Chapter 5
Energy Resources and Regional Balances

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5.1 Global Overview of Energy Resources and Conversion Capacity

In 2011, the total electricity production breakdown was: renewables 4 400 TWh (4,39766E + 12 kWh), nuclear 2 580 TWh (2,58368E + 12 kWh), hydro electric 3 470 TWh (3,46712E + 12 kWh), natural gas 4 850 TWh(4,84773E + 12 kWh) and coal 9 130 TWh (9,13062E + 12 kWh). In 2011, 81% of all primary energy globally was from fossil fuels.

Renewables and waste were 9.8% of the total primary energy globally. In 2006, this corresponded to 1 184 909 tonne.

In Fig. 5.1, we see how the pump price for gasoline varies between different regions. Here, we see that the price is approximately two times as high in the EU compared to Russia, but also a strong increase generally between 2002 and 2012. During this period the raw oil spot price at the market was around 100 US$/barrel. During 2014–2016 the price then dropped to approximately 30 US$/bl at the beginning of 2016, but then started to increase a little again and is around 50 US$/bl. Many oil producing countries have used the income from oil to finance their overall budget, although some countries like Norway have invested the oil money in buying shares in international corporations. Due to this dependency on oil, countries like Russia, Nigeria and others have run into problems with national economy. As Iran reenters the oil market after the trade embargo, more oil comes to the market than there is demand, which of course influences the oil price. Saudi-Arabia probably wants to keep the oil price a bit lower to counter that the US and Canada produce oil and gas using fracking and oil tar sand respectively.

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Springer International Publishing AG 2017
E. Dahlquist, S. Hellstrand (eds.), *Natural Resources Available Today and in the Future*, DOI 10.1007/978-3-319-54263-8_5

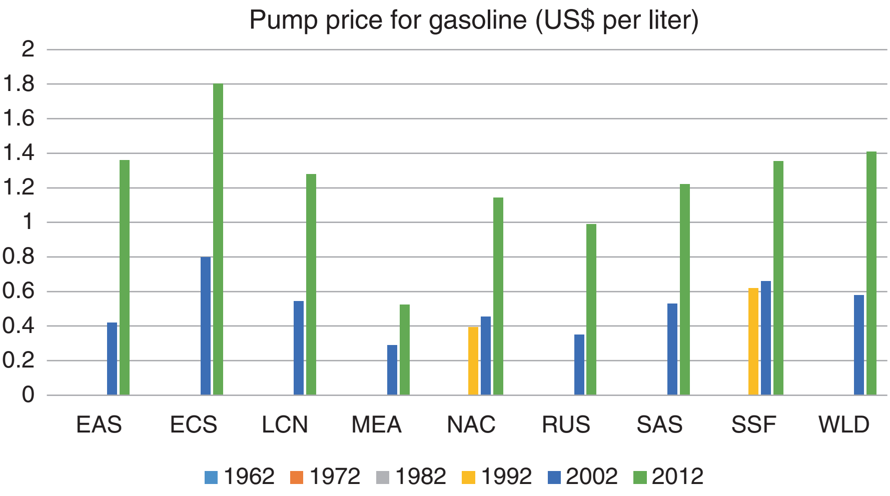


Fig. 5.1 Pump price for gasoline in US$/liter 1992–2012 in different regions

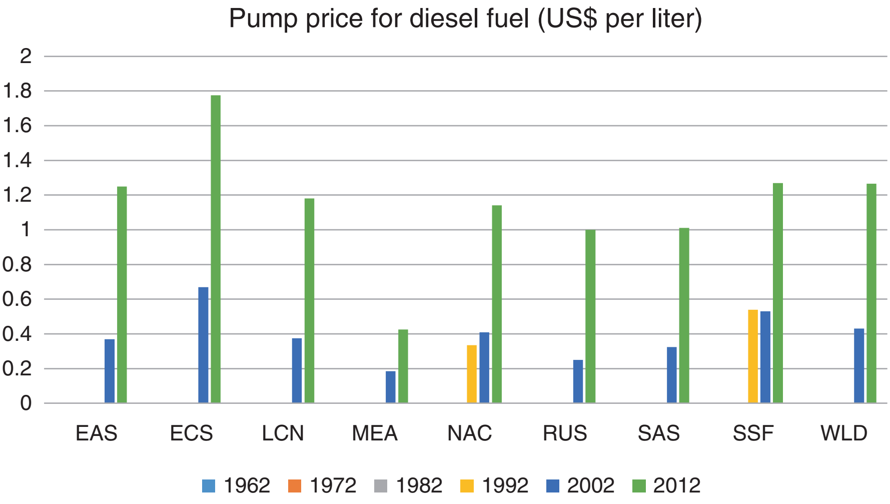


Fig. 5.2 Price for diesel per liter in US$/liter in different regions

In Fig. 5.2 we see the corresponding price for diesel. Here, we can see that the price today is almost the same as for gasoline.

In Fig. 5.3 we see the percentage of all energy used that comes from fossil fuels in different regions. Here, we can see that the percentage decreases in Europe and North America while it increases in East Asia and very strongly in South Asia (India mostly).

In Fig. 5.4 we see the energy use given as kg oil equivalents per capita in different regions. North America is several times higher than the average. In the EU, the

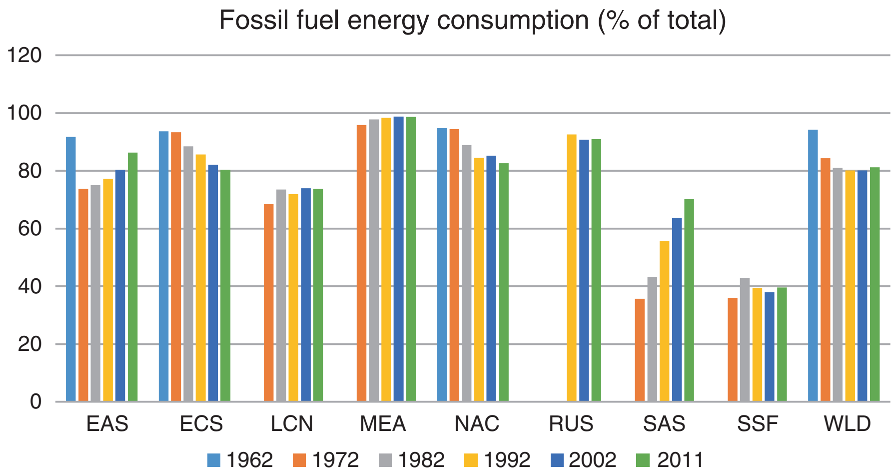


Fig. 5.3 Fossil fuel energy consumption as % of total energy consumption in different regions

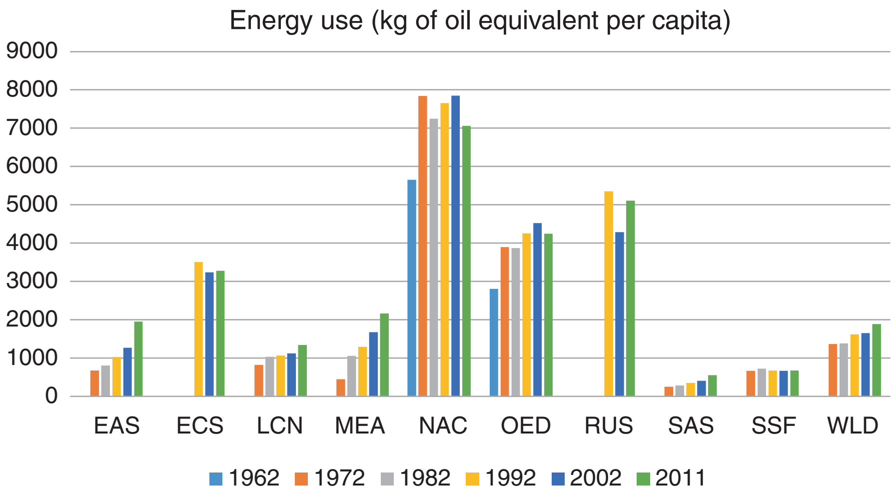


Fig. 5.4 Energy use per capita as kg oil equivalents (oe)

deviation is significant between different countries, and in China the increase has been significant over the last few decades due to the strong development of industry production. To some extent the figures are misleading as countries with a high amount of energy intensive industries get high values, although the products are sold in other countries and regions. If we look at counties instead this is seen even stronger.

In Fig. 5.5 we see how much of the electricity was produced from renewables 1962–2011 excluding hydro power, which is renewable but also seen as "conventional". It is interesting to see the dramatic increase in most regions during the last

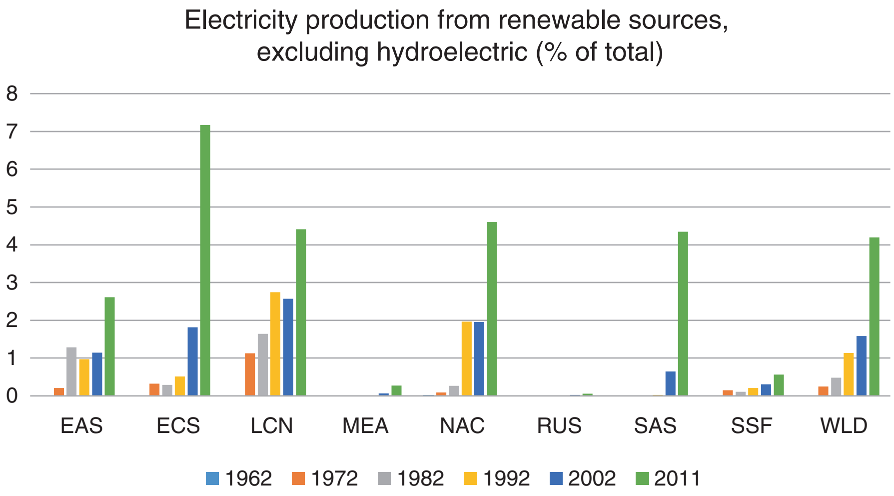


Fig. 5.5 Electricity production from renewables excluding hydro power in percent of total

few decades. The trend is also proceeding, although the figures are not in the World Bank data set yet. In a country like Germany, the installed capacity of solar power (PV) was 35 000 MW 2015 and more than 40 000 MW wind power. In Sweden and Brazil, the amount of biomass is higher than the amount of fossil fuels as the primary energy source. Different countries focus on what is suitable there, and thus we see solar power in some, wind in others and biomass in those with a lot of biomass. As a complement, we have hydro power, which produces 98% of all electric power in oil-producing Norway! They use hydro power for their own demands and export the oil and gas to other countries. We also see that both Norway and Sweden use the large amounts of hydro power to balance more unreliable sources like wind and solar power in the rest of Northern Europe with Germany, Denmark, Poland, Finland and the Netherlands.

In Fig. 5.6 we see the absolute figures for electricity production in kWh; 10^{-12} kWh is 1000 TWh. We can see that East Asia, the EU and North America all produce around 1000 TWh/y from renewable sources including hydro power. Since, South America also has a very high capacity of hydro power, they produce almost the same amount! The total capacity from renewables is more than 4 000 TWh_{el}/y, or 20–25% of the total electric power production globally. It is noteworthy that it has increased from around 500 TWh/y in 1962 to 4300 TWh/ in 2011, and the trend continues.

In Fig. 5.7 we see the development of hydro power in % of total. Since the total has greatly increased, the figures show more that the development has been equal to the one using fossil fuels in most regions (Europe, Latin America, Russia and Africa south of Sahara) except in North America, China and India, where other sources, mostly fossil, have expanded while hydro power has not. In the Middle East and North Africa this is even more significant, where expansion using fossil fuels has been very high.

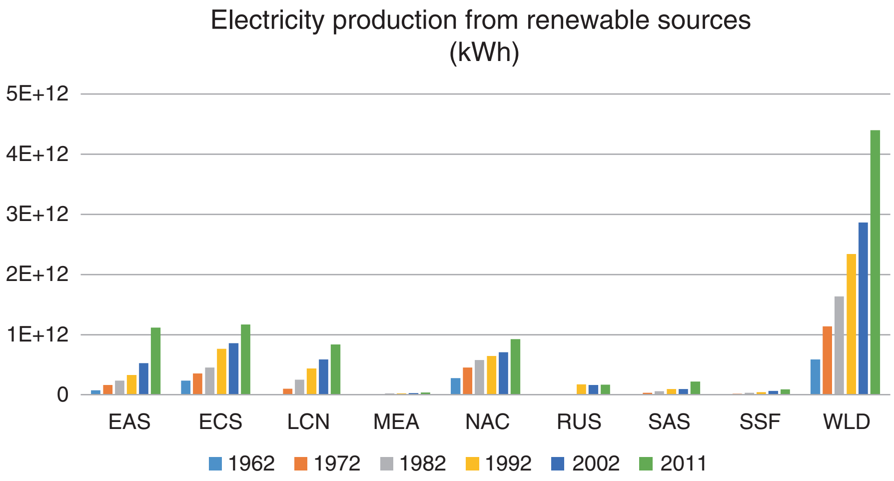


Fig. 5.6 Electricity production from renewable sources including hydro power in different regions

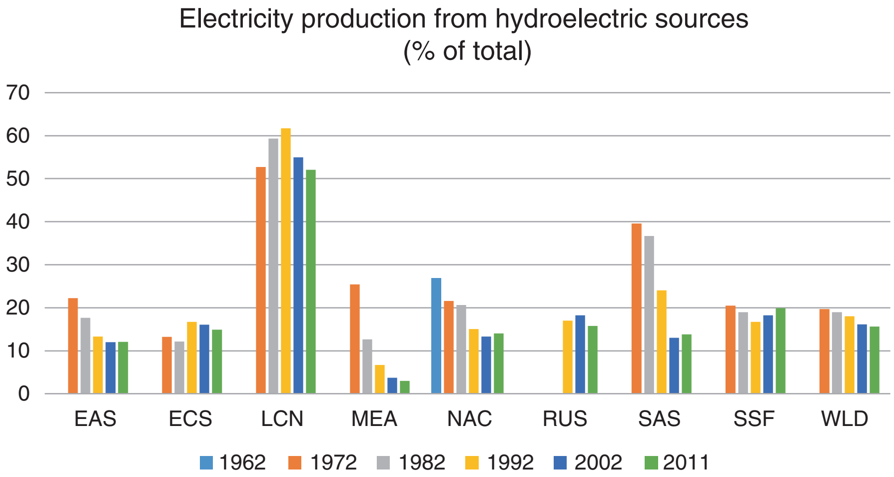


Fig. 5.7 Electricity production from hydro power in % of total in different regions

If we also include nuclear power alongside other renewable sources we get the total non-fossil production. In Fig. 5.8 we see the percentage of these in relation to total energy use. The value 13–14% in the EU and North America reflects that approximately 50% of the electricity is actually produced without using fossil fuels, but a lot of other energy demands like transportation still utilize fossil fuels.

In Fig. 5.9 we see the nuclear electricity production for different regions. What we can see is that nuclear power is of significant importance in the EU and North America, and to some extent also in East Asia, but less important in most regions.

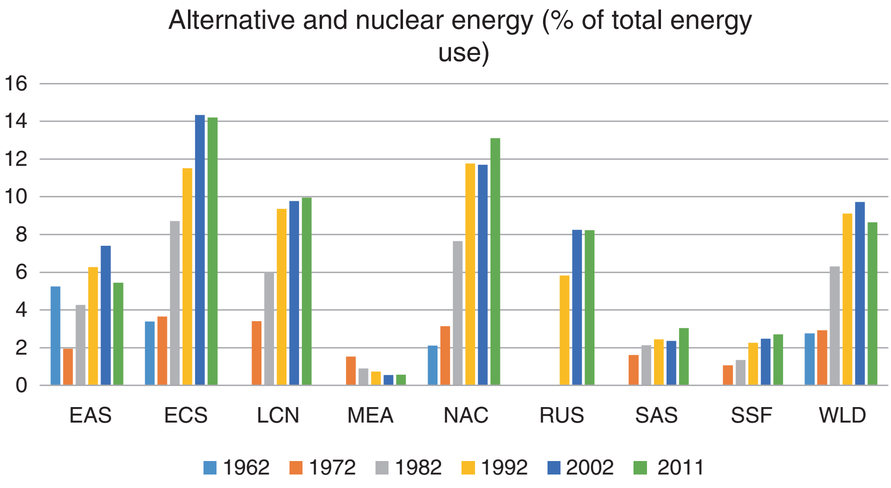


Fig. 5.8 Alternative and nuclear energy in percentage of total energy use in different regions

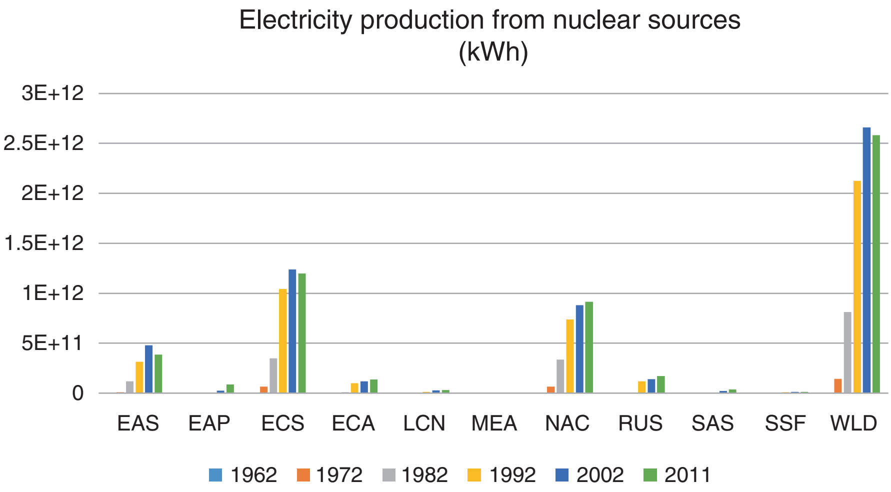


Fig. 5.9 Electricity production in kWh/y using nuclear sources in different regions (10^{12} kWh is 1000 TWh)

In Fig. 5.10 we can see that the total electricity production is approximately 23 000 TWh/y, which can be compared to the total production of non-fossil electricity which was some 7 300 TWh/y (31.5% of total electricity produced). The fossil driven electricity production was 66.8% of the total; where, 40.3% is coal, 22.4% natural gas and 4.1% oil. This data is for 2012 from World Bank Development Indicators.

If we look at the total amount of renewable energy (~7300 TWh/y) from electricity production, and include biomass we can add some 10% of the total energy used

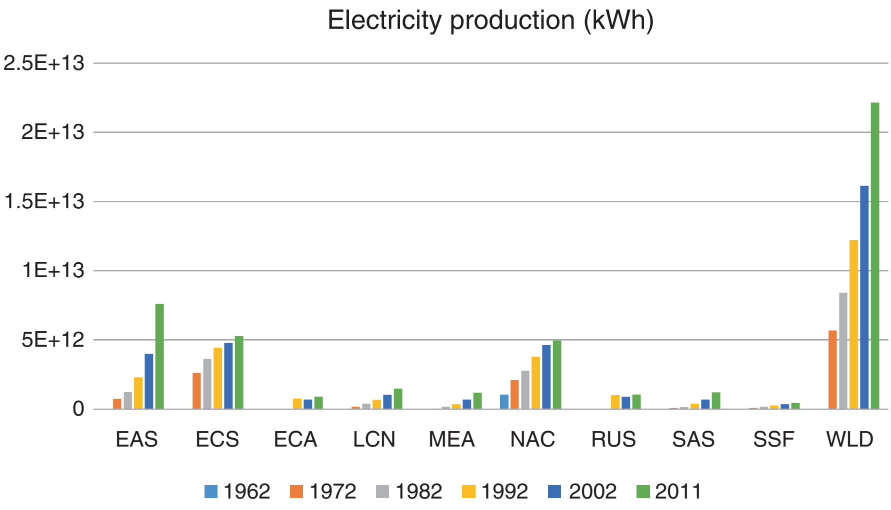


Fig. 5.10 The global electricity production distributed to regions. 10^{13} kWh = 10 000 TWh/y

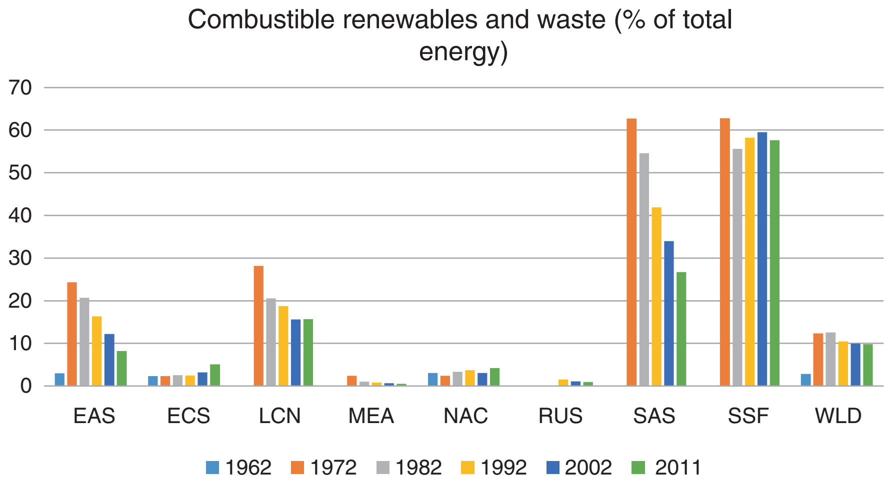


Fig. 5.11 Combustible renewables and waste in % of total energy used globally

as seen in Fig. 5.11. These 10% correspond to some 13 000–14 000 TWh/y, and the total percentage of non-fossil energy used is thus some 15%, including nuclear and hydro power.

We now can look at the distribution of electricity (Fig. 5.12) and total energy (Fig. 5.13) for countries with different average income levels as seen in Table 5.1.

The first thing we can see is that all income groups, except low income countries (LIC), have had a fast development of electricity production.

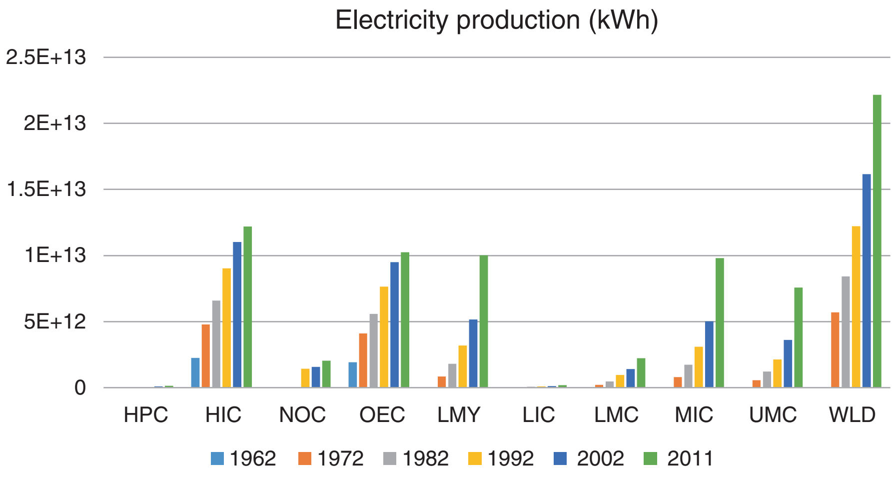


Fig. 5.12 Electricity production distributed based on countries with different income levels (kWh/y)

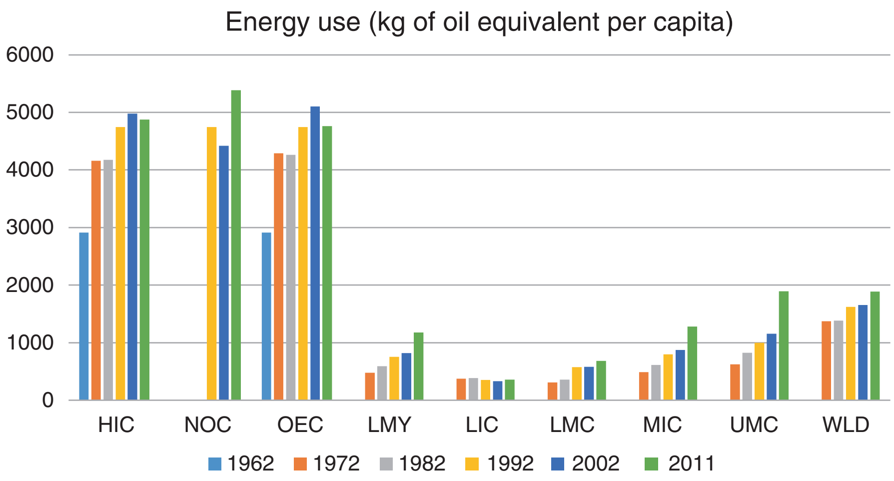


Fig. 5.13 Kg oil equivalents used per capita in different income level countries

Total energy use has not developed in the same way. It is primarily upper-middle income (UMC) and middle income (MIC) countries where energy use has increased most over the last few decades (Fig. 5.13).

This could be explained with the fact that electricity consumption is more correlated to economic development than energy as such. For some rich countries we even see a lowered energy use during the last 10 years due to energy conservation measures.

Table 5.1 Different income categories

Heavily indebted poor countries (HIPC)	HPC
High income	HIC
High income: nonOECD	NOC
High income: OECD	OEC
Low & middle income	LMY
Low income	LIC
Lower middle income	LMC
Middle income	MIC
Upper middle income	UMC
World	WLD

5.2 Renewable Energy: Wind Power and Solar Power

We have already mentioned that renewable energy is strongly increasing. What is meant by renewable energy in the statistics is usually wind and solar power, while biomass and waste are presented separately.

5.2.1 Wind Power

The total global installed wind power capacity was 318 105 MW in 2013; from this 121 474 MW was in Europe, 115 927 MW in Asia and 70 811 MW in North America.

Fig. 5.14 shows the installed capacity of wind power globally in 2013.

A few years ago, Germany dominated installations but was passed by China in 2013 with 16 088 MW new capacity, and a strong increase in India is also noteworthy.

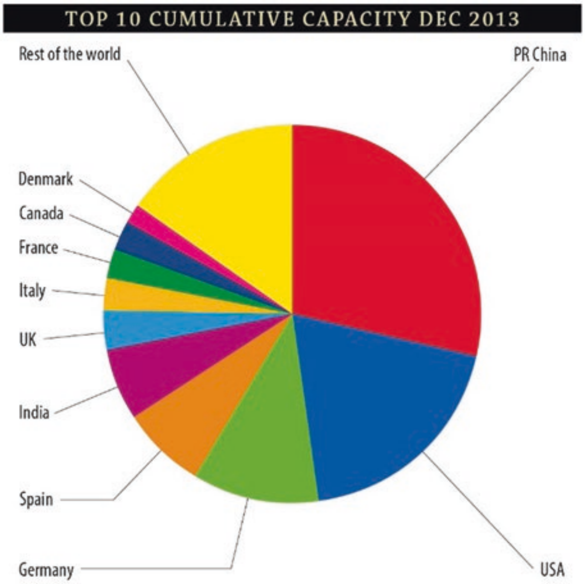
In Table 5.2, we see both the total capacity in different countries and the new capacity in 2013.

We can see that China has the highest installed capacity for a single country with 91 GW, while the US is close with 61 GW. Germany with 35 GW, Spain with 23 GW and India with 20 GW also produce a lot of wind power. The total installed capacity was 318 GW 2013, and has increased to some 350 GW in 2016 (Fig. 5.15).

5.2.2 Solar Power, PV

We have seen a tremendous increase in solar power installed capacity over the last 10 years. The driving force has been the feed-in tariff in Germany, where there was 35.5 GW installed capacity in 2013. In 2010 the capacity increase was 9.8 GW, and in 2010–2012 additional capacity was 6 GW per year. Aside from the feed-in tariff

Fig. 5.14 Installed capacity in 2013 of wind power globally



Country	MW	% SHARE
PR China	91,412	28.7
USA	61,091	19.2
Germany	34,250	10.8
Spain	22,959	7.2
India	20,150	6.3
UK	10,531	3.3
Italy	8,552	2.7
France	8,254	2.6
Canada	7,803	2.5
Denmark	4,772	1.5
Rest of the world	48,332	15.2
Total TOP 10	**269,773**	**84.8**
World Total	**318,105**	**100.0**

Source: GWEC

there were also ways to finance new installations, and a number of skilled PV-installation companies to support installations. However, the PV cells were mostly imported from China, and the biggest domestic PV cell producer, Q-cell, went bankrupt. They have started up again but now in a smaller scale and with international partners. Germany currently has 26% of global installed capacity.

China had 18.3 GW installed capacity in 2013, and is the second biggest. In 2010, China only had 0.3 GW installed, so we can see that the increase was very fast, and they are expected to pass Germany within a few years. Especially, since the installed capacity has slowed down. The target in China is to have 70 GW PV cell capacity installed by 2017, as they want to reduce the demand for new coal power capacity due to the severe climatic and environmental issues in many Chinese cities.

Table 5.2 Total installed and new capacity of wind power for 2013

Global Installed Wind Power Capacity (Mw) – Regional Distribution				
		End 2012	New 2013	Total (End of 2013)
Africa & Middle East	Ethiopia	81	90	171
	Egypt	550	–	550
	Morocco	291	–	291
	Tunisia	104	–	104
	Iran	91	–	91
	Cape Verde	24	–	24
	Other (1)	24	–	24
	Total	**1 165**	**90**	**1 255**
Asia	PR China	75 324	16 088	91 412
	India	18 421	1 729	20 150
	Japan	2 614	50	2 661
	Taiwan	571	43	614
	South Korea	483	79	561
	Thailand	112	111	223
	Pakistan	56	50	106
	Sri Lanka	63	–	63
	Mongolia	–	50	50
	Other (2)	71	16	87
	Total	**97 715**	**18 216**	**115 927**
Europe	Germany	31 270	3 238	34 250
	Spain	22 784	175	22 959
	UK	8 649	1 883	10 531
	Italy	8 118	444	8 552
	France	7 623	631	8 254
	Denmark	4 162	657	4 772
	Portugal	4 529	196	4 724
	Sweden	3 746	724	4 470
	Poland	2 496	894	3 390
	Turkey	2 312	646	2 959
	Netherlands	2 391	303	2 693
	Romania	1 905	695	2 600
	Ireland	1 749	288	2 037
	Greece	1 749	116	1 865
	Austria	1 378	308	1 684
	Rest of Europe (3)	4 956	832	5 737
	Total Europe	**109 817**	**12 031**	**121 474**
	of which EU-28 (4)	106 454	11 159	117 289

(continued)

Table 5.2 (continued)

Global Installed Wind Power Capacity (Mw) – Regional Distribution				
		End 2012	New 2013	Total (End of 2013)
Latin America & Caribbean	[a]Brazila	2 508	953	3 461
	Chile	205	130	335
	Argentina	142	76	218
	Costa Rica	148	–	148
	Nicaragua	146	–	146
	Honduras	102	–	102
	Dominican Republic	33	52	85
	Uruguay	56	4	59
	Carribean [(5)]	136	–	136
	Others [(6)]	54	20	74
	Total	**3 530**	**1 235**	**4 764**
North America	USA	60 007	1 084	61 091
	Canada	6 204	1 599	7 803
	Mexico	1 537	380	1 917
	Total	**67 748**	**3 063**	**70 811**
Pacific Region	Australia	2 584	655	3 239
	New Zealand	623	–	623
	Pacific Islands	12	–	12
	Total	**3 219**	**655**	**3 874**
	World total	**283 194**	**35 289**	**318 105**

[1]Israel, Jordan, Kenya, Libya, Nigeria, South Africa
[2]Bangladesh, Philippines, Vietnam
[3]Bulgaria, Cyprus, Czech Republic, Estonia, Finland, Faroe Islands, FYROM, Hungary, Iceland, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Norway, Romania, Russia, Switzerland, Slovakia, Slovenia, Ukraine
[4]Austria, Belgium, Bulgaria, Cyprus, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, UK
[5]Caribbean: Aruba, Bonaire, Curacao, Cuba, Dominica, Guadalupe, Jamaica, Martinique, Granada
[6]Bolivia, Colombia, Ecuador, Peru, Venezuela
Note:
[a]Projects fully commissioned, grid connections pending in some cases
Project decommissioning of approximately 374 MW and rounding affect the final sums

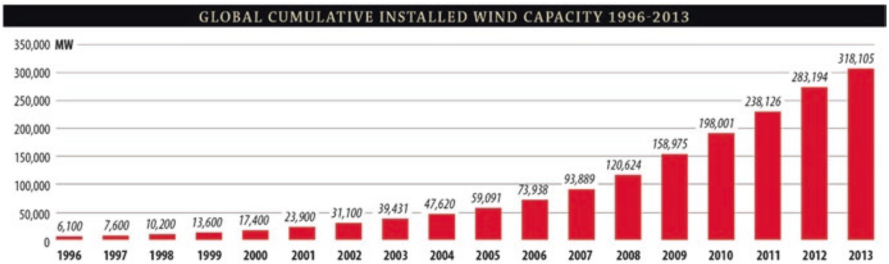


Fig. 5.15 The global installed capacity of wind power from 1996 to 2013

Italy had almost as much PV installed in 2013, with 17.6 GW, which is a significant increase from 2010 when they only had 1.2 GW. At 17.6 GW Italy had the highest percentage of electric power produced from PV with 7.8%, compared to 6.2% in Germany. In Italy, there are both feed-in tariffs and net-metering that is not taxed if you use the power internally. In combination with a lot of sunshine this has been very successful for stimulating expansion.

Japan also has a significant amount of solar power with 13.6 GW installed in 2013 and 2.6 GW in 2010. Government residential PV programs, net-metering, high national solar energy goals to reach 28 GW by 2020 and 53 GW by 2030 as well as the support of local authorities and the private sector has stimulated the expansion. The Fukushima reactor melt-down has stimulated replacement of nuclear power as well. A plan now is to build floating solar farms as well.

The first PV cells were developed in the US. In 2010, they had 1.6 GW installed and in 2013 12 GW. New business models have been implemented in, e.g. California, where power companies install PV plants in residential buildings and the inhabitants pay for only produced power without having to pay for the actual installation. This has driven the expansion, and the strongly reduced PV cell cost over the last few years has made it even more interesting.

Other countries who have installed large areas of PV cells are Spain with 5.6 GW, France 4.6 GW, Australia 3.3 GW, Belgium 3 GW, UK 2.9 GW and India 2.3 GW.

As the price per m^2 has dropped to less than half and the efficiency almost doubled over the last 5–10 years, PV systems now are economic even without large subsidies, compared to alternatives like nuclear power. Still, there must be a demand for new capacity and the alternative to save energy is normally the most economic.

5.2.3 Biomass Conversion

System aspects of biomass use in complex applications include bio-refineries for production of heat, electric power and chemicals like fuels for vehicles, clothes etc. such that different conversion processes are important. This includes production of bio-diesel by mixing fatty acids with methanol, biogas production from waste and high temperature gasification for production of hydrogen, methane and carbon monoxide, which can be used directly or reacted further. Torrefaction for production of biochar and pyrolysis for production of organic liquids and biochar are other processes. Ethanol production using saccharomyces or bacteria are other routes, where biorefineries usually take these processes a step further.

Today we can see that biomass resources are primarily used as food, for cooking food, for heating buildings and in forest industry applications. In the future, we can expect that these applications will be developed further to replace routes for production of all the chemicals produced today from fossil fuels like oil. As oil becomes scarce and probably more expensive, use of biomass instead will be attractive. As Newsprints and fine papers are replaced by electronic media we see a trend to stop producing these qualities, and cellulosic raw material becomes available for other products. Today, tissue is increasing as well as packaging, but also replacement in cloth production of wool is increasing as an environmentally friendly alternative. All kinds of lignin components are also used for production of chemicals for paint, tensides, bio-diesel, tall oil for combustion etc.

The focus of this book is not the biomass conversion but more to look at the resources as such. For those who are interested, a number of articles for deeper study are proposed in the reference list below, and the titles are self-explanatory.

5.3 Energy Situation in Different Countries and Regions

The available energy resources are very different in different countries and regions. In Russia, there are enormous amounts of forestry wood; in China straw from agriculture; in Norway potential for wave power. Along most coasts the potential for wind is high. Solar power is interesting in many countries, but especially in regions around the Mediterranean Sea and in dessert areas like in Arizona.

5.3.1 EU27 Energy Situation 2014 and Onwards

Available *biomass* resources in the EU are in the range of 8 500–12 500 TWh/y for the EU27. The first figure comes from multiplying all arable areas with 10 ton DS/ha, and all forest areas by 3 ton DS/ha, and assuming 5.2 MWh/ton DS as heating value. The second figure is an estimated potential if we use specific species with high yield and optimize production with respect to irrigation and fertilizers.

Wind power today produces some 100 TWh/y in the EU27 but with a potential for at least 1000 TWh/y. The major potential is in the coastal areas, where both wind speed and time when windy is best.

Solar power potential could produce some 200 TWh/y within some 20 years, if the expansion was the same across the entire EU as it has been the last few years in Germany. However, even with the price dramatically decreased over the last 5 years, it is still relatively high. Tax regulations and subsidies will be important for the penetration, and the regulatory system generally still does not favour renewables and biomass use.

Hydro power makes up 10.2% of the total electric power produced in the EU27 today. This corresponds to 350 TWh/y as the total production is approximately 3400 TWh/.

Nuclear accounts for 29.5% of all electric power produced in the EU27 or 1000 TWh/y. The debate on if we should proceed with nuclear power or not is intense in several countries, where France and Finland are very positive towards building new nuclear plants, while Germany and Sweden do not want "competing power" by nuclear. The tax profitability has been poor in both countries, and thus there is not motivation for new capacity, especially where old units are closed for economic reasons.

Table 5.3 Installed capacity as % of total electric power (GW) as well as the share in electric energy (TWh/y) for each separate energy conversion technique in the EU27 at the end of 2010 by Eurostat

	% of 850 GW	% of 3400 TWh/y	
Oil 55 GW	(56%)	55.2	Fossil 55–56%
Coal 231 GW			
NG 212 GW			
			Non-fossil 44–45%
Nuclear 127 GW	(15%)	29.5	
Large hydro 121 GW	(14%)	10.2	
Small hydro 5 GW	(1%)		
Wind 85 GW	(10%)	2.4	
PV 25 GW	(3%)	< 1%	
Biomass 6 GW	(1%)	2.7	
Waste 4 GW	(0%)		
Peat 2 GW	(0%)		
Geothermal 1.5 GW	(0%)		
CSP 0.5 GW	(0%)		
Tidal and wave 0.25 GW	(0%)		

If we accept nuclear as a non-fossil resource the *available resources* would be (8500–12 500)bio + (100–1000)wind + (5–200)solar +350hydro + 1000 nuclear **=9 955–15 050 TWh/y** (Table 5.3).

The following section covers some important regions a bit more in detail. Especially, the official figures are presented together with my own estimates for the total production, and not only the "valuable parts" that are traded. The overview does not cover all countries and regions, but represents approximately half of the population on earth, and most types of climate zones.

5.3.2 EU27: An Overall Energy Balance

I have made some calculation of the agricultural and forestry production with respect to bioenergy for the EU27 (the EU with 27 member countries). The conservative figures Dahlquist et al (2012) say the annual growth of biomass is around 8 500 TWh/y, which can be compared to the 16 000 TWh/y primary energy used today according to official figures. With reasonable improvements in the growth rate due to selection of crops with higher yields, improved irrigation and addition of nutrients, the production of biomass in the EU region could possibly reach 12 500 TWh/y. By implementing energy efficiency improvements in transportation, buildings and industry it should be possible to reduce the need for primary energy to around 12 500 TWh/y. Together with hydro power, solar power and wind power the balance between available renewable resources and consumption should be possible to reach without the need for fossil fuels.

Fig. 5.16 Typical cereal agricultural land in Northern Europe (Nibble farm, Vasteras. Photo E. Dahlquist)

In Europe, cereals like wheat are the most important crop. A typical view of farmland for cereals is seen in Fig. 5.16. In this case we see a field with spring wheat as well as autumn wheat.

5.3.3 China: Today and in the Year 2050

The Chinese Academy of Engineering has made predictions for the energy utilization in China until the year 2050 (Du Xiangwan 2008). The prediction is that renewable energies should deliver 0.88–1.71 billion tce 2050 (tce = ton coal equivalent, approximately 7.4 MWh), reaching a 17–34% share of the national total demand. Including hydropower the renewables will give 1.32–2.15 billion tce providing 26–43% of the national total energy demand. 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 renewable energies will contribute 2% in this scenario, where the total utilization is predicted to be five billion tce 2050. The production of bio pellets and briquettes will increase to 50 million tons by 2050. The increase of electric power from biogas fueled power plants will be 20 GW by 2020 and 40 GW by 2030. Some of this will be through co-firing of biomass in coal fired power plants. Also, CHP will most probably increase to enhance the total efficiency for both coal and biomass fuels. Only 200 MW of electric power was installed in 2006 using biomass fuels, but the capacity is increasing fast.

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 two billion Nm^3/y biogas to 44 billion m^3 by 2020 and 80 billion m^3 by 2030 (the figure in 2006 was 10 billion m^3 per year) according to Professor Li Shi-Zhong at Tsinghua University (2011). Also, 39 million tons of bioethanol and six million tons of bio-diesel were produced in 2007.

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.

There are about 16 million ha of marginal land available for planting starch tuber crops like cassava and sweet potato (Subramanian Narayana Moorthy).

High ethanol yield has been achieved: 4.7 m^3/ha for sweet sorghum stalk vs. 3.7 m^3/ha for corn and 3.8 m^3/ha for sugarcane. This can be compared to 1.5 m^3/ha for sweet sorghum grains and 4.8 for bagasse. Straw from agricultural crops results in 600–700 million tons of agricultural waste in China annually; 1.7 million tons of livestock and fowl's manure is produced annually from the breeding industry in China as well. The most important food crops in China are wheat in the north with a total of 114.5 million tons produced in 2009, and rice in the south with 197 million tons produced the same year.

5.3.4 India

In India, rice is the most important food crop (99.2 million ton/y) followed by wheat (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. Coarse cereals give 39.5 million ton/y and pulses 14.7 million ton /y. This gives 233.9 million ton/y (2009) of all major crops altogether. Singh (2010) at the National Directorate of Wheat Research in India states that wheat makes up ~50% of the caloric intake of the Indian population. The productivity with respect to wheat has increased from 0.9 tons/ha in 1965 to 3 tons/ha,y today on an average. The increase has been due to selection of suitable clones for each type of soil and other conditions. This, of course, is very promising. The highest yields are in Punjab and Haryana with 4–4.3 tons/ha,y, while Karnataka has only 0.7 tons/ha,y. This shows that there is still potential for improvements. Today, the production is 67 kg/capita, while the demand is 73 kg/capita. It is believed with further improvements there will be a balance within 10 years. Rusts, leaf blight, insects as well as climatic issues are still potential threats. There is almost the same amount of biomass production available as straw, 240 million tons. Altogether, this means some 480 million tons of 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.

5.3.5 USA

Georg Huber and Bruce Dale (Scientific American, July 2009) made a review of US biomass potential especially for the purpose of fuels for vehicles. The authors presented the following figures for the US: 428 million tons agricultural waste, 377 million tons Energy crops, 368 million tons forest products, 87 million tons corn and other grains and 106 million tons other types of organic residues. Totally, this gives 1366 million tons/year of crop residues. They also discuss possible energy crops as a complement, where the following are considered to be of highest interest in the US: ewitchgrass, sorghum, miscanthus and energy cane. The authors estimate that these residues and crops could produce 3.5 billion barrels of oil equivalents, which is roughly 50% of the 7.1 billion barrels of oil used today in the US. If we make an assumption that these crops have a HHV of 5.4 MWh/ton, it means 7376 TWh/y. In many areas in the western US we see relatively arid biotopes.

We can also make another calculation to estimate the bioenergy potential in the US. From World Bank indicators (2011) we see that the 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 is produced, that is 2270 TWh/y, 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.

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. To decrease the political risks with oil import, the US government stimulated ethanol production by paying a guaranteed price per liter ethanol. There is no request on how the ethanol is produced, and thus oil and coal is often used to produce and distil the ethanol, giving a poor ratio between the heating values of ethanol produced in relation to fossil fuels used for the production. This is the major reason for claims that ethanol is bad for the environment heard especially in the European mass media.

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. In (Ronald S. Zalesny, Richard B. Hall, Jill A. Zalesny, Bernard G. McMahon, William E. Berguson, Glen R. Stanosz, BioEnergy Research, 2009) the growth rate of different clones of hybrid poplar was evaluated. The average of 10 clones at 10 sites was approximately 11 ton DS/ha,y. If we assume 30% of the US forest land area is planted with this it would mean 304 022 000 ha * 0.3 * 5.4 MWh/ton* 11 ton/ha,y = 5 420 TWh/y and a total of 5420 + 4 900*0.7 = 8 850 TWh/y.

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 is 84% today). These figures show that the available biomass resources should be enough to cover all energy needs if used efficiently. The US government has stated that by 2030 biofuels will have replaced 30% of fossil fuels. An obstacle for this to happen is the strong push from the oil industry to do fracking, where explosives are used in oil and gas containing soils, to get the gas out. This has been very popular alongside extracting oil from oil tar sand, especially in Canada. The big drawbacks are environmental issues as well as high costs, especially for the oil tar sand production.

The conditions for biomass production to cover "own needs" in Canada are principally even better than in the US, while Mexico has more limitations for biomass production due to drier climate.

5.3.6 Brazil

Brazil is generally a very "green" country with a lot of forests and farm land areas. Since the 1980s, Brazil has been a leading country with respect to production of bio-ethanol for vehicles. First, there were many cars running on ethanol during the 1980s. Then oil became more favourable due to new political decisions and regulatory rules. Since the beginning of the new millennium, ethanol has taken back its position as a dominating car fuel. Thus, Brazil is now the major producer of ethanol globally alongside the US.

There have been a lot of discussions about environmental issues around the ethanol production in, among others, Brazil. It has been claimed that rain forests have been cut down to plant sugar cane, where the sugar is fermented to ethanol, and the bagasse used for the distillation of the ethanol. In reality this is not correct, as sugar cane normally is grown at land areas with a different climate, further to the south of Amazonas. Instead soya beans are planted where rain forests are cut down. The Soybean powder is then, to a large extent, exported to western animal farms for production of the meat we eat.

Carlos H. de Brito Cruz writes in the report "Bioethanol in Brazil. 2008" that 15% of all energy used in Brazil is sugar cane. In 1988, 50% of all vehicle fuel was ethanol; in 2004 it was 30%. Sugar cane gives 6 m^3 ethanol/ha. The total arable land in Brazil was 354.8 million ha in 2007. 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 were 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 additional ethanol production. If we triple the production 11.3 million ha would be needed, or 7.9 million alongside what is already utilized. This would mean 7.5% of the available arable land not used intensively today. It is noteworthy 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).

Furtado et al (2011) has investigated the Brazilian sugar cane innovation system. What further developments can be made to make ethanol production even more economic? Also Goldemberg (2007) has studied development of ethanol production and Khatiwada et al has compared Brazil to Nepal concerning this, where Brazil is the good example to follow. Leite et al (2009) is even looking for the possibility that Brazil could replace a lot of fossil fuels even on a global scale with environmentally produced ethanol. Pousa et al (2011) is making a historical review of the development.

In ABRAF: Statistical Yearbook (2011) we can see data on Brazilian biomass resources. These are of high importance and approximately 35% of primary energy is actually from Biomass (EPE: BEN 2011). Baer (2008) was discussing the economic development which was strong before the economic crisis. This has been slowing down after 2008 significantly. Pulp and paper (BRACELPA, 2011) still is doing quite well. FAO (2003) has studied the development of forestry while Ferreira et al (2007) has investigated deforestation by sensing hotspots by remote sensors. Silveira (2005) has made a review of the potential for further development of the biomass resources. Nogueira et al (2007) also see biomass as a sutiable soruce for production of charcoal and Weidenmier et al (2012) have looked at the marcoeconomic impact of Brazil's alternative energy program, where etanol as a vehicle fuel is the most important part.

Yusuf et al (2011) also look at the biodiesl production, which is another alternative for bio-fuels for vehicles, while Gomez & Silveira (2010) have investigated the rural electrification, where also biomass play an important role.

5.3.7 Africa south of Sahara

Africa has many different climatic conditions, from very dry areas in the north to tropical and subtropical south of the Sahara. In the north, biomass has difficult conditions due to too little rain; while south of the Sahara the conditions are mainly quite good, especially in Western and Central Africa. In the very south, we see other areas with less rain, and thus difficult conditions for crops. This is especially true in Namibia, Botswana and parts of South Africa. The potential to use biomass for most needs is thus quite high in most countries south of the Sahara. The issue in many countries is the unstable political conditions causing problems in the development of both society and economy.

One interesting initiative to improve the productivity of African crops is the new species bred at the African Rice Center under the name "New Rices for Africa" (NERICA). Here, rice is selected to the tolerate harsh growing conditions and low nutrient levels.

In South Africa, we also have areas with conditions quite good for crops, and there are many wine yards in the region close to Stellenbosch and Cape Town.

5.3.8 Other Regions

There are many areas with poor conditions for agriculture where animal breeding may be an alternative. The amount of arable land globally is distributed in the following way for the largest countries: USA 179 000 ha, India 169 700 ha, China 135

557 ha, Russia 126 820 ha, Brazil 65 200 ha, Australia 50 600 ha, Canada 45 700 ha, Indonesia 33 546 ha, Ukraine 33 496 ha, Nigeria 30 850 ha, Mexico 27 300 ha, Argentina 27 200 ha, Turkey 26 672 ha, Pakistan 21 960, Kazakhstan 21 671 ha, France 19 582 ha, Spain 18 217 ha, Thailand 18 000 ha, Sudan 16 433 ha, South Africa 15 712 ha, Poland 14 330 ha and Germany 12 020 ha.

As can be seen, the distribution of arable land to some extent follows where we have a lot of people, e.g. India, China, Brazil and Indonesia, while some countries have huge surpluses in relation to their populations, e.g. the USA, Canada and Russia, especially Canada. In Australia, there is a lot of this type of land in the south eastern part. In a typical landscape of this there are some trees and much grass. At some places the rain is enough for more intense farming, while in other areas it is too little.

5.3.8.1 Global Perspectives

We should then also notice that the amount of straw is approximately the same as the grain that is harvested. So, the total biomass production that can be utilized in high income countries then is approximately 11 ton/ha,y. In forest areas, we can assume that the official production of approximately 2 ton DS/ha, y in reality is at least 3 tonDS/ha,y. In arable land we can assume slightly lower productivity and approximately 1.5–2 ton DS/ha, y can be reasonable figures to use. We also assume that the higher heating value (HHV) is 5.4 MWh/ton DS, which is a reasonable value.

We first take the official figures of land area for each group and multiply the cereal production in each group by 2. To this figure we add the total forest area times 3 t/ha,y and arable land multiplied by 2 t/ha,y, and multiply the total mass by 5.4 MWh/ton and we get:

Arable land with agriculture incl straw 187 000 TWh/y.
Forests 65 000 TWh/y.

Totally, this adds up to c 250 000 TWh/y as the higher heating value (HHV) of all the biomass produced on land. This can be compared to the total energy use of approximately 150 000 TWh/y globally. From this we can conclude that there is enough biomass energy for the global population if we use the energy in a good way. This means to first use wood for buildings, and then later use the waste wood for energy purposes. Use the grain of the plants as food, but also utilize the straw and other agricultural residues for first biogas or ethanol production, but also recycle the residues back to farm land areas as fertilizer etc.

It is also important to have sustainable farming and forestry that utilizes all resources in an effective way. Nutrients, for example, can be administrated in open soil during autumn or to growing crops during spring/summer. In the first case, a lot of the nutrients come out as leachate polluting waters or emissions to the air. In the second way, most of the nutrients will go into the crops instead. Administrating nutrients in a good way means lower amounts needed and less environmental impact, which is a win-win situation!

References

ABRAF: Statistical Yearbook. http://www.abraflor.org.br/estatisticas/ABRAF11/ABRAF11-EN.pdf (2011). Accessed July 2012

Baer, W.: The Brazilian Economy – Growth and Development. Lynne Rienner Publishers. https://www.rienner.com/uploads/47e29b0ea1787.pdf (2008). Accessed July 2012

Bailey, C., Dyer, J.F., Teeter, L.: Assessing the rural development potential of lignocellulosic biofuels in Alabama. Biomass Bioenergy. **35**, 1408–1417 (2011)

BRACELPA (Brazil Pulp and Paper Association): Brazilian Pulp And Paper Industry. http://www.bracelpa.org.br/eng/estatisticas/pdf/booklet/booklet.pdf (2011). Accessed July 2012

CEPI: Key Statistics 2008. European Pulp and Paper Industry. Confederation of European Paper Industry (2008)

Dahlquist, E., Vassileva, I., Thorin, E., Wallin, F.: How to save energy to reach a balance between production and consumption of heat, electricity and fuels for vehicles. J. Energy. **46**(1), 16–20 (2012). (ISSN 0360–5442)

de Brito Cruz, C.H.: Bioethanol in Brazil. http://www.biofuels.apec.org/pdfs/apec_200810_brito-cruz.pdf (2008). Accessed July 2012

de Leite, R.C.C., Lima Verde Leal, M.R., Barbosa Cortez, L.A., Griffin, W.M., Gaya Scandiffio, M.I.: Can Brazil replace 5% of the 2025 gasoline world demand with ethanol? Energy. **34**(5), 655–661 (2009)

Dupriez, H, De Leener, P.: Agriculture in African rural communities–Crops and soil. Macmillan Publishers, London (1988)

EC: Eurostat: Statistical Pocketbook 2010. EU Commission, Brussels. http://ec.europa.eu/energy/publications/statistics/statistics_en.htm (2010). Accessed July 2012

EIA: Annual energy outlook 2011with projections to 2035. US Department of Energy, Energy Information Administration, Office of Integrated and International Energy Analysis, Washington, DC. www.eia.gov/forecasts/aeo/ (2011). Accessed 28 Mar 2012

EPE: BEN – Brazilian Energy Balance. Ministry of Mines and Energy (MME). Brazilian Government. https://ben.epe.gov.br/BENSeriesCompletas.aspx (2011a). Accessed July 2012

FAO: Forests and the forestry sector – Brazil. Food and Agriculture Organization of the United Nations, Rome. http://www.fao.org/forestry/country/57478/en/bra/ (2003). Accessed July 2012

Ferreira, N.C., Ferreira, L.G., Miziara, F.: Deforestation hotspots in the Brazilian Amazon: evidence and causes assessed from remote sensing and census data. Earth Interactions. **11**(1), 1–16 (2007)

Furtado, A.T., Scandiffio, M.I.G., Cortez, L.A.B.: The Brazilian sugarcane innovation system. Energy Policy. **39**(1), 156–166 (2011)

Goldemberg, J.: Ethanol for a sustainable energy future. Science. **315**(5813), 808–810 (2007)

Gomez, M., Silveira, S.: Rural electrification of the Brazilian Amazon – achievements and lessons. Energy Policy. **38**(10), 6251–6260 (2010)

Gordon, D.R., Tancig, K.J., Onderdonk, D.A., Gantz, C.A.: Assessing the invasive potential of biofuel species proposed for Florida and the United States using the AustralianWeed Risk Assessment. Biomass Bioenergy. **35**(1), 74–79 (2011)

Kazmerski, L.: Solar Power Today and in the Future. Presentation at World Renewable Energy Technology Conference. 21–23 April 2011. New Delhi (2011)

Kazmierczyk, P., Tsutsumi, R., Watson, D. (eds): Sustainable consumption and production in South East Europe and Eastern Europe, Caucasus and Central Asia. Joint UNEP-EEA report on the opportunities and lessons learned EEA Report No 3/2007. http://www.eea.europa.eu/publications/eea_report_2007_3/Sustainable-consumption-and-production-in-South-East-Europe-and-Eastern-Europe–Caucasus-and-Central-Asia (2007). Accessed July 2012

Khatiwada, D., Seabra, J., Silveira, S., Walter, A.: Power generation from sugarcane biomass – a complementary option to hydroelectricithy in Nepal and Brazil. Energy. **48**(1), 241–254 (2012)

Li, S.: The studies of biomass fuel ethanol business under recycling economic mode (D). PhD thesis, Agricultural University, Beijing (2005)

Li, S.H.: The priorities and goals of the development of China's biomass resources. Workshop between Chinese Academy of Engineering and Swedish Royal Academy of Engineering, 17 June 2008, Stockholm (2008)

Liao, C.P., Yan, Y.J., Wu, C.Z., Huang, H.B.: Study on the distribution and quantity of biomass residues resource in China. Biomass Bioenergy. **27**(2), 111–117 (2004)

Longman, K.A.: Preparing to plant tropical trees. Blakton Hall, London (2002)

Nogueira, L.A.H., Coelho, S.T., Uhlig, A.: Sustainable Charcoal Production in Brazil. Food andAgriculture Organization of the United Nations, Rome. http://www.fao.org/docrep/012/i1321e/i1321e04.pdf (2007). Accessed July 2012.

Opeke, L.K.: Tropical tree crops. Spectrum Books Limited, Ibadan. ISBN 978–246–152-0. 1997.

Pousa, G.P.A.G., Santos, A.L.F., Suarez, P.A.Z.: History and policy of biodiesel in Brazil. Energy Policy. **35**(11), 5393–5398 (2011)

Silveira, S.: Bioenergy – Realizing the Potential. Elsevier, Oxford (2005)

Singh, S.S.: Wheat production in India and future prospects. 8th International Wheat Conference, 1–4 June 2010. St. Petersburg, Russia (2010)

Swedish Energy Agency: Report on the annual Energy in Sweden. Swedish Energy Agency, Stockholm. http://www.energimyndigheten.se/en/ (2009). Accessed July 2012

Swedish Forest Industries: The report on the Swedish Forest Industries – Facts and figures 2010. Stockholm.

Thuijl, E., Roos, C., Beurskens, L.: An Overview of Biofuel Technologies, Markets and Policies in Europe. ECN-C–03-008, 2003.

US Department of Energy: Annual energy outlook 2011 with projections to 2035. DOE/EIA-0383, US Department of Energy, Washington, DC (2011)

US Department of Energy: Views on renewable energy and biomass. http://www.energy.gov/energysources/bioenergy.htm (2012). Accessed July 2012

USDA: Oilseeds: World market and trade. United States Department of Agriculture, Foreign Agricultural Service, Circular Series FOP 1–09. http://www.fas.usda.gov/oilseeds/circular/2009/January/Oilseedsfull0109.pdf (2009). Accessed July 2010

Weidenmier, M.D., Davis, J.H. & Aliaga-Diaz, R.: Is sugar sweeter at the pump? The macroeconomic impact of Brazil's alternative energy program. NBER Working Paper No. 14362. http://www.nber.org/papers/w14362.pdf (2008). Accessed July 2012

Widen, J.: System studies and simulations of distributed photovoltaics in Sweden. PhD Thesis, Uppsala University, Uppsala. http://urn.kb.se/resolve?urn=urn:nbn:se:uu:diva-132907 (2010). Accessed July 2012

Xiangwan, D.: Development of Renewable Energy in China: Significance & Strategic Objectives. Chinese Academy of Engineering, Sweden (2008)

Xie, G., Wang, X., Ren, L.: China's crop residues resources evaluation. Chinese J. Biotechnol. **26**(7), 855–863 (2010.) (in Chinese with English abstract)

Yusuf, N.N.A.N., Kamarudin, S.K., Yaakub, Z.: Overview on the current trends in biodiesel production. Energy Convers. Manage. **52**, 2741–2751 (2011)