ABSTRACT

An overview of population distribution, economy, crop production, forestry and use of energy in the countries of the world is first presented. From this an estimate is made of the present situation and possible potential production of biomass for different geographic and economic zones. This is complemented with potential for wind, solar and hydro power. Next the present use of energy is given and the potential for future new energy technologies for both production of electricity and saving potential for energy in industry, transportation, offices and households. The balance between production and consumption is discussed with the perspective of long term production possibilities without destroying nature. Means to sustain agriculture long term by better use of fertilizers is one aspect discussed and exemplified. Some specific technologies are discussed more in detail like biogas production from house hold waste and crop waste; high temperature gasification of biomass to produce methane in combination with large scale CHP; TPV (Thermo Photo Voltaic) where electricity is produced from biomass at the same time as heating and cooling is implemented for small scale applications. The potential for covering house roofs with solar cells and implement energy efficient buildings and smart grids are other aspects, as well as systems for electric and hybrid electric vehicles using biogas as fuel.

1. INTRODUCTION

TABLE 1. LOW INCOME, MIDDLE INCOME AND HIGH INCOME COUNTRIES DISTRIBUTED ON REGIONS.

<table>
<thead>
<tr>
<th>Region</th>
<th>EurCA</th>
<th>EastAsia</th>
<th>LatAm</th>
<th>SoAsia</th>
<th>SubSah</th>
<th>MEasNAf</th>
<th>NAm</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low income</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>26</td>
<td>0</td>
<td>0</td>
<td>35</td>
</tr>
<tr>
<td>Middle income</td>
<td>21</td>
<td>21</td>
<td>29</td>
<td>5</td>
<td>21</td>
<td>13</td>
<td>0</td>
<td>110</td>
</tr>
<tr>
<td>High income</td>
<td>35</td>
<td>11</td>
<td>10</td>
<td>0</td>
<td>1</td>
<td>8</td>
<td>3</td>
<td>68</td>
</tr>
<tr>
<td>Global total</td>
<td>58</td>
<td>35</td>
<td>40</td>
<td>8</td>
<td>48</td>
<td>21</td>
<td>3</td>
<td>213</td>
</tr>
</tbody>
</table>

and North America have most countries in High income countries, although Central Asia have significant amount of countries also in middle income. For Sub Sahara countries on the other hand we have most of the countries in the low income or middle income categories. The grouping of
countries after average income is interesting as the use of fertilizers, tractors and other factors demanding money is related to this. In Table 2 we see some of these statistics. The cereal yield is very much higher as a function of average income, and it has increased faster in high income countries than in low income countries during the last 40 years. In low income countries and especially in middle income countries the percentage of fossil fuels have increased during the same period, while it has slightly decreased in the high income countries, which is of interest to note in association with our need to move away from the dependency of fossil fuels. We also can see that electricity consumption per capita is extremely different between different populations, while the difference in energy use totally is a less. The GDP per capita is seen in the last column.

In Table 3 we see how the population is distributed on different ages for the different categories of countries. In low income countries children are dominating while there are also many people older than 65 years in high income countries.

As the income increases we can expect that the same or similar demography will be the case in all populations within the next 100 years. Also the total global population is predicted to stabilize at around 9 billion people during the second half of this century, and then probably slowly decrease again. What we want to avoid is that even more fossil fuels are used short term to compensate for this, as global warming may cause big changes causing political instability in many countries as draft and rain will move geographically.

**TABLE 2. STATISTICS FROM WORLD BANK DEVELOPMENT INDICATORS RELATING TO DIFFERENT AVERAGE INCOME PER CAPITA IN DIFFERENT CATEGORIES OF COUNTRIES.**

<table>
<thead>
<tr>
<th></th>
<th>Cereal yield kg/ha</th>
<th>El from fossil fuel %</th>
<th>El consump kWh/cap</th>
<th>Energy use 2008 kgoe/cap</th>
<th>Fossil fuel % of total</th>
<th>GDP US$/cap</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low income</td>
<td>1296</td>
<td>1952</td>
<td>17,9</td>
<td>31,4</td>
<td>222</td>
<td>350</td>
</tr>
<tr>
<td>Middle income</td>
<td>1515</td>
<td>3202</td>
<td>37,2</td>
<td>73</td>
<td>1606</td>
<td>1255</td>
</tr>
<tr>
<td>High Income</td>
<td>2766</td>
<td>5448</td>
<td>71,7</td>
<td>62,9</td>
<td>9515</td>
<td>5127</td>
</tr>
<tr>
<td>World wide</td>
<td>1829</td>
<td>3513</td>
<td>61,6</td>
<td>67,2</td>
<td>2874</td>
<td>1834</td>
</tr>
</tbody>
</table>

**TABLE 3. LIFE EXPECTANCY AND POPULATION DISTRIBUTION BETWEEN DIFFERENT CATEGORIES OF COUNTRIES**

<table>
<thead>
<tr>
<th>Life expectancy</th>
<th>Population</th>
<th>Population</th>
<th>Population</th>
<th>Population</th>
<th>Total population</th>
</tr>
</thead>
<tbody>
<tr>
<td>at birth</td>
<td>%of all</td>
<td>%of all</td>
<td>%of all</td>
<td>year in %</td>
<td>million</td>
</tr>
<tr>
<td>Low income</td>
<td>57,5</td>
<td>39,4</td>
<td>57,1</td>
<td>3,5</td>
<td>2,16</td>
</tr>
<tr>
<td>Middle income</td>
<td>68,7</td>
<td>27,3</td>
<td>66,3</td>
<td>6,4</td>
<td>1,11</td>
</tr>
<tr>
<td>High Income</td>
<td>79,8</td>
<td>17,5</td>
<td>67,1</td>
<td>15,4</td>
<td>0,6</td>
</tr>
<tr>
<td>World wide</td>
<td>69,2</td>
<td>27,2</td>
<td>65,3</td>
<td>7,5</td>
<td>1,15</td>
</tr>
</tbody>
</table>

This is one of the major reasons for moving into a fossil fuel free society as soon as possible. In this paper we thus will discuss the potential for doing this.

**Energy resources**

We have one major source for energy at earth. This is the sun, which is creating wind, is driving the buildup of carbohydrates through photo synthesis, and drives the water cycle giving us hydro power and potentially wave power. Aside of this we have
Nuclear power, which is not a renewable energy source, but one not increasing the CO2 content in the atmosphere. If we were just using the existing nuclear technology uranium would soon be a limited resource. If we on the other hand develop the so called fourth generation, where also Uranium 238 and Thorium can be utilized; we would have a resource at the same level as today for at least 2-3000 years to come. In this paper we will focus on the non-nuclear renewable energy sources.

Productivity for crop production is a function of different soils, fertilizer additions, water and climate as well as genetics of the species.

In Table 4 we see how the land area is distributed on agricultural, arable and forestry land. As we can see this is relatively evenly distributed between high income, middle income and low income economies, in proportion to the population.

In table 5 we see how the productivity is related to economy. Fertilizers are used most in mid income economies, but the total production as ton per ha is highest in high income countries. The mechanization is highest in high income economies as well.

### TABLE 4. DISTRIBUTION OF AGRICULTURE, ARABLE AND FOREST LAND ON ECONOMIC CATEGORIES, FROM WORLD DEVELOPMENT INDICATORS [1].

<table>
<thead>
<tr>
<th></th>
<th>Agricult land km²</th>
<th>Agric % of tot</th>
<th>Arable land</th>
<th>Land area cereal prod ha</th>
<th>Cereal production</th>
<th>Forest area km²</th>
<th>Forest area % of tot</th>
<th>Total landarea km²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low income</td>
<td>5 678 692</td>
<td>37,8</td>
<td>9,3</td>
<td>88 349 486</td>
<td>172 000 000</td>
<td>4 154 870</td>
<td>27,6</td>
<td>15 043 470</td>
</tr>
<tr>
<td>Middle income</td>
<td>30 498 090</td>
<td>37,8</td>
<td>10,9</td>
<td>473 000 000</td>
<td>1 510 000 000</td>
<td>26 420 030</td>
<td>32,8</td>
<td>80 675 467</td>
</tr>
<tr>
<td>High Income</td>
<td>12 596 994</td>
<td>37,3</td>
<td>10,9</td>
<td>147 000 000</td>
<td>803 000 000</td>
<td>9 629 420</td>
<td>28,8</td>
<td>33 842 634</td>
</tr>
<tr>
<td>World wide</td>
<td>48 773 776</td>
<td>37,7</td>
<td>10,7</td>
<td>708 000 000</td>
<td>2 490 000 000</td>
<td>40 204 320</td>
<td>31,1</td>
<td>130 000 000</td>
</tr>
</tbody>
</table>

### TABLE 5. AGRICULTURE AND FOOD PRODUCTION AS A FUNCTION OF ECONOMIC CATEGORIES

<table>
<thead>
<tr>
<th></th>
<th>Fertiliser consumption of prod %</th>
<th>Fertiliser consumption kg/ha</th>
<th>Cereal yield kg/ha</th>
<th>Agriculture tractors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low income</td>
<td>207</td>
<td>16,5</td>
<td>1296</td>
<td>1952</td>
</tr>
<tr>
<td>Middle income</td>
<td>104</td>
<td>138,6</td>
<td>1515</td>
<td>3202</td>
</tr>
<tr>
<td>High Income</td>
<td>73,2</td>
<td>109,3</td>
<td>2766</td>
<td>5448</td>
</tr>
<tr>
<td>World wide</td>
<td>95</td>
<td>119,3</td>
<td>1829</td>
<td>3513</td>
</tr>
</tbody>
</table>

The production as ton per ha is as seen doubled from 1970 to 2009 in both middle income and high income economies but only increased by 50 % in low income economies. This both shows that there is a significant potential for improvements, but also shows that the improvements need an economic power and organization, that is not that well developed in many low income countries. It is also interesting to see that the use of fertilizers is lower in high income economies than middle income economies, but the use is almost 10 times lower in low income economies than in middle income economies.

By distributing fertilizers in a good way we can both reduce the total usage but also reduce the leakage to the surrounding waters. This has been demonstrated clearly at Nibble pig farm close to Vasteras in Sweden. By spreading fertilizers on “fixed roads” in the farm land and first distributing 1/3 going one direction, and then the rest by going back, half the amount of nitrogen has given the same yield on cereals [2] The fertilizer has only been distributed in green crops, roughly 1 dm high.

In this way all ammonia is taken up instead of leaking out or evaporate to the air. At the same time we can avoid a lot of emissions of N2O and CH4. [3]. By using ERA, Environmental Recycling
Agriculture emissions to lakes can be almost eliminated [4], although here also the production is predicted to be reduced. By improving the crop yield by genetic selection of high producing crops this can be counteracted.

In experiments with Hemp at Brunnby test farm, Västerås, the production varied between 6.5 ton/ha to 10.5 ton/ha DS for exactly the same operating conditions (same soil, nutrients, water) and when optimized with respect to nutrients and water it was up to 12 ton DS/ha. [5]. At Nibble farm close by there was one ha planted with Hemp as well. In September the production was 17 ton/ha, y, but when harvested in February the following year organic content had dropped to 10 ton/ha, y. Instead it was much easier to harvest as the straw now was more brittle. This shows a bit the possibility to optimize the production as ton per ha at the same time as leakage to the surroundings and evaporation to the air is avoided. On the other hand yield is lost when left on the farmland over the winter.

2. REGIONAL FIGURES ON PRODUCTIVITY WITH RESPECT TO CROPS

In this chapter especially the biomass resources, but also other renewable energy resources, are presented and discussed for important countries and regions.

2.1 USA

Reference [6] reviews the biomass potential in the US. They are especially focusing on the potential use as biofuel feedstock. Their figures are that the following quantities could sustainably be produced in 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 others of organic residues. Totally this is 1366 million tons/year. The energy crops are primarily assumed to be Switch grass, Sorghum, Miscanthus and Energycane. 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. If we just make an assumption that these crops have a HHV of 5.4 MWh/ton, it means 7376 TWh/y.

From [1] we see that the average cereal yield is 7238 kg/ha in the US. The agricultural area is 58 001 425 ha, giving 4.4 *10^8 ton/year, or with 5.4 MWh/ton = 2270 TWh/y additional as cereals. Compared to the total agricultural land, 411 200 000 ha, this is only 14%. If we just make an estimate that there is the same amount of straw, 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 forest land area is 304 022 000 ha. If we assume an average of 3 ton/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 [7] the growth rate of different clones of hybrid poplar was evaluated. The results for different clones and sites are as follows: For each site, biomass ranges (ton/ ha,y) of the best six clones were: Westport: 2.3 to 3.9 (5 years), 8.0 to 10.1 (8 years), and 8.9 to 11.3 (10 years); Waseca: 10.4 to 13.4 (7 years); Arlington: 5.1 to 7.1 (3 years), 14.8 to 20.9 (6 years), and 16.1 to 21.1 (8 years); and Ames: 4.3 to 5.3 (4 years), 11.1 to 20.9 (7 years), and 14.3 to 24.5 (9 years). The average of these 10 clones at 10 sites was approximately 11 ton DS/ha,y. We can’t have only hybrid poplar everywhere, but a significant portion would be reasonable. If we assume 30 % of the land area 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 84 %). These figures show that the available biomass resource should be enough to cover all energy needs if used efficiently. As a complement we also have hydro power, solar power and wind power. US government points out that by 2030 wind power generation will have reached 20% of total electric power capacity, and bio-fuel will have replaced 30% of fossil fuels;

2.2 EU27

If we do a similar calculation for EU27 we end up at a production of approximately 8 500 TWh/y as biomass today, but with a potential of some 12 000 TWh/y, which can be compared to the total utilization of energy that is 16 000 TWh/y today of primary energy. In [8,9,10,11] estimates of the potential savings is presented showing that by making more efficient transportations using series hybrid vehicles and using biomass as the fuel after conversion to CH₄ or ethanol, low energy buildings and savings in industry, we could reach a total energy utilization in the range of 12 000 TWh. The hydro power is today around 350 TWh/y, wind power 100 TWh/y (85 000 MW) but with a potential of at least 1000 TWh/y within some 20 years. Solar power gives significantly lower energy contribution, although 25 000 MW installed capacity, but could give at least 200 TWh/y if half
of the house roofs were covered with PV-cells. To this comes 1000 TWh/y nuclear power today. Wave power is still marginal but can give a significant contribution in the future as well. The total electricity consumption is 3 400 TWh/y in EU27, from which already today 45% is non-fossil fuelled. The total production of renewable energy could be some 14 000 TWh/y, while the consumption could be reduced from 16 000 to some 12 000 TWh. This means that the balance between use and renewable energy production should be possible to reach until approximately 2050 with good control mechanisms. EU has set a goal that by 2020 and 2050 consumption of renewable energies will have made up 20% and 50% in total energy consumption, according to the plan made by the EU commission;

2.3 China

Chinese Academy of Engineering has made predictions for the energy utilization for the next 40 years until year 2050 [12]. If we look more in detail renewable energies should deliver 0.88-1.71 billion tce (ton coal equivalents) 2050, reaching 17-34% share of the national total demand or even higher. The supplies will reach about 1.32-2.15 billion tce when the contribution of hydro energy is added, and providing 26-43% of the national total energy demand. Of the 1.7 billion tce, hydro power will contribute by 26%, biomass energy 20%, solar energy 34%, wind energy 18%, and other renewable energies 2%. This should be compared to a predicted total consumption of 5 billion tce 2050. By the end of 2006, the installation of solar water heaters in China was 90 million m². The figures of solar water heaters in operation would come to 150 million m² in 2010, 540 million m² in 2020, 980 million m² in 2030 and 1680 million m² in 2050 respectively. By 2050, the target of the per capita 1 m² of solar heater would be achieved. The production of bio pellets and briquettes will also be increased to 30 million by 2010 and 50 million tons by 2050. Hydro power production capacity is 190 GW today, but should increase to 300 GW by 2020 and the rate of utilization increase from 35 % to 55 % by then. The increase of electric power from biogas fueled power plants will increase to 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 increase. Only 200 MW electricity was installed 2006, but the capacity is already 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 2 billion Nm3/y the biogas production 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 [13]. Also 39 million tons of bioethanol and 6 million tons of bio-diesel was produced 2007.

China has about 120 million hectares of marginal lands and 40 million hectares of degraded arable lands. Tubers crops have high biomass production yield (15-45 t/ha.) and starch content (20-33%). Cassava is suitable for growing in south China with special character such as easy to survive, less diseases and insects, resistance to drought etc. Sweet potato can also be planted in poor soil. There are about 16 million ha of marginal lands available for planting starch tuber crops. High Ethanol yield has been achieved: 4700 l/ha for Sweet Sorghum stalk vs. 3750 l/ha for Corn & 3850 for Sugarcane, 1530 l/ha for sweet sorghum grains and 4800 l/ha for bagasse. Agricultural Crop Straw results in 600-700 million tons in China and 60-70 million tons in Henan province. 1.7 million tons of livestock and fowl’s manure is produced annually from the breeding industry in China. Totally we can assume some 800 million tons of straw and the same amount grain and similar, which means 8640 TWh/y.

2.4 India

For India rice is the most important 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. 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 [14].

3. SOME GLOBALLY IMPORTANT CROPS

First some of the most important crops on a global perspective are presented and thereafter some crops that have a good potential as energy crop for the future. There are many more crops that could be of interest, but these are chosen as being of special interest, to both investigate the existing situation as well as openings for the future.

3.1 Rice

Rice is grown in many tropical and subtropical countries. The average productivity is 3. 9 tons per ha, but with significantly higher yields where there is intensive irrigation like in Australia with 9.5 tons/ha, y and Egypt with 8.7 tons/ha, y. On the other hand, some countries have “traditional” methods like the Republic of Congo with only 0.75 tons/ha, y! As a result of this we have 75% of the world production of rice at the 55% of the rice area that is irrigated.
In 2009 the global production of rice was 678 million tons. The production per ha varies a lot. In China it was 6.6 ton/ha, y and the total production 197 million tons. With this China is the biggest producer. India comes as number two with 131 million tons, but with only 45% of the production per ha compared to China. Indonesia is the third largest producer with 64 million tons. The production per ha is in-between the others. If India was increasing their productivity to the same level as in China it would mean another 100 million tons per year, which would feed another 400 million inhabitants as staple food!!

Normally we will have approximately the same amount of rice straw as grain, that is if 8 tons/ha, y of grain, we also have 8 tons/ha, y of straw. [15]

### 3.2 Wheat

690 million tons of wheat is produced annually and globally. The biggest producer is China with 112 million ton produced annually [16]. India with 79 million ton/y is number second, USA with 68 third and Russia with 64 million fourth. This is the most important crop from a food perspective, but as much biomass is produced as straw, that is around 700 million ton/y, corresponding to some 3 500 TWh/y heating value. Most of this is not utilized.

### 3.3 Corn

The biggest producer of Corn is the US with a production of 333 million tons/year (2009). The second largest is China with 163 million tons/year. Brazil with 51 and Mexico with 20 million comes next. Totally 817 million tonnes are produced annually in the world. The amount of blast is in the same range.

### 3.4 Soy beans

Soybean is a very popular crop for production of very good protein. The beans contain 40% with a very good distribution between amino acids making it suitable as replacement for animal protein. 2009 the world production was 222 million ton [16]. If we would distribute this on all people in the world it would be 13 kg per capita or almost 100 g protein per day. This could replace all animal and fish protein we eat today. Still, only a little more than 10% is used as direct human food [17]. 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, the world’s top producers of soy are the United States, Brazil, Argentina, China and India. About 85 percent of the world’s soybeans are processed, or "crushed," annually into soybean meal and oil. Approximately 98 percent of the soybean meal that is crushed is further processed into animal feed with the balance used to make soy flour and proteins. Of the oil fraction, 95 percent is consumed as edible oil; the rest is used for industrial products such as fatty acids, soaps and biodiesel. Soy is one of the few plants that provide a complete protein as it contains all eight amino acids essential for human health. World soybean production has increased by over 500 percent in the last 40 years.

### 3.5 Oil crops

18.1 million tons Rape seed was produced in EU27 2007. Most of it was produced in the temperate countries north of the Alps. In the southern countries Olive oil is more common.

The global rape seed oil production was in 2006 47 million tons. Major producers were China with 12.2, Canada with 9.1, India 6.0, Germany 5.3, France 4.1, UK 1.9 and Poland with 1.6 million tons [17].

In 2007/08 the production of different vegetable oils was: Palmoil 41.3 million tons, Soybean oil 41.3, Rapeseed 18.2, Sunflower 9.9, Peanut 4.8, Cottonseed 5.0, Palm kernel 4.9, Coconut 3.5 and Olive oil 2.8 million tons. [18].

### 3.6 Sugar cane

Sugar cane is an important crop for production of sugar, but also for ethanol in e.g. Brazil. The total harvested sugar cane area was in 2010 [16] 23.8 billion hectares giving 1.69 billion tons sugar. The largest producer is Brazil followed by India, China, Thailand, Pakistan and Mexico. 80% of all sugar is produced from sugar cane, with sugar beets as the second most important sugar crop.

### 3.7 Switch grass

Switch grass is a relatively new energy crop. In field tests in the US the biomass yield was 5.2 -11.1 tonnes/ha, y. The net energy yield (NEY) becomes 60 GJ/ha/y. Switch grass produced 5.40 times more renewable energy as ethanol than fossil energy consumed for the production. With respect to green-house gas (GHG) production this means a reduction by 94% compared to gasoline.

### 3.8 Giant Kings Grass
Giant Kings Grass has proven to be very fast growing if there is enough water, even at marginal land. It is not a food crop, but very good for conversion to ethanol or biogas or thermal conversion. It can be harvested 2-3 times per year. Unfortunately it can only be grown in mild climates where there is no risk for frost. It also demands a lot of sun shine aside of water. The amount of fertilizers needed is moderate. The production can be up to 100 tonnes DS/ha, y! This has been shown by Viaspace in China in full scale production [19].

4. TECHNICAL SOLUTIONS

To reduce the energy demand we have to possibilities – new more efficient conversion technologies and changed behaviour. The latter can be achieved by a combination of economic incentives and information about how to save energy. With respect to new technologies we can see introduction of more efficient biogas production using better control, combination of different substrates and gas upgrading technologies. For high temperature gasification we have similar actions, but also new flexible system solutions. If we produce gas with a high content of methane we also produce significant amount of tars. By separating out tars, water, CO2 and finally methane by condensation, we can get biogas that can replace natural gas for many applications, especially as fuel for vehicles. The residual gas can be used as fuel in CHP plants. The gas can be used in electrical vehicles of e.g. series hybride type to make extension of the travel distance without having to invest in very large batteries. New type of CHP can be also local solutions where e.g. PV-cell systems are combined with TPV, where biomass is combusted. The heat is used to produce heat fotons, which are concentrated and filtered to remove low energy photons, before the rest of the photons reach special TPV-cells and create electric power. The remaining heat in the exhaust gas is used for production of heat, hot water and to drive absorption cooling machines. The cost for such systems is estimated to be cheaper than for new nuclear power plants! By combining PV cells summer time and TPV winter time gives a new type of energy system. The potential for covering house roofs with solar cells and implement energy efficient buildings and smart grids are other aspects.

5. DISCUSSION ABOUT AVAILABLE RENEWABLE RESOURCES

We should keep in mind that generally we produce approximately the same amount of biomass as straw or stalks as the grains that are registered in the official data banks. For forestry production the bark, roots, branches and similar is also approximately the same amount as the actual stem wood. The global cereal production is according to [1] and seen in table 4, 2 490 000 000 tons/year. With an assumption of twice as much as biomass and 5.4 MWh/ton this corresponds to 26 900 TWh/year, from which half as food, half as waste. If we instead look at agricultural land area 4 877 377 600 ha * 10 tons/ha * 5.4 MWh/ton we get 263 400 TWh/y. For 5 tons/ha the figure would be half, that is 132 000 TWh/y.

For forestry the land area is 4 020 432 000 ha globally and with 3 ton/ha * 5.4 MWh/ton we get 65 100 TWh/y. The total biomass production then becomes approximately 200 000 - 330 000 TWh/y.

This is significantly more than the total energy utilization globally which is some 140 000 TWh/y. As we also are expanding the production capacity for wind power and solar power, and already have a significant amount of hydro power, the situation for changing into a fossil fuel free society looks good. What are needed are primarily good incentives driving the societies from using fossil fuels into using more renewables. Here we also have to be observant so that biomass is used in an efficient way. Today it is still common to just burn straw in the fields or setting fire on forests to achieve agricultural land for some years. This is not only a waste of biomass, but also causes problems from an environmental point of view.

Generally we also waste a lot of what we produce. [20] and [21] covers estimates of where we have losses in the chain from production of crops and meat into conversion, transportation and use in homes and restaurants. We are talking about 10th of percentages being lost. Here we have a great potential to improve the handling of food.

6. CONCLUSIONS

From what has been discussed in the paper we can see that there is enough available renewable energy resources to cover all the needs we have with respect to both energy and food. The problem more is to get us to use the available resources in a good way. This demands both knowledge about how to be more efficient as well as regulatory frameworks and incentives to drive the society in the right direction. As long as there is very cheap energy from fossil sources this is a problem, but as the oil resources get more expensive the renewables also becomes more competitive. If we also consider the Global Warming issues, the development into a fossil fuel free society should be speeded up very fast, and we shall not just wait for the price mechanisms to handle it for us.

References:


