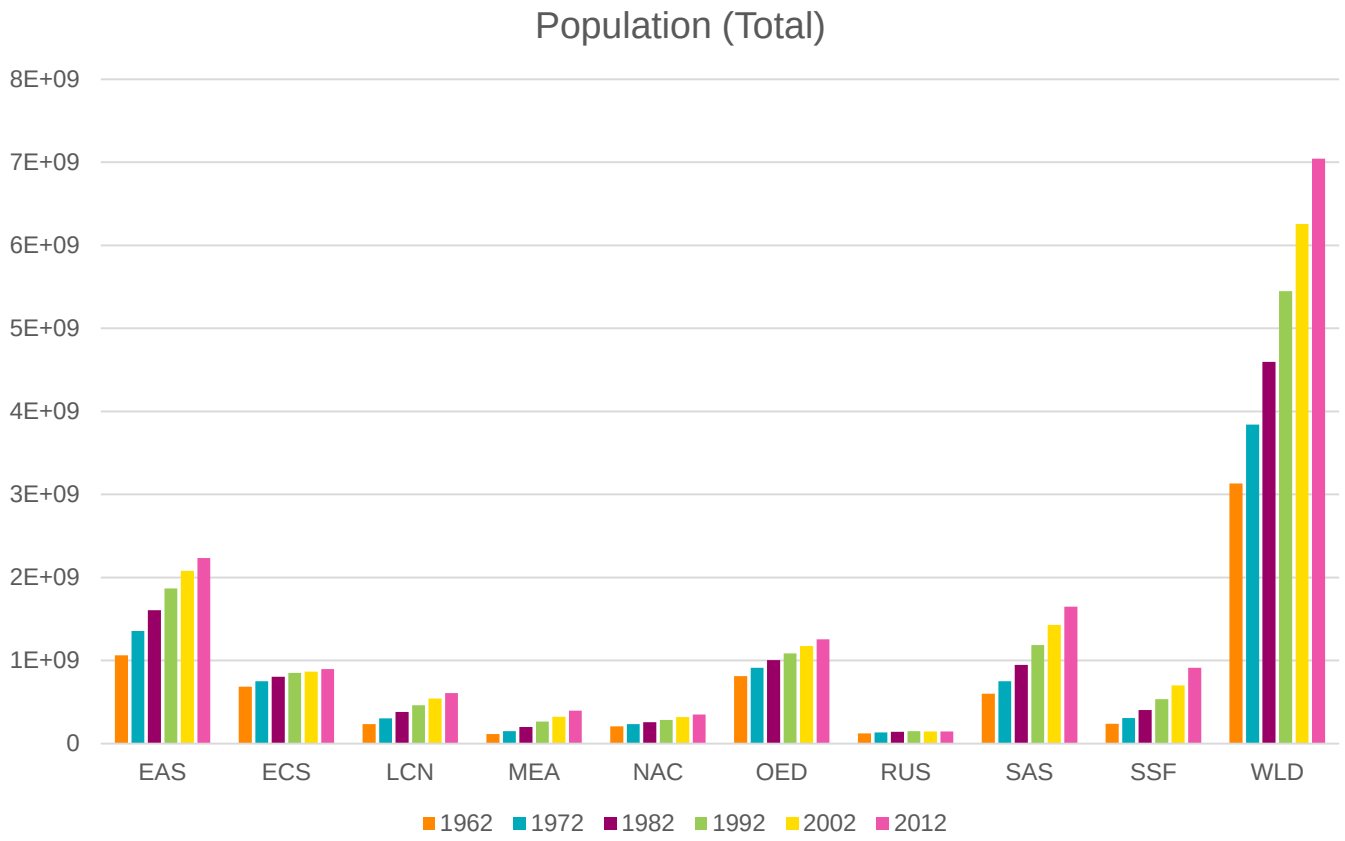
- In 2013 UN estimated the world population to be 7 124 543 962 inhabitants globally.
- Of these 53,0 % were living in urban areas. This shows that now more people live in urban areas than rural. The situation differs between low income countries, middle income and high income countries.
- In low income countries only 28,7 % were living in urban areas, in middle income 50,1 % while 80,5 % in high income countries 2013.

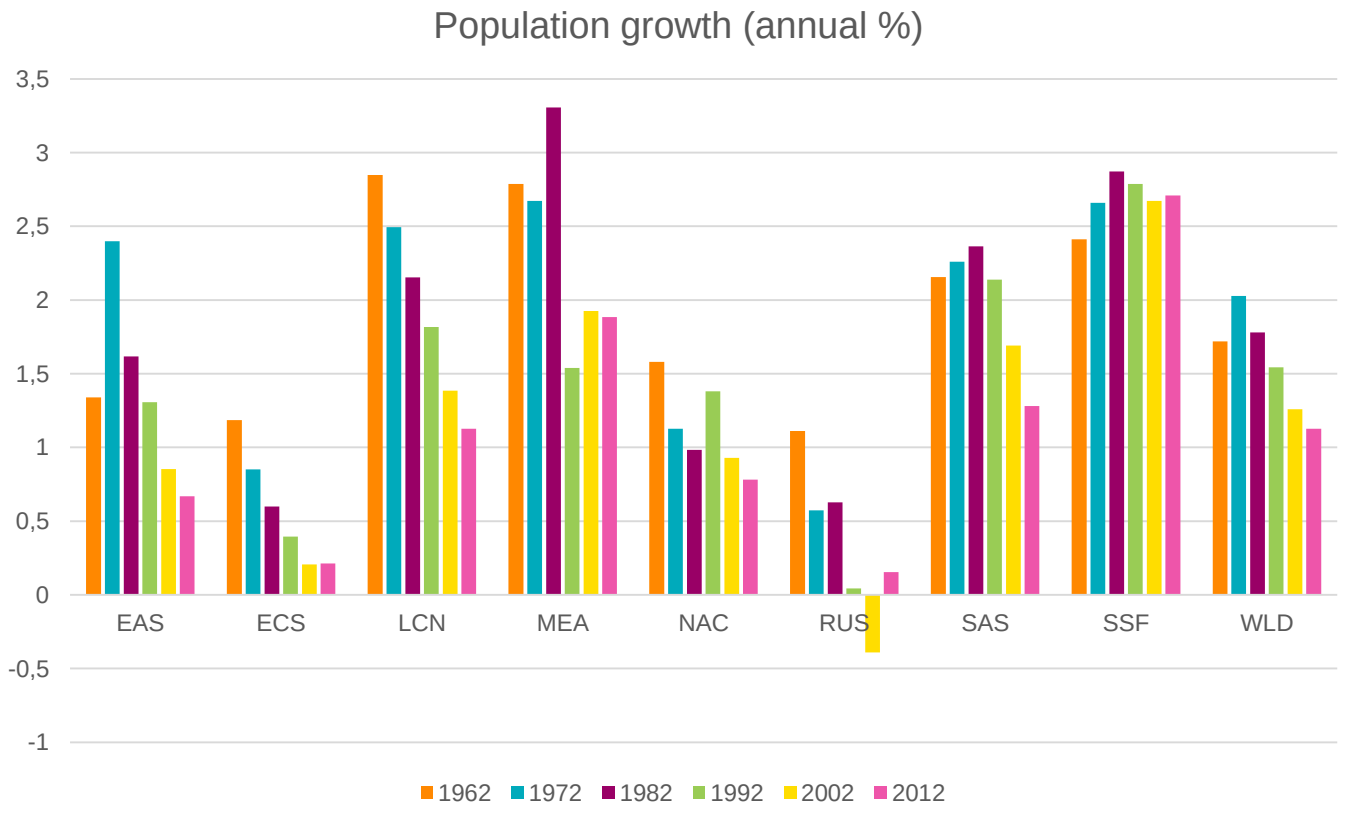
# Low income, middle income and high income countries distributed on regions

| | EurCA | EastAsia | LatAm | SoAsia | SubSah | MEasNAf | NAm | Total |
|---|---|---|---|---|---|---|---|---|
| Low income | 2 | 3 | 1 | 3 | 26 | 0 | 0 | 35 |
| Middle income | 21 | 21 | 29 | 5 | 21 | 13 | 0 | 110 |
| High income | 35 | 11 | 10 | 0 | 1 | 8 | 3 | 68 |
| Global total | 58 | 35 | 40 | 8 | 48 | 21 | 3 | 213 |

# Regional distribution of global population

EAS=East Asia; ECS=Europe and central Asia; LCN=Latin& central america; MEA=Midlle east and North Africa; NAC=North America; OED=OECD RUS=Russia; SAS= South Asia; SSF Africa south of Sahara; WLD World




Population growth (annual %)
3,5
3
2,5
2
1,5
1
0,5
0
-0,5
-1
EAS
ECS
LCN
MEA
NAC
RUS
SAS
SSF
WLD
1962
1972
1982
1992
2002
2012

# Different average income per capita in different categories of countries

| | Cereal yield kg/ha | | El from fossil fuel % | | El consump | Energy use | Fossil fuel | GNI |
|---|---|---|---|---|---|---|---|---|
| | 1970 | 2009 | 1970 | 2008 | 2008 | 2008 | 2008 | 2012 |
| | | | | | kWh/cap | kgoe/cap | % of total | US$/cap |
| Low income | 1296 | 1952 | 17,9 | 31,4 | 222 | 350 | 30,1 | 444 |
| Middle income | 1515 | 3202 | 37,2 | 73 | 1606 | 1255 | 81,3 | 2696 |
| High Income | 2766 | 5448 | 71,7 | 62,9 | 9515 | 5127 | 82,7 | 31 583 |
| World wide | 1829 | 3513 | 61,6 | 67,2 | 2874 | 1834 | 81,1 | 9 197 |

# Distribution of Agriculture, arable and forest land on economic categories

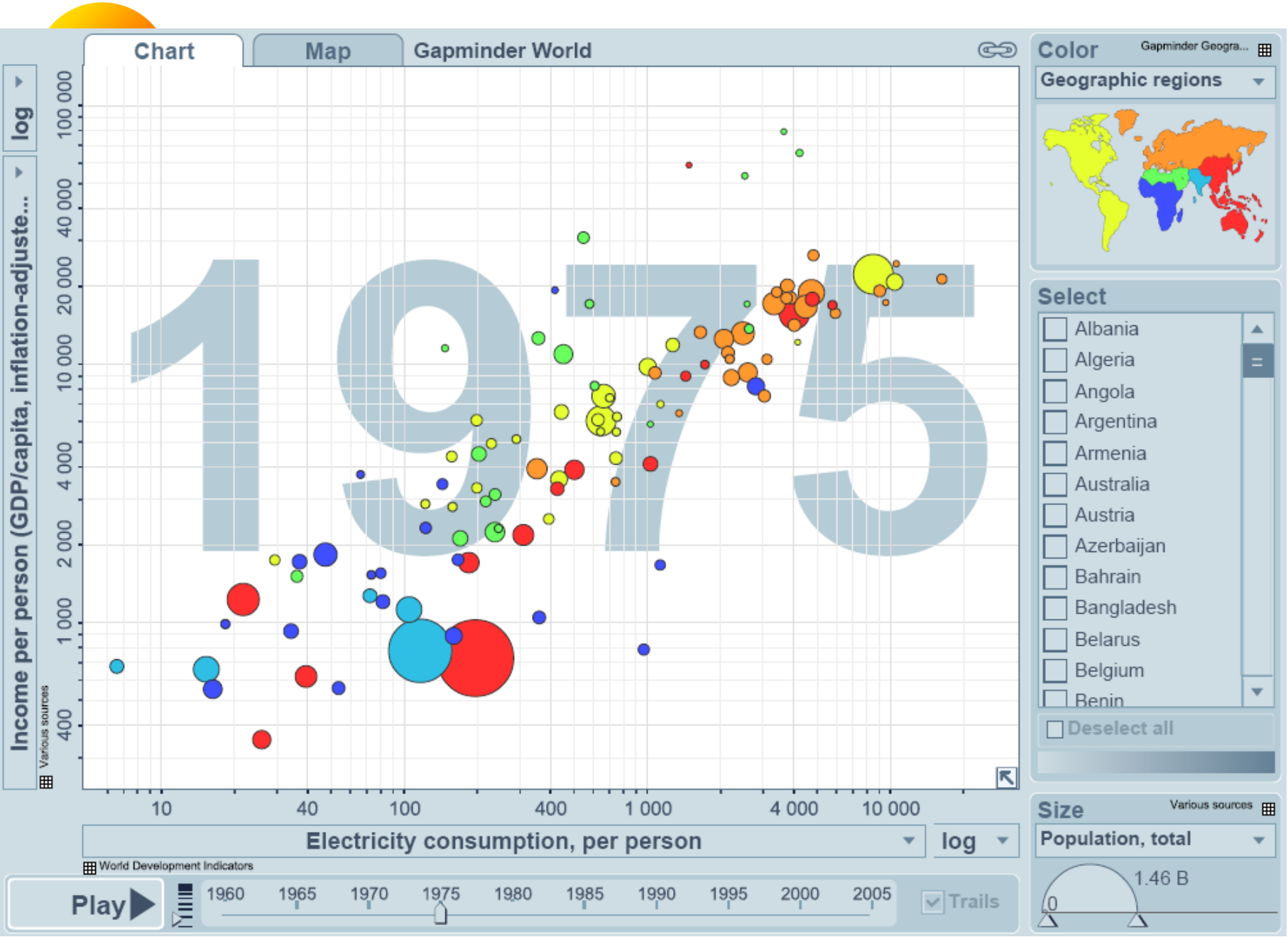
| | Agricul +forest | Agric land | Arable land | Land area | Cereal | Forest | Forest | Total |
|---|---|---|---|---|---|---|---|---|
| | ha/capita | % of tot | % of tot | cereal prod | production | area | area in | landarea |
| | | | | ha | ton | km^2 | % of tot | km^2 |
| | 2008 | 2008 | 2008 | 2008 | 2009 | 2010 | 2010 | 2009 |
| Low income | 1.9 | 37,8 | 9,3 | 88 349 486 | 172 000 000 | 4 154 870 | 27,6 | 15 043 470 |
| Middle income | 1.6 | 37,8 | 10,9 | 473 000 000 | 1 510 000 000 | 26 420 030 | 32,8 | 80 675 467 |
| High Income | 3.1 | 37,3 | 10,9 | 147 000 000 | 803 000 000 | 9 629 420 | 28,8 | 33 842 634 |
| World wide | | 37,7 | 10,7 | 708 000 000 | 2 490 000 000 | 40 204 320 | 31,1 | 130 000 000 |

# Global biomass production

**Today**´s biomass production appr **160 000 - 270 000 TWh/y**

- agriculture incl straw 95 000 - 190 000
- forests 65 000 - 80 000

**This can be compared to** the **150 000 TWh** energy used today per year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Income per person (GDP/capita, inflation-adjuste...
Various sources
100 000
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Electricity consumption, per person
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World Development Indicators
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Belarus
Belgium
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Size
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Population, total
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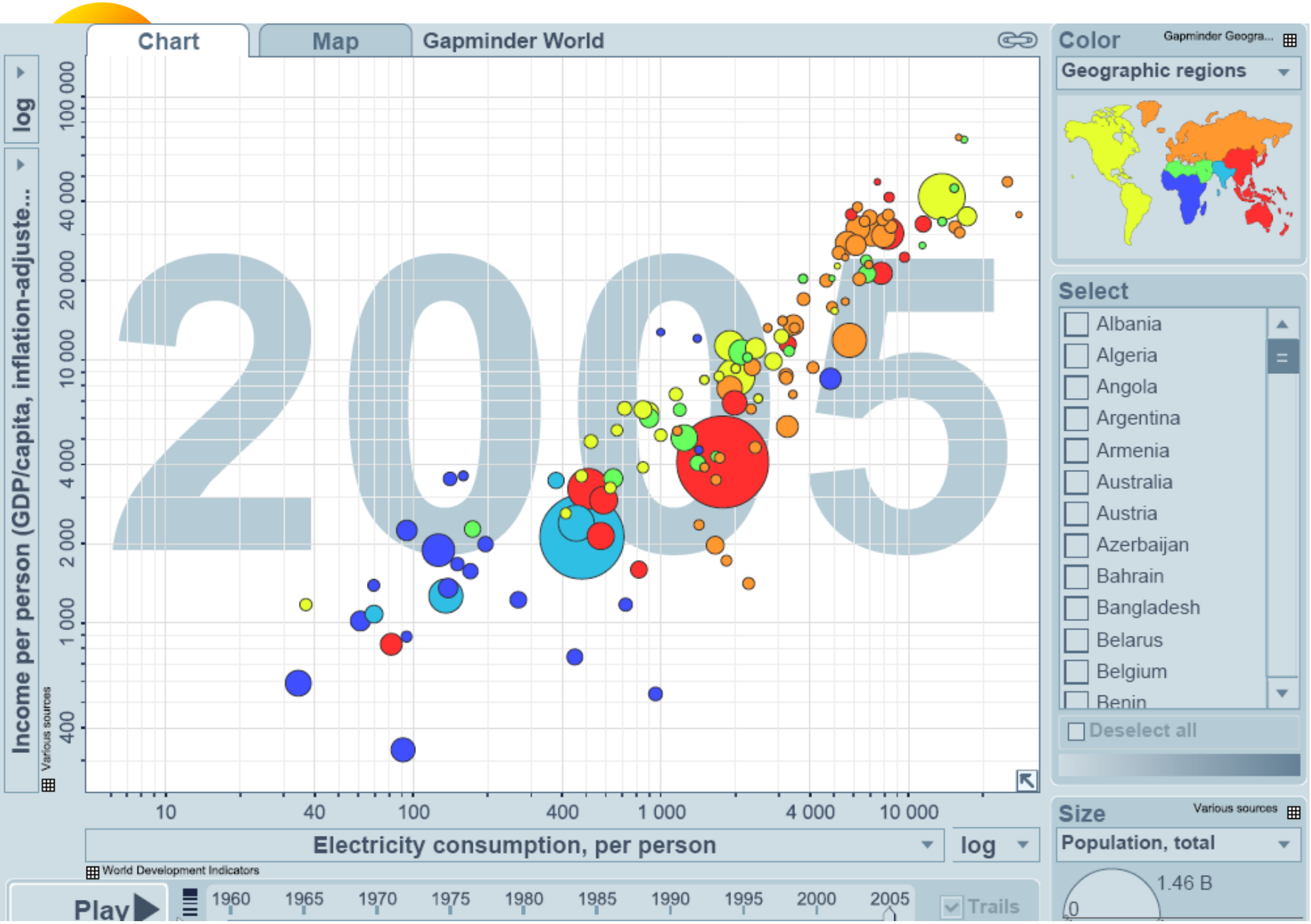
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World Development Indicators
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0
Play
1960
1965
1970
1975
1980
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1995
2000
2005
Trails

# Conclusion

The **natural resources** are relatively equally distributed between rich and poor countries at a high level.

There is principally **enough biomass** to cover all needs

We have gone from a **difference** in wealth **between** countries to a difference **within** countries

The distribution of **wealth** is directly **correlated to** use of energy, especially **electricity**

# Use of agricultural and arable land

- We have 4900 million ha agricultural land and 1400 million ha arable land globally.
- By more efficient milk production 150 million ha agricultural and 67 million ha arable land could be used for other purposes than breeding animals
- 700 million ha is used for cereal production as a comparison

# Pathways for the photosynthesis

- The most common is called the **C3 system**. This is most common in colder and tempered climates, and produces 3-carbon organic acid (3-phosphoglyceric acid).
- The second main system is more common in warm climates. It is called the **C4 system**, as the first product is 4-carbon organic acids (malate and aspartate).

# Pathways for the photosynthesis

- This means that increased CO2 concentration will be beneficial for C4 plants, but may be inhibiting C3 plants.
- Well-known C4 crops are Sorghum, Sugarcane, Maize, Miscanthus and Cord grass. Most species still have the C3 system.
- The third enzyme system for photosynthesis is called the **CAM** system, or Crasulacean acid metabolism.
- Two crops are of agricultural interest from this group – pineapple and sisal (kind of Agave that gives strong fibers).

# Soy bean

- The beans contain 40% protein. Soy is one of few plants that provide a complete protein as it contains all eight amino acids essential for human health.
- Soybean thus is a very good alternative to meat as food. 2009 the world production was 222 million ton. If we would distribute the production on all population in the world it would be 13 kg per capita or almost 100 g protein per day per capita.
- This could replace all animal and fish protein we eat today. Still, only a little more than 10% of soy bean is used as direct human food (www.soyatech.com/soy_facts.htm. 2010-12-12).
- The rest is used to feed 18.6 billion chicken and hen, 1.4 billion cows and bulls and 940 million pigs worldwide annually. Today soybean is produced in many countries, and unfortunately often at former rain forest areas in e.g. Brazil.

# Rice

- Rice is a crop for tropical and subtropical countries.
- The global average production is 3. 9 tons per ha and year
- The yield may be much higher where there is intensive irrigation like in Australia with 9.5 tons/ha,y and Egypt with 8.7 tons/ha,y.
- Some countries having “traditional” methods like the Republic of Congo on the other hand have production levels as low as 0.75 tons/ha,y!
- Thus 75% of the world production of rice is harvested at the 55% of the area that is irrigated.

# Rice

- The global production of rice was **678 million tons** in 2009.
- In China with a total production of 197 million tons 2009 the average yield was 6.6 ton/ha,y.
- From a total production point of view India comes as number two with 131 million tons 2009, but with only 45 % of the production per ha compared to China.
- If India could increase its productivity to the same level as in China it would mean another 100 million tons per year. This could feed 400 million people as staple food!!

# Wheat

- The world production of wheat is **690 million tons per year**. The biggest producer is China with 114.5 million tons produced 2009
- Wheat is considered being the most important crop from a food perspective globally.
- Unfortunately the production varies quite a lot between years

# Wheat

- The **straw** production from cereals will be **around 700 million tons/y**, corresponding to approximately 3 500 TWh/y if used as fuel. Straw is generally not used very efficiently from an energy point of view, and here we have a huge potential.

# Corn (*Zea mays*)

- The major producer of Corn is USA with a production of 333 million tons/year (2009). As number two comes China with 163 million tons/year. The **total** annual production was **817 million tons** globally grown at 159 million ha in 2009.
- The biomass in the blast is at least the same amount as in the grains.

# Corn (*Zea mays*)

- Before corn is ripe it produces a very powerful antibiotic substance, 2,4-dihydroxy-7-methoxy-1,4-benzoxazin-3-one (DIMBOA) which is accumulated in the crop. This is a natural defense against a wide range of pests, including insects, pathogenic fungi and bacteria.
- Due to its shallow root system corn is sensitive to droughts, and should be grown on soils with enough nutrients. It may also be sensitive to strong winds.
- Different species of Maize have been grown and compared. Different species gave 11-21 tons DS/ha for similar conditions.
- In the US and Canada 85 % of the Maize produced 2009 was genetically modified (GMO)

# Sugar cane

- Sugar cane is an important crop for production of sugar, but also for ethanol in e.g. Brazil.
- Sugarcane was the world's largest crop in 2010 with respect to production. Worldwide harvest of **1.69 billion tons**.
- **Brazil** was the **largest** producer of sugar cane in the world. The next five major producers, in decreasing amounts of production, were India, China, Thailand, Pakistan and Mexico.

# Cassava

- Cassava is the third largest carbohydrate source for humans with **136 million tons** produced in 1985.
- More than 1/3 is grown in Africa, where it is very important as food crop.
- It is good as feed stock to ethanol production as well.

# Animals

- Cow, pig, sheep and hen are the most common, but at least 1400 types of insects are also used as food, especially in tropical countries in Africa, Asia and South America. (Nyström, 2012).
- To produce 1 kg of Beef 10 kg fodder is needed, while 10 kg fodder may produce 9 kg of insects. In Thailand grass hoppers are common as food. In Cambodia Tarantel spiders are fried and eaten. In China many different types are eaten.

# Insects as food in China

# Giant Kings Grass

- Giant Kings Grass has been able to produce up to 100 tons DS/ha,y at a farm in China by Viaspace company (reference Carl Kukkonen).
- It can grow with high yields also on marginal land if there is enough water through rain or irrigation. There may be 2-3 harvests per year and the need for fertilizers is relatively low.

# Switch grass

# Switch grass

- Switch grass is seen as a potential important energy crop. Yield has been 5.2 -11.1 tons/·ha,y in test fields in the US. The net energy yield (NEY) has been 60 GJ/·ha,y.
- Switch grass has been used as a feed stock for bio-ethanol production and then has gained 5 - 40 times more renewable energy as ethanol than fossil energy consumed for the production. This means a reduction of green- house gas (GHG) by up to 94% compared to gasoline when used as a fuel.
- It can also be pelletized or bricquetized

# Algae

- These are primarily micro-algae and macro-algae. Micro-algae like green algae produce large amounts of fatty acids and fatty oil, which from a human perspective is interesting as a bio-fuel.
- Macro-algae are among others brown algae like Kelp, which can grow by 0.5 meter per day under favorable conditions, and exist in large quantities in many regions. Along the Californian coast and at Faeroe Islands where it is estimated to grow some 15 TWh of Kelp (Ocean Forests, 2010).

# Macro algae

Cape Good Hope, South Africa

# Algae

- The total world production of algae for commercial use is around 10 000 ton per year according to Beneman J.  (2008).
- The total growth rate of algae globally is very difficult to calculate, but we are talking about at least 100th or even 1000th of TWh/y if we include both micro-algae and macro-algae.

# Algae for combined biomass production and WWT

# Hybrid poplar

- Among trees Hybrid poplar is very interesting for the future.
- With respect to dry weight production it varied between 5.2 and 23 tons/ha,y, with the average 12.5 tons/ha,y.

# Quorn

- During the 60th J. Arthur Rank started a project to develop fungus into good food. After several years of development work and tests of soil from 3000 sites they found a fungus Fusarium Veneatum that turned out to be possible to grow on a large scale, tasted good and had a high productivity and gave good protein.
- A plant started up in Billingham, and is still producing the fungus. In 2011 it produced 17 000 tons and there also seems to be expansion plans. This product is called Quorn. The feed stock is primarily starch.

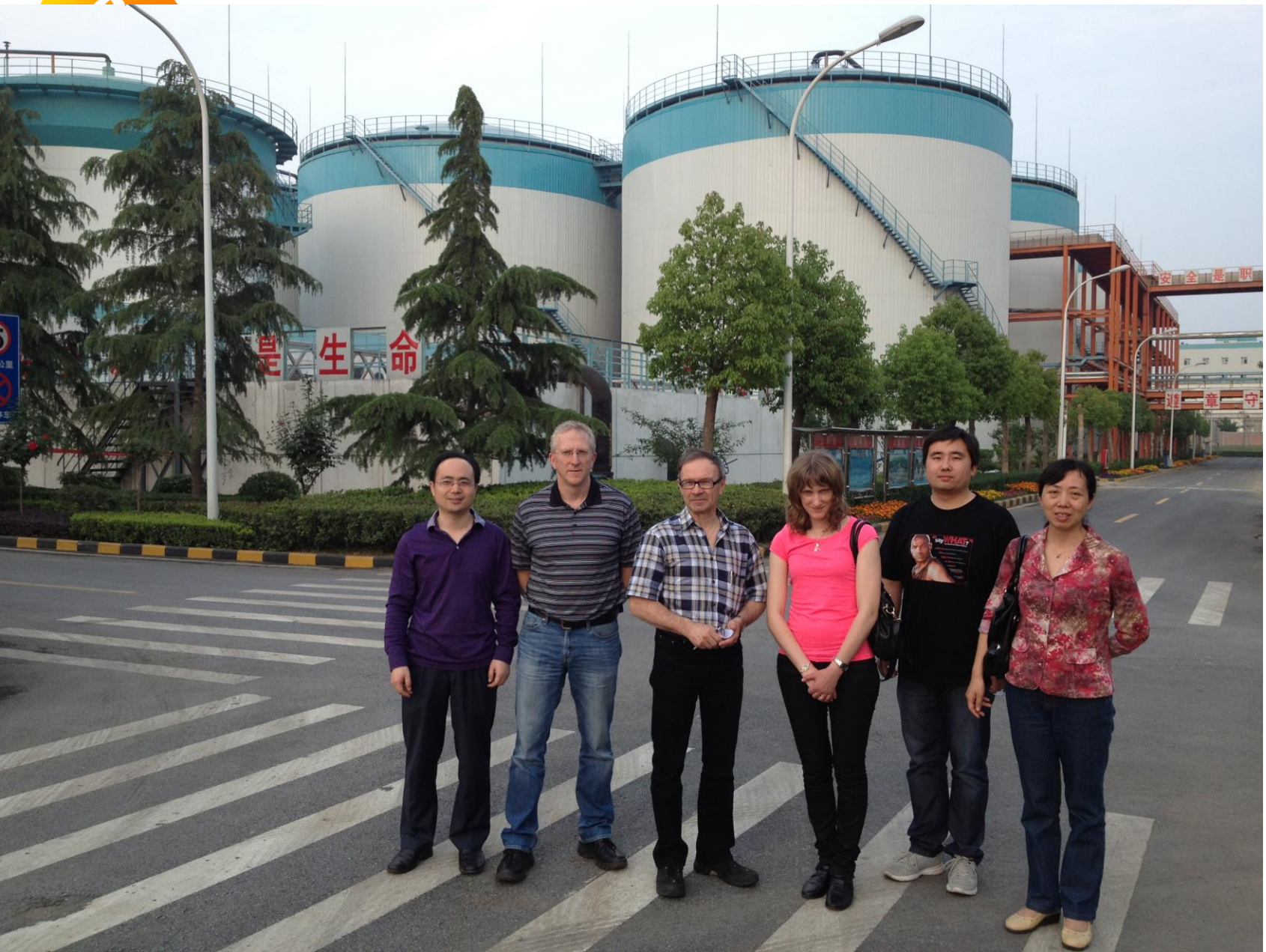
# Quorn

- To the starch solution nitrogen, phosphate, trace elements and air is added.
- A draw back in the production is that large amounts of RNA is produced, but by heat treatment at 70 oC the content is reduced to the  level where the product is accepted to use as fodder for animals.
- It is also used as food for humans as meat replacement, and is then  known as Quorn.
- Unfortunately 30% of the product is lost during the treatment to remove RNA.

# China

- There are already more than 22 million small scale biogas plants producing 8.5 billion Nm3/y. Medium and large scale biogas projects will increase from 3671 year 2007 producing 2 billion Nm3/y biogas to 44 billion m3 by 2020 and 80 billion m3 by 2030 (the figure in 2006 being 10 billion m3 per year).
- This is according to professor Li Shi-Zhong at Tsinghua University (2011). Also 39 million tons of bioethanol and 6 million tons of bio-diesel was produced 2007.
- Tianguan group in Henan are building 10 plants right now for bio ethanol and biogas production from straw. Will be 500 000 m3 bioethanol 2015 and 3 million m3 2020, with 1 billion m3 biogas as well. This is for E85 in Henan.

# Ccoperation Tianguan group, SEKAB and MDH



# China

- China has about 120 million hectares of marginal land and 40 million hectares of degraded arable land.
- Tuber crops have high biomass production yield (15-45 t/ha) and starch content (20-33%).
- Cassava is a good crop in southern China as it is less sensitive to diseases and insects, resistance to drought etc.
- Sweet potato can also be planted in poor quality soil.

# India

- For India rice is the most important food crop (99.2 million ton/y) followed by wheat at second place (80.6 million ton /year 2009). The productivity of wheat varies a lot between different states, from 0.7 to 4.3 ton/ha,y. This gives 233.9 million ton/y (2009) of all major crops altogether.
- 50% of the calories are at an average coming from wheat to the Indian population. The productivity with respect to wheat has increased from 0.9 tons/ha in 1965 to 3 tons/ha,y today at an average. The increase has been due to selection of suitable clones for each type of soil and other conditions. The highest yields are in Punjab and Haryana with 4- 4.3 tons/ha,y, while Karnataka has only 0.7 tons/ha,y.

# India

- This shows that there is still a potential for improvements. Today the production is 67 kg/capita, while the demand is 73 kg/capita. A potential threat still is rusts, leaf blight and insects as well as climatic issues.
- Total biomass production some 480 million tons biomass from these crops with a HHV of 480 *106 *5.4 MWh/ton = 2 600 TWh/y.
- Still, this is just a minor share of the total biomass available.

# USA

- We also can make another calculation to estimate the bioenergy potential in the US.
- Average cereal yield is 7.2 tons/ha in the US. The agricultural area is 58 001 425 ha, giving 4,4 *108 ton/year, or with 5,4 MWh/ton = 2270 TWh/y additional as cereals. This is 14 % of the total agricultural land, 411 200 000 ha.
- If we assume the same amount of straw we get 4540 TWh/y from cereals including straw, and if we get the same amount of production on the rest of the land with energy crops, it would be 4540/0,14 = **32 430 TWh/y**.

# USA

- The most widely grown crop in the US is corn with 332 million tons per year.
- From this figure 130 million tons or 40% is used for production of ethanol fuel.

# USA

- The **forest land** area is 304 022 000 ha. If we assume an average of 3 ton DS/ha,y or 16 MWh/ha, we should produce some **4 900 TWh/y** from this as well. A **total production** then would be approximately **37 350 TWh/y** in the US
- If we compare this to the **total use** of energy in the US this is 4160 TWh/y electricity and 2 172 107 kton of oil equivalents/y, or with 10 MWh/ton o.e. **21 720 TWh/y** totally (from which fossil fuels 84 % today).

# Brazil

- Bioethanol in Brazil. 2008 15% of all energy used in Brazil is Sugar cane. In 1988 50% of all vehicle fuels was ethanol. 2004 it was 30%. Sugar cane gives 6 m3 ethanol/ha.
- The total arable land in Brazil was 2007 354.8 million ha. From this 76.7 million ha were used for crops: 20.6 for soybean, 14.0 for corn, 7.8 for sugar cane. From this 3.4 million ha was used for **ethanol production**.
- This corresponds to **1 % of the arable land** area, but **replaces 30% of the fossil fuel** used for vehicles. 172.3 million ha are pastures and thus we have 105.8 million ha left for e.g. additional ethanol production.

# Brazil

- If we triple the production to cover all fossil fuels with ethanol, 11.3 million ha would be needed, or 7.9 million aside of what is already utilized.
- This would mean 7.5 % of the available arable land not used intensively today.
- It can also be interesting to note that the cost for sugar cane ethanol production is 0.25 $/liter compared to 0.4-0.7 $/liter for fossil gasoline in Brazil, according to Carlos H. de Brito Cruz (2008)
- Today 1/3 of all official energy use in Brazil is from Biomass

# Different zones

# CHP/Gasification – 20 kWel + 50 kW heat from 15 kg wood chips/h

# Organic waste


CMT

# Pulp and Paper Industry (Billerud-Korsnäs)

# Sorted household waste



# Lay crops for biogas production

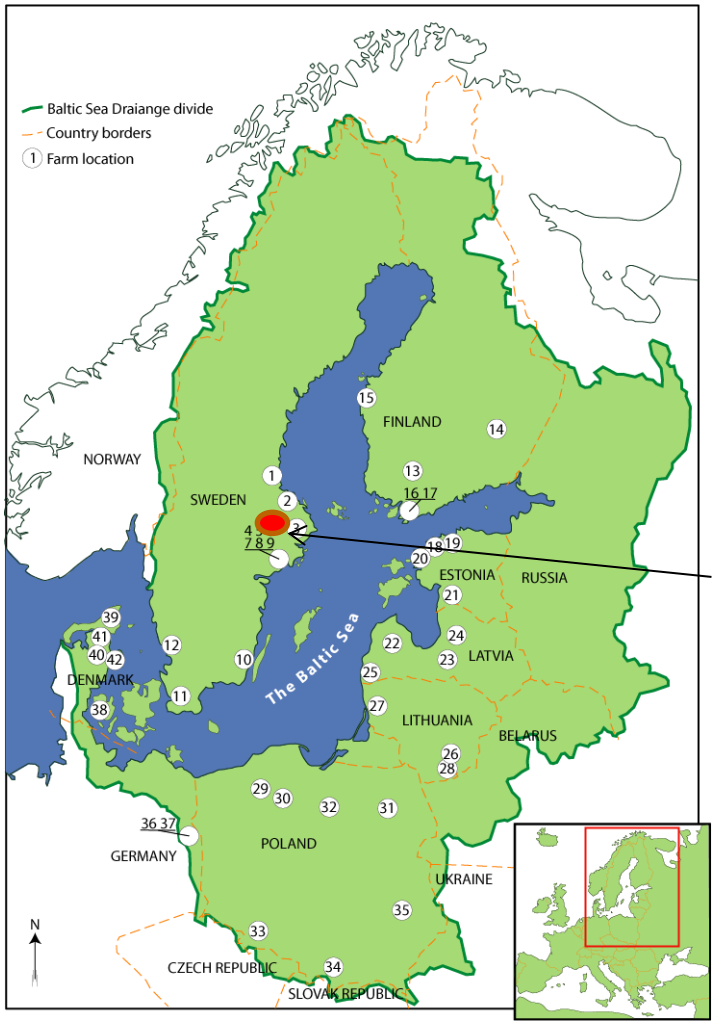
# Material is mostly from the book

**Taylor-Francis Book series:** Sustainable Energy Developments
**Volume 3: Biomass as Energy Source Resources, Systems and Applications**
**Erik Dahlquist**, Malardalen University, Vasteras, Sweden
March 2013: 246 x 174: 300pp
Hb: 978-0-415-62087-1: **£82.00 $129.95**
To order: www.crcpress.com/9780415620871

# Biomass production in Northern Europe

| 2008/2009 | Cereal Inc. Straw | Other Agro than cere | Forestry | Energy use | Prod-Use |
|---|---|---|---|---|---|
| | TWh | TWh | TWh | TWh | TWh |
| Austria | 56 | 204 | 63 | 332 | -10 |
| Belgium | 36 | 103 | 11 | 586 | -436 |
| Denmark | 110 | 196 | 9 | 190 | 125 |
| Esthonia | 9 | 60 | 36 | 54 | 51 |
| Finland | 46 | 188 | 359 | 353 | 240 |
| Germany | 537 | 1207 | 179 | 3353 | -1429 |
| Netherland | 22 | 153 | 6 | 797 | -617 |
| Norway | 10 | 86 | 163 | 297 | -37 |
| Ireland | 22 | 275 | 12 | 150 | 159 |
| Latvia | 18 | 135 | 54 | 45 | 162 |
| Lithuania | 41 | 189 | 35 | 92 | 173 |
| Poland | 322 | 1108 | 151 | 979 | 602 |
| Sweden | 57 | 258 | 457 | 496 | 275 |
| Switzerland | 11 | 100 | 20 | 267 | -136 |
| UK | 240 | 1128 | 47 | 2085 | -669 |
| Russian Fed | 1027 | 16249 | 13107 | 6868 | 23515 |
| Belarus | 88 | 661 | 140 | 281 | 607 |

# Environmental Recycling Agriculture




**recycling P, N, K in the Right way harvests could Be high without leakage**

**At Nibble same harvest with half amount of N and no emission to water and air**

# ERA

- The primary target for the ERA concept was the Baltic sea and the countries around this. To get a balance we should reduce the consumption of meat by some 60-70 %.
- The production of crops will be reduced per hectar by 20%, but by reducing the number of animals more cereals will be available for humans. Thus  we will still get the food needed for the population around the Baltic sea.
- At the same time the leakage of P would be eliminated totally and the amount of N halvend. This would thus give a recovery of the strongly eutrophied Baltic sea long term.

# Summary potential renewable energy ”production” in EU27

Available **biomass** resources in the range of 8 500 – 12 500 TWh/y for EU 27.

**Wind** power is already today producing some 100 TWh/y but with a potential for at least 1000 TWh/y,

**Solar** power potential produce 200 TWh/y within some 20 years.

**Hydro** power is today 10.2 % of the total 3400 TWh/, that is 350 TWh/y while

**Nuclear** is 29.5% or 1000 TWh/y.

If we accept nuclear as a non-fossil resource the **available resources** would be (8500- 12500)bio + (100-1000)wind + (5- 200)solar + 350hydro + 1000 nuclear = **9 955 – 15 050 TWh/y.**

# Meat today and in the future

| Year | 2010 | 2020 | 2030 | 2050 | Growth 2010 to 2050 |
|---|---|---|---|---|---|
| Human population billions | | | | | |
| | 6.83 | 7.54 | 8.13 | 8.91 | |
| (*Consumption million tons per billion people)* | | | | | |
| Bovine meat | 9.85 | 10.25 | 10.93 | 11.93 | 121% |
| Ovine meat | 1.94 | 2.08 | 2.28 | 2.64 | 136% |
| Pig meat | 14.98 | 15.29 | 15.98 | 15.79 | 105% |
| Poultry meat | 12.58 | 14.72 | 17.65 | 21.69 | 173% |
| Dairy | 96.24 | 100.19 | 106.77 | 116.55 | 121% |

*Sources:* FAO, 2006c; World Population Prospects, 2002. Some calculations made by the authors.

# China

- Chinese Academy of Engineering has made predictions for the energy utilization in China until year 2050 (Du Xiangwan, 2008).
- Assuming the 1.7 billion tce total renewables in 2050, 26 % will come from hydro-power, 20 % from biomass, 34% from solar power and 18% from wind power.

# Other crops

- See table

| | | | |
|---|---|---|---|
| Banana | Musa paradisiaca | 15.0-50 | TR/ST,>60%RH |
| Aleman grass | Echinochloa polystachya | 20-100 tDM/ha,y | C4,TR-TE,floodbank |
| Alfalfa | Medicago sativa | 10.0-20.0 | All climates |
| Elephant grass | Pennisetum purpureum | 20.0-85 | TR/ST |
| Eucalyptus | Eucalyptus spp. | 25.0-50 | TR-TE,adaptive |
| Fodderbeat | Beta vulgaris rapacea | 20.0-50 | TE |
| Giant knotweed | Polygonum sachalinensis | 20.0-30 | EU/AS 1/2 undergrd |
| Giant reed | Arundo donax | 20-40 | ME,PE grass, |
| Hemp | Cannabis sativa | 8.0-21 | TE >700 mm/y |
| Kenaf | Hibiscus cannabinus | 20-30 | AN,AF,>500mm/y |
| Leucaena | Leucaena leucocephala | 20-35 | TE-TR, >600 mm/y |
| Miscanthus | Miscanthus spp. | 10.0-40 | C4,Eu,SEAsia,PE |
| Sorghum | Sorghum bicolor | 14.0-40 | C4,TE-TR,AN, 4m |
| Sweet sorghum | Sorghum bicolor | 12.0-45 | C4,EU,USA,TR-TE |
| Sorrel | Rumex acetosa | 10.0-40 | PE,2m,TE,Tolerant |
| Water hyacinth | Eichornia crassipes | 30.0-90 | PE,TR/STaquatic herb |