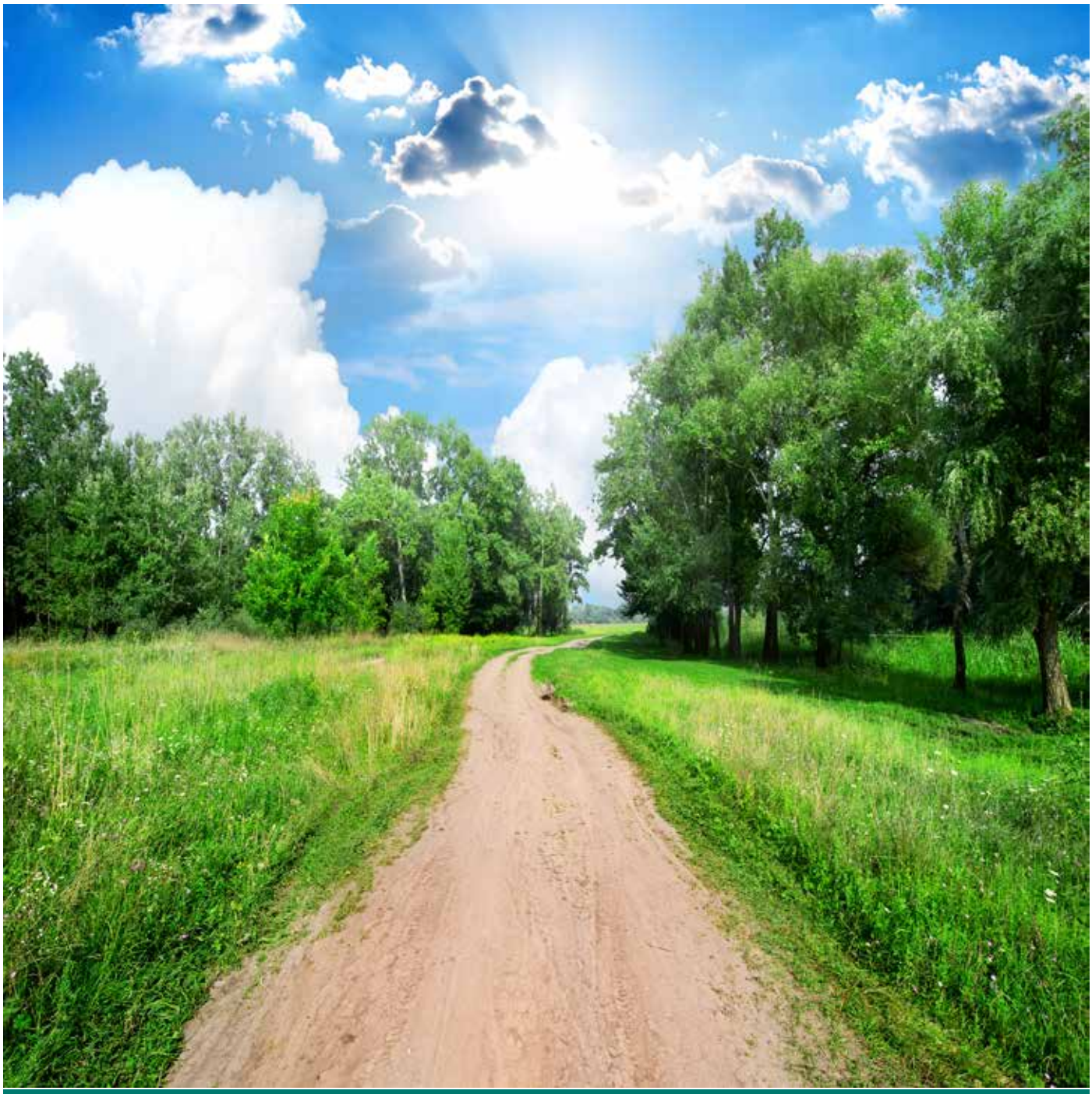

WBA GLOBAL BIOENERGY STATISTICS 2015

WORLD BIOENERGY ASSOCIATION

www.worldbioenergy.org

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MESSAGE FROM THE PRESIDENT

Dear reader,

Welcome to the 2nd Global Bioenergy Statistics report 2015. This report informs about the supply of biomass and its use for heat, electricity and transport on all five continents.

The report aims to improve the understanding of bioenergy, to make the contribution of biomass for a climate compatible energy system more visible and to provide a data basis for business, politics and research to promote a sustainable further growth of bioenergy.

Between 2011 and 2012 the growth of bio-energy in absolute terms was as big as the growth of all other renewable sources together. Bioenergy came up for 14.2% of the global final energy, all renewables together 18.4%. In Africa, 55% of the final energy demand was covered by bioenergy.

This report is a work in progress. It is an important extension as compared to the 1st report published in May 2014. This report includes more details on the supply of biomass from byproducts from agriculture, on the dominating role of biomass in selected African and Asian countries, more details on the development of the pellets sector and on the underestimated role of charcoal as energy source.

There might be still important issues missing. For example, the accuracy of data could be improved. Readers are invited to propose improvements to the staff of WBA.

My thanks go to our Project officer, Mr Bharadwaj V Kummamuru, and the members of our steering committee for this report and all contributors for providing information and support.

Regards

Dr Heinz Kopetz
President, World Bioenergy Association
June 2015

WORLD BIOENERGY ASSOCIATION – THE GLOBAL VOICE OF BIOENERGY

Mission: To promote the use of sustainable Bioenergy globally and support the business environment for bioenergy

Together with our members

- We work for an increased use of biomass in the global energy system in the markets for heat, electricity and mobility
- We follow the principles of sustainable, efficient and economic biomass development
- We influence and inform the public opinion in favor of sustainable biomass solutions worldwide and in individual countries
- We promote bioenergy as an important player in the global climate mitigation policy
- We cooperate with global institutions such as UNEP, UNFCCC, IPCC, IEA, IEA Bioenergy, IRENA, REN Alliance, FAO, REN 21 etc. towards the target of 100% Renewable

How we work

- **Office** in Stockholm, Sweden
- **Our board:** 21 members from 5 continents (Africa 3, America 7, Asia 6, Oceania 2, Europe 3)
- **Our members:** Companies, associations, individuals from all over the world
- **Main areas:** Biomass potential, sustainability of biomass, pellets, small scale heat with biomass, combined heat and power, conventional & advanced biofuels, biogas, carbon neutrality of biomass, bioenergy statistics, biomass trade, bioenergy policy, traditional biomass
- **Main activities:** Fact sheets, statistics, position papers, policy reports, workshops, press-releases, networking, presen tations in conferences & exhibitions

What kind of membership is possible

Full members
Bioenergy associations on regional, national or international level, (fee between 300 and 5 000 Euro annually, depending on situation and size)

Associated members
Companies, energy agencies, research institutes, consultants working in the field of bioenergy (fee between 300 and 5 000 Euro annually, depending on situation and size)

Individual members
Individuals, interested in the global development of bioenergy as sustainable and renewable energy source (fee 50 Euro annually)

Benefits of WBA membership

- Strengthen of the lobbying in favor of biomass on a global scale
- Exchange of information and experience between the bioenergy sector worldwide
- Possible cooperation in working groups and projects
- Access to new global studies and information about bioenergy

We invite you: join WBA!

EXECUTIVE SUMMARY

Renewable energy sources are growing and so is bioenergy. By end of 2012, the share of renewable energy sources in primary energy supply was 13.5%. Biomass alone had a share of 10%. Almost 50% of the energy supply in Africa was from renewable sources while renewables supply in Europe stood at 9.2%. Among the top 10 largest energy suppliers in the world, Brazil, India, Canada, Germany and China have the highest renewable energy share in supply.

The share of renewables in final energy consumption has increased from 17.7% in 2000 to 18.4% in 2012. The top 10 energy consumers in the world together consumed 60% of the energy. The countries with highest share of renewables among them were Brazil (43%), India (39%) and Canada (21.6%).

Among the renewables, biomass is still by far the most important renewable energy source. Solar and wind technologies have seen a tremendous growth in the past decade. But, in absolute terms, biomass supply during 2011 – 12 was equal to the supply of all other renewable energy sources combined. 86% of all the biomass supply is used in end-use sectors for heating and cooking applications.

Biomass supply is categorized into three sectors: agriculture, forestry and wastes. The global agricultural area has reduced by 14 million ha during 2000 – 2012. An overview of major crops for agriculture shows that, for example, in the world scenario, a 27% increase in yield (during 2000 – 2012) and a 35% increase in area have led to almost doubling the production of maize. Productivity gains in agriculture based on the use of better varieties, improved soil management, weed control and better education of farmers etc. had the same impact as 23% additional land availability. Also, there is a lot of potential to use agricultural residues for energy generation – an estimated 3.6 to 17.2 billion tonnes of residues are available globally.

Forestry sector is the largest contributor to biomass supply with a share of 87% - in the form of woodfuel, charcoal, residues etc. The forestry area globally has decreased by 1.6% during 2000 – 2013. Woodfuel is a major biomass supply source, which is used for cooking, heating or power production. In 2013, 1.9 billion m^3 of fuelwood was produced globally out of which almost 75% was produced in Africa and Asia.

The final biomass supply sector is waste to energy. Europe produced 0.4 EJ of energy from renewable municipal waste in 2012.

439 TWh of electricity was generated from biomass sources in the year 2012. Only 10% of all biomass supply was used for electricity generation. Europe uses most of its biomass for electricity production while Africa uses the least.

The use of biomass for heating has increased rapidly as it is a sustainable alternative to the use of fossil fuels. The use of biomass in heating and combined heat and power plants has more than doubled in the past 12 years. In the global production of heat, Asia and Africa lead the way due to their high dependence on traditional biomass sources.

Biofuels for transport are important strategy to improve fuel security, mitigate climate change and support rural development. 79% of all biofuels were produced in Americas – predominantly from corn in USA and sugarcane in Brazil. Conventional biofuel production not only delivers ethanol and biodiesel but also protein feed, with the quantities of these both being produced on a similar scale. In 2012, 67 million tonnes of protein was produced along with 82 million tonnes of biofuels.

Biomass is also used to produce other energy carriers including biogas, pellets, charcoal and traditional biomass. In 2012, an estimated 56.1 billion m^3 of biogas was produced. Germany is the world leader in installation and production of biogas. Pellets are one of the fastest growing energy commodities globally – an estimated 27 million tonnes were produced in 2014. Accurate and updated statistics for charcoal production and use are not available. According to some estimates, 51.9 million tonnes of charcoal were produced in 2013, though the actual figure may be higher. Other developing technologies include pyrolysis oil, torrefied biomass and advanced biofuels. An estimated 6.5 million people were employed in the renewable energy sector globally.

WBA compiled data for three countries – Kenya, Malaysia and Sudan. Statistics were obtained from country representatives. Kenya used 76.1 million m^3 of woodfuel in 2014 – 70% of it is used for producing charcoal for cooking. In 2014, 243 GWh of electricity was produced from biomass in Malaysia. Bioenergy has recently seen an uptake in Sudan with 45 GWh of bioelectricity production. Also, current installed capacity of bioenergy includes 65 million litres for biofuels and 64 m^3 of biogas.

Bioenergy developments are taking place globally. In the future, bioenergy will play a crucial role in climate change mitigation, energy security and generating local employment. However, a crucial missing link is reliable data and this report tries to address it. It is a work in progress and readers interested in sharing data are requested to get in touch with WBA.

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INTRODUCTION

Bioenergy – a versatile energy source!

Biomass is the only renewable energy source, which can be used for the production of heat, electricity and can be converted to other energy carriers like liquid biofuels and pellets. It is one of the earliest forms of energy. In recent times, the unsustainable use of fossil fuels has led to increasing emphasis on the use of biomass for fighting climate change. To meet the future energy and climate goals, bioenergy will play a crucial role.

The importance of biomass can be observed in both industrialized countries as well as developing countries. In many countries, biomass provides 60% of the energy supply. For such an important energy source, basic data on the potential, supply and consumption are lacking. The statistics are incomplete, inaccurate or just rough estimations. Most importantly, the relations between the agriculture, forestry and waste sectors are often not reported. Hence, the issue of sustainable bioenergy production is often ignored.

Therefore, the World Bioenergy Association started the project on 'Improving global bioenergy statistics' in 2014. The objective was the publication of an annual report compiling statistics on the global potential, supply and production of bioenergy. The first report was published in May 2014 and this is the 2nd version.

In this report, the reader is advised to review certain key terminology, which is constantly used throughout the report:
- TPES (Total Primary Energy Supply): It is the energy content of the energy sources and is calculated as production + imports – exports +/- international bunkers +/- stock changes.
- TFEC (Total Final Energy Consumption)
- GFEC (Gross Final Energy Consumption): It is the sum of:
    - o Total final energy consumption – It is the final consumption of energy sources in agriculture/forestry, commercial and public services, fishing, industry and others etc. It excludes the use of fossil sources in non-energy use
    - o Consumption of electricity and heat by the transformation sector, including the energy industry own use
    - o Losses in transmission and distribution of electricity and heat

In this report, chapter 1 provides an overview of the global energy supply, renewable energy system and statistics on bioenergy supply and consumption. Chapter 2 is on biomass supply. Chapters 3, 4 and 5 deal with conversion of biomass to electricity, heat and liquid biofuels. Data on special sectors of biogas, pellets, charcoal and traditional biomass is available in Chapter 6. Chapter 7 gives an overview of the developments in technologies of pyrolysis oil, torrefied biomass and advanced biofuels. Chapter 8 has data on bioenergy jobs. Finally, country statistics for Kenya, Malaysia and Sudan are available in Chapter 9.

The bulk of the data is compiled from various online sources: International Energy Agency (IEA) and Food and Agricultural Organization (FAO). Other sources used include: Renewable Energy Policy Network for the 21st century (REN21), International Renewable Energy Agency (IRENA). Also, statistics were obtained from WBA network of experts and the compilation of the report was coordinated with the steering committee of bioenergy experts.

Readers are requested to send their comments to info@worldbioenergy.org

CHAPTER 1: GLOBAL OVERVIEW

1. In 2012, the primary energy supply of renewables in global energy supply was 13.2% out of which biomass share was 10%.
2. Among the top 10 energy consumers, Brazil and India have the highest share of renewables at 43% and 39% respectively.
3. During the period 2000 – 2012, the bioelectricity generation increased by 269 TWh, which is almost thrice as much as solar electricity, and half of electricity from wind.

1.1 Global energy system

Primary energy supply

Primary energy supply (PES) is defined as the production of energy sources, including imports and excluding exports as well as the use of energy in international aviation and marine bunkers. It is usually defined in terms of energy content of the fuel.

The global energy supply has increased by 33% since 2000 (Table 1). In the year 2012, the share of energy sources in the energy supply was: fossils – 82%, nuclear – 4.8%, and renewables – 13.2%.

Table 1: Primary energy supply of energy sources globally (in EJ)

	Total	Coal	Oil	Natural gas	Nuclear	Renewables
2000	422	98.7	153	86.8	28.3	55.0
2005	482	124	168	98.7	30.2	60.7
2010	540	151	173	115	30.1	71.0
2011	550	159	173	117	28.2	72.9
2012	560	162	176	119	26.9	75.4

(IEA 2015)

Asia is the world's largest supplier of energy (Table 2). 255 EJ of energy was in supply in 2012 out of which 45% was from coal produced predominantly in China and India. Africa used 50% of its energy via renewables – predominantly from biomass.

Table 2: Primary energy supply of energy sources continentally in year 2012 (in EJ)

	Total	Coal	Oil	Natural gas	Nuclear	Renewables	Population (in millions)
Africa	30.7	4.41	6.71	4.18	0.14	15.2	1 083
Americas	135	20.1	52.0	36.7	10.1	16.2	951
Asia	255	114	68.0	37.0	3.75	32.5	3 938
Europe	118	22.1	32.6	39.8	12.9	10.9	824
Oceania	6.16	2.03	2.13	1.41	0.00	0.60	27.6
World	560	162	176	119	26.9	75.4	7 037

(IEA 2015)

China is the world's largest supplier of energy and the energy mix is dominated by the production of coal (Table 3). In 2012, 68% of the energy supply in the country was from coal. The top 10 countries are dependent on different energy sources for supply. USA, Japan, Germany, South Korea are highly dependent on crude oil; China and India are heavily reliant on coal; and

France is gets 43% of its energy from nuclear energy sources.

Table 3: Primary energy supply of energy sources in top 10 countries in 2012 (in EJ)						
	Total	Coal	Oil	Natural gas	Nuclear	Renewables
China	121	82.4	19.4	5.05	1.06	13.2
USA	89.6	17.8	32.3	24.9	8.74	5.69
India	33.0	14.8	7.42	2.05	0.36	8.32
Russia	31.7	5.59	7.07	16.2	1.95	0.93
Japan	18.9	4.70	8.80	4.41	0.17	0.86
Germany	13.1	3.36	4.24	2.92	1.09	1.55
Brazil	11.8	0.64	4.89	1.14	0.18	4.80
South Korea	11.0	3.23	4.07	1.88	1.64	0.21
France	10.6	0.48	3.07	1.60	4.64	0.94
Canada	10.5	0.77	3.45	3.50	1.04	1.93
Total (Top 10)	351	134	94.7	63.7	20.9	38.5
EU - 28	68.8	12.3	22.0	16.4	9.63	8.29
World	560	162	176	119	26.9	75.4

(IEA 2015) *Countries selected according to Total PES

Imports/Exports

Asia is the world's largest importer of energy due to the increased demand for petroleum products – predominantly from Middle Eastern countries (Table 4, Table 5). Crude oil is the largest traded energy commodity. It makes up 60% of Europe's energy imports. There is no significant trade of renewables among continents as most of energy produced from solar, wind, geothermal etc. are locally consumed except for trading of biomass in the form of liquid biofuels and pellets.

Table 4: Total imports of energy sources in 2012 (in EJ)						
	Total	Coal	Oil	Natural gas	Renewables	Electricity
Africa	5.89	0.32	5.15	0.29	0.00	0.13
Americas	40.7	1.57	32.7	5.05	0.07	0.45
Asia	97.9	23.0	62.2	12.4	0.02	0.25
Europe	68.6	7.68	41.4	17.3	0.57	1.62
Oceania	2.29	0.00	2.08	0.21	0.00	-

(IEA 2015). Electricity imports and exports are not differentiated by the energy source and hence, reported separately.

Table 5: Total exports of energy sources in 2012 (in EJ)						
	Total	Coal	Oil	Natural gas	Renewables	Electricity
Africa	23.4	2.24	17.6	3.47	0.01	0.11
Americas	39.2	6.30	26.2	6.12	0.16	0.46
Asia	80.5	11.4	59.7	9.15	0.07	0.18
Europe	63.8	5.56	39.5	16.8	0.29	1.39
Oceania	9.96	8.21	0.80	0.94	0.00	-

(IEA 2015). Electricity imports and exports are not differentiated by the energy source and hence, reported separately.

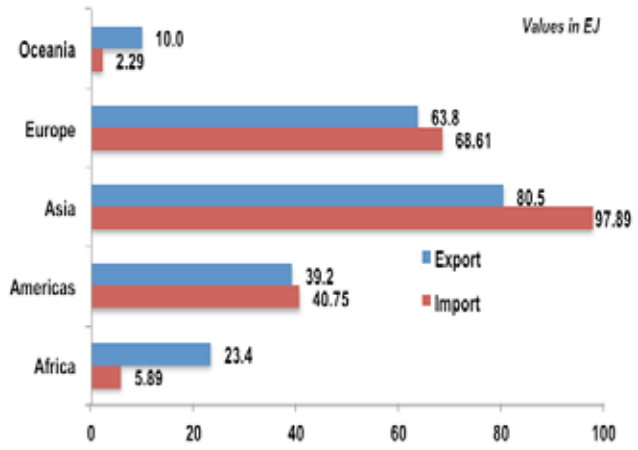

Figure 1 Energy imports and exports in continents in 2012 (in EJ)

Final energy consumption (FEC)

Gross final energy consumption (GFEC) or final energy consumption is the energy commodities delivered to the end-use sectors (industrial, commercial, residential, transport etc.) for the use as energy including the consumption of electricity and heat and excluding the losses occurred during generation and transmission.
The gross final consumption of energy sources in the year 2012 was 342 EJ (Table 6). In 2012, renewables share was 18.4%. Renewables grew by 15 EJ since 2000. Coal, oil and natural gas consumption has also increased significantly during 2000 – 2012. Nuclear energy consumption has decreased since 2010 – 2011. According to the Sustainable Energy for All (SE4All) initiative, the renewables share has to double from 18% in 2010 to 36% by 2030. This requires significant investment for renewables development and to reduce the use of fossil fuels.

Table 6: Final energy consumption of energy sources globally (in EJ)

	Total	Coal	Oil	Natural gas	Nuclear	Renewables	Renewables (%)
2000	271	44.4	115	55.5	7.64	47.8	17.7%
2005	301	54.9	125	60.7	8.23	52.1	17.3%
2010	332	64.8	130	68.9	8.26	60.0	18.1%
2011	338	67.6	131	69.9	7.74	61.4	18.2%
2012	342	68.7	132	70.3	7.39	63.0	18.4%

(IEA 2015)

Figure 2 Global growth in renewable energy share (% share in final energy consumption)

The Asian and African continents are the largest and lowest consumer of energy at 42% and 6% respectively (Table 7). The African continent is also the lowest emitter of greenhouse gases and renewables account for more than 50% of its energy mix due to high dependence on biomass. In Europe, fossil fuel consumption in the final energy mix is still more than 80%. This demands for more ambitious renewable energy targets to reduce the use of fossil fuels.

Table 7: Final energy consumption of energy sources continentally in year 2012 (in EJ)

	Total	Coal	Oil	Natural gas	Nuclear	Renewables	Renewables (%)
Africa	22.3	1.52	6.38	1.72	0.04	12.7	56.7%
Americas	89.6	7.14	44.7	22.2	2.85	12.8	14.3%
Asia	151	49.8	52.1	19.5	1.06	28.7	19.0%
Europe	74.8	9.75	27.3	25.9	3.48	8.40	11.2%
Oceania	3.84	0.71	2.00	0.72	-	0.42	11.0%
World	342	68.7	132	70.3	7.39	63.0	18.4%

(IEA 2015)

Among the top 10 energy consumers, Brazil and India are leading the race for renewables share at 43% and 39% respectively (Table 8). Such high shares of renewable energy are due to the high dependence on biomass and hydroelectricity for energy in both countries. Along with China, these countries are implementing various policy measures for increasing the renewables share and at the same time providing basic electricity access to the population.

Table 8: Final energy consumption of energy sources in top 10 countries in 2012 (in EJ)

	Total	Coal	Oil	Natural gas	Nuclear	Renewables	Renewables (%)
China	65.6	35.9	14.1	3.16	0.29	12.1	18.5%
USA	55.5	6.03	26.4	15.9	2.47	4.58	8.26%
India	19.9	5.91	5.32	0.82	0.09	7.77	39.0%
Russia	16.3	2.54	3.80	8.87	0.46	0.63	3.85%
Japan	11.3	2.09	5.88	2.74	0.05	0.58	5.11%
Germany	8.39	1.33	3.06	2.54	0.31	1.15	13.7%
Brazil	8.56	0.37	3.84	0.63	0.05	3.68	43.0%
South Korea	5.15	1.21	1.85	1.40	0.49	0.19	3.77%
France	6.14	0.20	2.50	1.34	1.29	0.81	13.2%
Canada	7.78	0.32	3.04	2.44	0.30	1.68	21.6%
Total (Top 10)	205	55.9	69.8	39.9	5.80	33.2	16.2%
EU	43.5	5.00	16.5	12.9	2.68	6.49	14.9%
World	342	68.7	132.4	70.3	7.39	63.0	18.4%

(IEA 2015)

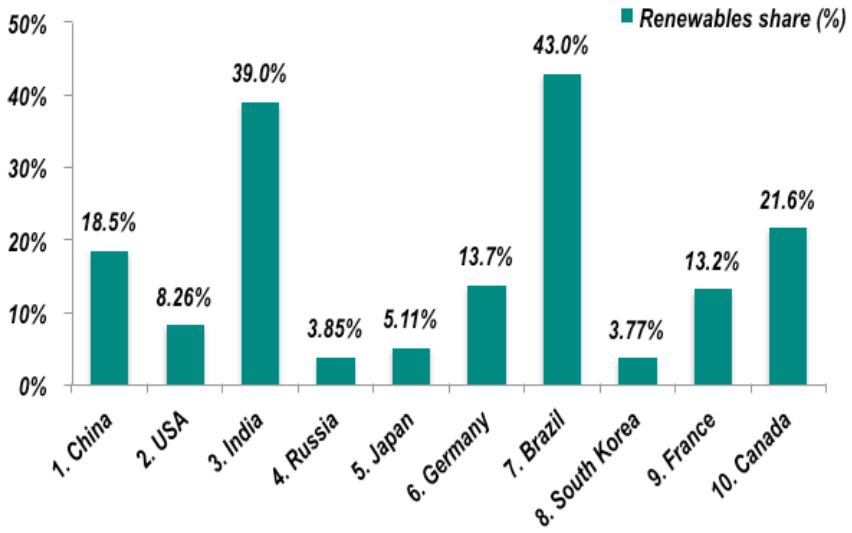

Figure 3 Renewables share in top 10 energy consuming countries in 2012 (in %)

Primary energy supply to final energy consumption – an overview

In 2012, 560 EJ of primary energy resulted in 342 EJ (61%) of useful end-use energy consumption – the remainder being lost as heat (Table 9). Most of the consumption was in the form of heat followed by the use of liquid fuels in transportation sector. Among the renewables, electricity from hydropower has the highest share while biomass contributes the most in the heating and transport sector. Biofuels share in the transportation mix was 2.4% in 2012.

Table 9: Overview of primary energy to final energy for all energy sources globally in 2012 (in EJ)

	Primary energy	Final energy			
		Total	Electricity	Heat	Transportation
Fossils	457	271	46.1	124	101
Nuclear	26.9	7.39	7.37	0.02	-
Hydro	13.2	11.2	11.2	-	-
Biomass	56.2	48.5	1.31	44.7	2.51
Other renewables	5.93	3.25	2.07	1.18	-
Total	560	342	68.1	170	104

(IEA, WBA 2015)

In the overall energy scenario, Asia is the largest producer and consumer of energy – most of it in the form of heat (56%). The use of energy in American continent is mostly in the transportation sector.

Table 10: Overview of primary energy to final energy for all energy sources continentally in 2012 (in EJ)

	Primary energy	Final energy			
		Total	Electricity	Heat	Transportation
Africa	30.7	22.3	2.10	15.7	4.49
Americas	135	89.6	19.6	30.6	39.4
Asia	255	151	30.5	84.3	36.3
Europe	118	74.8	14.9	36.8	23.1
Oceania	6.16	3.84	0.89	1.29	1.66
Total	560	342	68.1	170	104

(IEA, WBA 2015)

1.2 Global renewable energy system

Renewable energy technologies include bioenergy, hydropower, wind, solar, geothermal and ocean technologies. In the past decade, bioenergy has been the major renewable energy source.

Primary energy supply of renewables

In 2012, biomass share in primary energy supply of renewables was 75%, while hydropower share was 17.5% (Table 11). Solar and wind have seen a tremendous increase in their share of energy production during 2000 – 2012. The highest increase in renewables production for solar and wind has been in Europe (Table 12). The top 2 countries with highest share of renewables are China and India (Table 13). Biomass is still by far the largest renewable energy source. The increase in biomass supply in the year 2012, was the same as the combined total of hydro, wind solar, geothermal and ocean technologies.

Table 11: Primary energy supply of renewable energy sources globally (in EJ)

	Total	Biomass	Hydro	Wind	Solar PV	Solar Thermal	Geothermal	Tidal, ocean and wave
2000	55.0	43.1	9.43	0.11	0.00	0.21	2.18	0.002
2005	60.7	47.2	10.6	0.37	0.01	0.30	2.26	0.002
2010	71.0	53.9	12.4	1.23	0.12	0.64	2.69	0.002
2011	72.9	55.0	12.6	1.57	0.22	0.77	2.74	0.002
2012	75.4	56.2	13.2	1.87	0.35	0.92	2.79	0.002

(IEA, WBA 2015)

Table 12: Primary energy supply of renewable energy sources continentally in 2012 (in EJ)

	Total	Biomass	Hydro	Wind	Solar PV	Solar Thermal	Geothermal	Tidal, ocean and wave
Africa	15.2	14.7	0.40	0.01	0.00	0.00	0.06	-
Americas	16.2	9.73	5.09	0.59	0.03	0.10	0.70	0.000
Asia	32.5	25.1	4.76	0.50	0.06	0.66	1.42	0.000
Europe	10.9	6.46	2.83	0.75	0.24	0.14	0.44	0.002
Oceania	0.60	0.26	0.13	0.03	0.01	0.01	0.16	-
World	75.4	56.2	13.2	1.87	0.35	0.92	2.79	0.002

(IEA, WBA 2015)

Table 13: Primary energy supply of renewable energy sources in top 10 countries in 2012 (in EJ)

	Total	Biomass	Hydro	Wind	Solar PV	Solar Thermal	Geothermal	Tidal, ocean and wave
China	13.2	9.04	3.11	0.35	0.02	0.54	0.18	0.00
India	8.32	7.74	0.45	0.10	0.01	0.02	-	-
USA	5.69	3.71	1.00	0.51	0.03	0.07	0.36	-
Brazil	4.80	3.27	1.50	0.02	-	0.02	-	-
Nigeria	4.55	4.53	0.02	-	-	-	-	-
Indonesia	2.99	2.26	0.05	0.00	0.00	-	0.68	-
Ethiopia	1.80	1.78	0.02	0.00	-	-	0.00	-
Germany	1.55	1.17	0.08	0.18	0.09	0.02	0.00	-
Pakistan	1.36	1.25	0.11	-	-	-	-	-
Thailand	1.01	0.98	0.03	0.00	0.00	-	0.00	-
Total (Top 10)	45.3	35.7	6.36	1.16	0.16	0.67	1.22	0.00
EU - 28	7.93	5.73	1.21	0.74	0.24	0.004	0.01	0.002
World	75.4	56.2	13.2	1.9	0.3	0.92	2.8	0.002

(IEA, WBA 2015)

Electricity generation from renewables

The renewable energy sources generated 4 889 TWh of electricity in the year 2012, which is share of 21.5% in total electricity generation (Table 14). The highest increase in renewables electricity has been in solar and wind energy. During the period 2000 – 2012, the bioelectricity generation increased by 269 TWh, while solar and wind increased by 96 TWh and 489 TWh respectively. Americas and Asia have the highest renewable electricity generation. (Table 15, Table 16).

Table 14: Electricity generation from renewables globally (in TWh)

	Total electricity	Renewable electricity	Biomass	Hydro	Wind	Solar PV	Solar Thermal	Geothermal	Tidal, ocean and wave
2000	15 506	2 955	170	2 699	31.4	0.98	0.53	51.9	0.54
2005	18 367	3 421	237	3 017	104	3.98	0.60	58.3	0.52
2010	21 559	4 355	381	3 530	341	32.1	1.64	68.1	0.52
2011	22 252	4 572	409	3 593	435	62.3	2.86	69.3	0.52
2012	22 752	4 889	439	3 756	521	97.2	4.76	70.2	0.50

(IEA, WBA 2015)

Table 15: Electricity generation from renewables continentally in 2012 (in TWh)

	Total electricity	Renewable electricity	Biomass	Hydro	Wind	Solar PV	Solar Thermal	Geothermal	Tidal, ocean and wave
Africa	723	121	1.77	115	2.36	0.31	-	1.62	-
Americas	6 442	1 777	141	1 434	164	9.56	0.98	27.7	0.03
Asia	10 152	1 643	117	1 347	138	17.9	0.00	23.3	0.01
Europe	5 142	1 291	176	823	208	67.9	3.78	11.5	0.46
Oceania	293	55.8	2.97	37.0	8.19	1.49	0.00	6.19	-
World	22 752	4 889	439	3 756	521	97.2	4.76	70.2	0.50

(IEA, WBA 2015)

Table 16: Renewable electricity generation from top 10 countries in 2012 (in TWh)

	Total electricity	Renewable electricity	Biomass	Hydro	Wind	Solar PV	Solar Thermal	Geothermal	Tidal, ocean and wave
China	4 994	1 019	44.7	872	96.0	6.35	0.00	0.15	0.01
USA	4 291	547	78.9	298	142	9.07	0.96	18.14	-
Brazil	552	456	35.2	415	5.05	-	-	-	-
Canada	634	401	9.10	381	11.3	0.33	-	-	0.03
India	1 128	177	20.5	126	28.3	2.10	-	-	-
Russia	1 071	171	3.03	167	0.01	-	-	0.48	-
Germany	630	156	51.2	27.8	50.7	26.4	-	0.03	-
Japan	1 034	137	38.6	83.6	4.84	6.96	-	2.61	-
France	564	90.5	7.48	63.6	14.9	4.02	-	-	0.46
South Korea	535	11.3	1.66	7.65	0.92	1.10	-	-	-
Total (Top 10)	15 433	3 166	290	2 442	354	56.3	0.96	21.4	0.50
EU 28	3 295	819	170	366	206	67.2	3.78	5.76	0.46
World	22 752	4 889	439	3 756	521	97.2	4.76	70.2	0.50

(IEA, WBA 2015)

1.3 Global bioenergy system

Most of the use of bioenergy is in the residential sector in the form of traditional biomass (71.5%). Only 11% of biomass is used in the energy transformation sector (Table 17, Table 18).

Table 17: Overview of biomass supply and consumption in 2012 (in EJ)

	Primary energy	Final energy			Final energy transformation							
		Electricity only	CHP	Heat only	Total	Industry	Transport	Residential	Commercial	Others	Electricity	Derived heat
Africa	14.7	0.04	-	-	12.3	0.84	0.00	11.01	0.31	0.16	0.01	-
Americas	9.73	0.94	0.75	0.00	7.76	3.30	1.72	1.98	0.12	0.19	0.43	0.03
Asia	25.1	1.65	0.02	0.09	23.2	2.50	0.15	19.72	0.35	0.10	0.36	0.07
Europe	6.46	0.77	1.40	0.38	4.98	1.03	0.62	1.90	0.19	0.09	0.54	0.61
Oceania	0.26	0.01	0.03	-	0.24	0.15	0.01	0.06	0.00	-	0.01	(0.00)
World	56.2	3.42	2.20	0.47	48.5	7.81	2.51	34.7	0.97	0.54	1.31	0.70

(IEA, WBA 2015)

Table 18: Overview of biomass supply and consumption in top 10 countries in 2012 (in EJ)

	Primary energy	Final energy			Final energy transformation							
		Electricity only	CHP	Heat only	Total	Industry	Transport	Residential	Commercial	Others	Electricity	Derived heat
China	9.04	0.64	-	0.06	8.51	-	0.05	8.29	-	-	0.13	0.04
India	7.74	0.48	-	-	7.32	1.25	0.01	5.72	0.28	0.00	0.06	-
Nigeria	4.53	-	-	-	4.16	0.31	-	3.72	0.13	-	-	-
USA	3.71	0.59	0.33	-	3.05	1.14	1.09	0.43	0.09	0.03	0.24	0.02
Brazil	3.27	0.01	0.26	-	2.47	1.47	0.50	0.29	0.01	0.10	0.10	-
Indonesia	2.26	0.00	-	-	2.23	0.26	0.02	1.94	0.01	-	0.00	-
Ethiopia	1.78	-	-	-	1.43	-	0.00	1.42	0.01	-	-	-
Pakistan	1.25	-	-	-	1.23	0.14	-	1.09	-	-	-	-
Germany	1.17	0.21	0.30	0.07	0.80	0.12	0.12	0.27	0.05	-	0.16	0.08
Thailand	0.98	0.10	-	-	0.67	0.35	0.04	0.27	-	-	0.01	-
Total (Top 10)	35.7	2.03	0.89	0.13	31.9	5.04	1.83	23.4	0.57	0.14	0.71	0.14
EU 28	5.73	0.77	1.24	0.24	4.41	0.97	0.62	1.64	0.12	0.08	0.52	0.47
World	56.2	3.42	2.20	0.47	48.5	7.81	2.51	34.67	0.97	0.54	1.31	0.70

(IEA, WBA 2015)

CHAPTER 2: BIOMASS SUPPLY OVERVIEW

1. During 2000 - 2012, the highest increase in biomass supply was in Africa (4.3 EJ) followed by Asia (3.4 EJ).
2. A conservative estimate of agricultural crop residues energy potential shows that 13.1 EJ of energy is available.
3. Europe produced 0.4 EJ of energy from renewable municipal waste in 2012

2.1 Overview of biomass supply

56.2 EJ of biomass was in supply during the year 2012 (Table 19). In comparison, the total supply of all energy sources was 560 EJ. In relative terms, since 2000, the biomass supply increased by 30%, mostly with increased production in Europe. In absolute terms, the highest increase was in Africa (4.3 EJ) followed by Asia (3.4 EJ) and Europe (3.1 EJ). The supply of biomass in Asia is the highest globally followed by Africa. The greater use of traditional biomass sources for cooking and heating are one of the reasons for high figures. Both the continents produced more than 70% of the total biomass in supply in the world.

Table 19: Primary energy supply of biomass (in EJ)

	World	Africa	Americas	Asia	Europe	Oceania
2000	43.1	10.5	7.33	21.6	3.35	0.26
2005	47.2	12.0	8.19	22.5	4.20	0.27
2010	53.9	13.7	9.64	24.3	5.97	0.22
2011	55.0	14.3	9.68	24.7	6.09	0.22
2012	56.2	14.7	9.73	25.0	6.46	0.26

(IEA 2015)

Seven of the top 10 countries with high biomass supply are either in Asia or Africa (Table 20). China and India have the highest supply of biomass. However, per capita, the biomass supply is between 6 – 7 EJ, which is low in comparison to other countries. The dependence of the African continent on biomass is significant. Biomass supplies more than 80% of the energy supply in Nigeria in comparison to 7.5% and 24% in China and India.

Table 20: Primary energy supply of biomass in top 10 countries in 2012 (in EJ)

	TPES biomass (EJ)	TPES per capita (GJ per capita)	TPES per GDP (MJ/$)	TPES (% in final energy)
China	9.04	6.69	2.00	7.5%
India	7.74	6.26	5.57	23%
Nigeria	4.53	14.4	0.32	81%
USA	3.71	11.8	0.26	4.1%
Brazil	3.27	16.5	2.88	28%
Indonesia	2.26	9.17	5.30	25%
Ethiopia	1.78	19.4	72.0	93%
Pakistan	1.25	6.99	9.04	35%
Germany	1.17	14.3	0.38	9.0%
Thailand	0.98	14.7	4.37	18%
Total (Top 10)	35.7			
EU 28	5.73	11.28	0.39	8.32%
World	56.2	7.99	1.03	10.0%

(IEA 2015)

Figure 4 Share of biomass in primary energy supply in 2012 (in %). Countries ordered according to top 10 energy consumers

The supply of biomass can be divided into the forestry, agriculture and waste sectors. In the IPCC special report on renewable energy sources and climate change mitigation, these categories of biomass supply are further subdivided (Table 21). The highest contributor to biomass supply is fuelwood from forestry followed by charcoal.

Table 21: Overview of biomass supply sources in 2012 (in EJ)

Sector	Fuel source	Share in primary energy (%)	Primary energy supply (in EJ)
Forestry	Fuelwood	67%	37.7
	Charcoal*	7%	3.94 (13.1)
	Forest residues	1%	0.56
	Black liquor	1%	0.56
	Wood industry residues	5%	2.81
	Recovered wood	6%	3.37
Agriculture	Animal by products	3%	1.69
	Agricultural by products	4%	2.25
	Energy crops	3%	1.69
Waste	MSW and landfill gas	3%	1.69
Total			56.2

(IPCC 2011) *Charcoal is not a primary energy source and is obtained from wood – a conversion factor of 30% from wood to charcoal is used.

In 2012, out of 13 billion ha of land area available, 37% was agricultural area (Table 22). Asia had the highest share of agricultural area at 53% - most of it as permanent meadows and pastures. Americas had the highest forestland while Asia had the highest share of arable land.

Table 22: Overview of land area in 2012 (in 1000 ha)							
			World	Africa	Americas	Asia	Europe	Oceania
Land area			13 009 102	2 964 848	3 879 103	3 103 326	2 213 170	848 655
	Agricultural area		4 922 207	1 177 752	1 224 641	1 632 712	468 026	419 076
		Arable land	1 395 895	237 135	368 841	466 924	274 749	48 245
		Permanent crops	163 893	33 815	28 140	85 196	15 158	1 584
		Permanent meadows and pastures	3 359 659	904 042	827 660	1 080 591	178 118	369 247
Forest land			4 021 911	667 620	1 562 619	595 898	1 006 534	189 240
Other land			4 074 445	1 131 751	1 091 842	871 875	738 611	240 366

(FAO 2015) * Land area = Agricultural area (Arable Land + Permanent crops + Permanent meadows and pastures) + Forestry area + other land

2.2 Agriculture

Agriculture area

Global agricultural area has reduced by 14 million ha since 2000 (Table 23). Though the arable land area has increased overall, the land available as permanent meadows and pastures has reduced.

Table 23: Global agricultural area (in 1000 ha)				
	Agricultureal area	Arable land	Permanent crops	Permanent meadows and pastures
2000	4 936 463	1 381 029	137 792	3 417 642
2005	4 927 677	1 390 967	148 446	3 388 264
2010	4 892 633	1 374 902	159 491	3 358 240
2011	4 910 710	1 382 903	162 368	3 362 679
2012	4 922 207	1 395 895	163 893	3 359 659

(FAO 2015). Agricultural area = Arable land + Permanent crops + Permanent meadows and pastures

Table 24: Continental agricultural area in 2012 (in 1000 ha)				
	Agricultureal area	Arable land	Permanent crops	Permanent meadows and pastures
Africa	1 177 752	237 135	33 815	904 042
Americas	1 224 641	368 841	28 140	827 660
Asia	1 632 712	466 924	85 196	1 080 591
Europe	468 026	274 749	15 158	178 118
Oceania	419 076	48 245	1 584	369 247
World	4 922 207	1 395 895	163 893	3 359 659

(FAO 2015)

During 2000 – 2012, the agricultural area increased in Brazil, Argentina and Kazakhstan. The area in the rest of the top 10 countries has reduced with the largest reduction in Mongolia and Australia.

Table 25: Agricultural land area in top 10 countries in 2012 (in 1000 ha)

	Agricultureal area	Arable land	Permanent crops	Permanent meadows and pastures	% change in agri area since 2000
China	515 361	106 521	16 006	392 834	-1.43%
USA	408 707	155 108	2 600	250 999	-1.37%
Australia	405 474	47 113	380	357 981	-11.0%
Brazil	275 605	72 605	7 000	196 000	5.43%
Russian Federation	214 350	119 750	1 600	93 000	-1.29%
Kazakhstan	207 975	22 900	75	185 000	0.58%
India	179 300	156 200	12 800	10 300	-0.93%
Saudi Arabia	173 390	3 160	230	170 000	-0.23%
Argentina	148 791	39 291	1 000	108 500	15.8%
Mongolia	113 396	648	3	112 745	-13.1%
Top 10	2 642 348	723 296	41 694	1 877 359	
EU 28	186 584	108 372	11 722	66 489	-6.80%
World	4 922 207	1 395 895	163 893	3 359 659	

(FAO 2015). Top 10 countries based on agricultural area

Agricultural crops data

One of the debates in the bioenergy sector has been that of food vs. fuel ever since agricultural crops have been used for biofuel production. The idea that biofuels lead to increasing food prices and competition with land for food is often misleading. As seen from the overview of crop details (Table 26), the yield of major crops in Africa is the lowest in comparison to world average. The average yield of maize in Africa is 2.03 tons/ha in comparison to world average of 5.50 tons/ha.

In the world scenario, a 27% increase in yield (during 2000 – 2012) and a 35% increase in area has led to almost doubling the production of maize. A similar increase in yield due to the use of improved agriculture techniques will enable the production of higher quantities of food for the African subcontinent. With the same yields as in the year 2000, an additional 134 million ha would have been needed in 2013 to harvest the same amount of corn, rice and wheat. Productivity gains in agriculture based on the use of better varieties, improved soil management, weed control and better education of farmers etc. had the same impact as 23% additional land availability. Models that ignore this innovation in agriculture often come up with misleading results. As mentioned by the FAO Director-General José Graziano da Silva recently, the debate has to be food and fuel instead of food vs. fuel (FAO 2015).

Table 26: Overview of crop area, production quantity and crop yields (in 2013)

			World 2000	World 2013	Africa 2013	Americas 2013	Asia 2013	Europe 2013	Oceania 2013
Cereal crops	Maize/corn	Area (Mha)	137 005	185 121	34 903	70 666	60 377	19 073	103
		Yield (t/ha)	4.32	5.50	2.03	7.39	5.05	6.24	7.08
		Production (Mt)	592	1 018	71.0	522	305	119	1
	Rice, paddy	Area	154 064	165 163	10 894	6 558	146 945	648	117
		Yield	3.89	4.49	2.64	5.50	4.57	6.01	10.00
		Production	599	741	28.7	36.1	671.0	3.90	1.17

			World	World	Africa	Americas	Asia	Europe	Oceania
			2000	2013	2013	2013	2013	2013	2013
Cereal crops (continued)	Wheat	Area (Mha)	215 437	219 047	9 917	36 663	101 839	57 599	13 029
		Yield (t/ha)	2.72	3.27	2.85	3.24	3.14	3.92	1.79
		Production (Mt)	586	716	28	119	320	226	23
	Barley	Area	54 516	49 148	4 604	5 774	10 913	24 593	3 264
		Yield	2.44	2.93	1.55	3.66	2.00	3.49	2.42
		Production	133	144	7.14	21.1	21.8	85.9	7.89
	Millet	Area	37 134	33 119	21 122	265	11 202	495	35
		Yield	0.75	0.90	0.71	1.62	1.23	1.28	1.14
		Production	27.7	29.9	15.0	0.43	13.8	0.63	0.04
	Oats	Area	12 676	9 780	185	2 198	541	6 153	703
		Yield	2.06	2.44	1.54	3.05	2.22	2.36	1.62
		Production	26.1	23.9	0.28	6.71	1.20	14.5	1.14
	Rye	Area	9 817	5 760	51.9	234	434	4 980	60.0
		Yield	2.05	2.90	1.80	1.98	2.65	3.00	0.58
		Production	20.1	16.7	0.09	0.46	1.15	14.9	0.04
	Sorghum	Area	41 217	42 227	26 518	6 835	7 885	393	596
		Yield	1.36	1.48	0.97	3.45	1.22	3.19	3.75
		Production	55.9	62.3	25.6	23.6	9.58	1.25	2.23
Oil crops	Olives	Area	8 350	10 309	3 355	129	1 766	5 017	42.0
		Yield	1.87	1.98	1.05	3.86	1.68	2.66	2.23
		Production	15.6	20.4	3.51	0.50	2.96	13.3	0.09
	Rapeseed	Area	25 844	36 499	119	8 917	14 880	9 307	3 274
		Yield	1.53	1.99	1.66	2.16	1.58	2.75	1.27
		Production	39.5	72.7	0.20	19.3	23.5	25.6	4.14
	Soybeans	Area	74 367	111 545	1 791	85 668	20 819	3 226	41.1
		Yield	2.17	2.47	1.25	2.81	1.28	1.89	2.23
		Production	161	276	2.25	241	26.7	6.10	0.09
	Sunflower	Area	21 201	25 454	1 897	2 604	3 993	16 929	30.3
		Yield	1.25	1.75	1.13	1.77	1.50	1.88	1.46
		Production	26.5	44.6	2.14	4.61	5.97	31.8	0.04
	Oil palm	Area	10 032	18 053	4 531	1 007	12 349	-	166
		Yield	12.0	14.8	4.18	15.4	18.6	-	14.1
		Production	120	266	18.9	15.5	230	-	2.34

			World	World	Africa	Americas	Asia	Europe	Oceania
			2000	2013	2013	2013	2013	2013	2013
Sugar crops	Cassava	Area (Mha)	16 958	20 393	13 742	2 448	4 182	-	21.3
		Yield (t/ha)	10.4	13.6	11.5	12.5	21.1	-	12.3
		Production (Mt)	176.1	276.8	157.7	30.5	88.3	-	0.3
	Sugar beet	Area	6 012	4 368	229	499	690	2 950	-
		Yield	41.6	56.4	53.2	64.8	50.0	56.8	-
		Production	250	247	12.2	32.3	34.5	167	-
	Sugar cane	Area	19 397	26 943	1 559	13 968	11 034	0	381
		Yield	64.7	70.9	62.5	74.3	67.7	85.2	76.3
		Production	1 256	1 911	97.4	1 038	747	0.01	29.1

(FAO 2015). Area in 1000 ha, yield in tons/ha, production in million tonnes

Agricultural crops residues potential

One of the major sources of biomass is the use of agricultural by products. Nowadays, most of the residues are left in the fields or burned. There is a lot of potential to utilize these residues for producing the energy needed for industry. An example is the use of cane leaves and tops along with bagasse from sugarcane to produce heat and electricity for sugar mills. Similarly, there is potential for using energy from other crop residues as well. An overview of the available agricultural crop residues shows an estimated potential of 13.1 (low) – 122 EJ (high) of energy available (Table 27) from 3.6 to 17.2 billion tonnes of residues. This is a theoretical potential available and the actual available residues may be less than estimates. The production quantity, yields and area-harvested details were from FAO database. Residue to Product Ratio (RPR) is obtained from Koopmans and Koppejan (1997). It is assumed that 50% of the residues are left on the fields. As there is a significant range gap, two estimates are presented – low and high. Low estimate is for low RPR ratio, high moisture content and low energy content of the residues and vice versa.

Table 27: Estimates of agricultural residue energy potential in 2013 (in EJ)

Major crop production				By products production (in million tonnes)				Estimated potential (in EJ)	
Major crop	Production (tonnes)	Yield (t/ha)	Area harvested (1000 ha)	By products	RPR (-)	Low	High	Low	High
Maize	1 018 111 958	5.50	185 121	Stalk	1 - 4.3	1 018	4 408	2.19	38.4
				Cob	0.2 - 1.8	204	1 833	1.36	13.9
				Husks	0.2 - 1	204	1 018	1.15	8.75
Rice	740 902 532	4.50	164 645	Straw	0.42 - 3.96	311	2 934	1.32	21.2
				Husk	0.2 - 0.35	148	259	0.81	2.28
Wheat	715 909 258	3.27	219 047	Straw	0.7 - 1.8	501	1 289	2.42	9.30
Barley	143 959 778	2.93	49 148	Straw	0.6 - 1.8	86.4	259	0.42	1.48
Millets/Rye/Oats	29 864 147	0.90	33 119	Straw	1.1 - 2	32.9	59.7	0.17	0.31
Sorghum	62 295 137	1.48	42 227	Straw	0.9 - 7.4	56.1	461	0.29	2.43
Olive oil	20 396 700	1.98	10 309	Kernels	0.23 - 0.23	4.59	4.59	0.04	0.04
Rapeseed/Canola	72 699 608	1.99	36 499	Straw	1.7 - 3.7	124	269	0.33	0.83
Soybean	276 032 362	2.47	111 545	Straw	1 - 3.94	276	1 088	1.45	5.72

Major crop production				By products production (in million tonnes)				Estimated potential (in EJ)	
Major crop	Production (tonnes)	Yield (t/ha)	Area harvested (1000 ha)	By products	RPR (-)	Low	High	Low	High
Sunflower seed	44 551 095	1.75	25 454	Straw	2 - 4.1	89.1	183	0.28	0.68
Oil palm	54 384 643	1.48	36 844	Shell	0.05 - 0.09	2.56	4.89	0.01	0.04
				Fibre	0.11 - 0.15	5.98	8.16	0.01	0.05
				Bunch	0.23 - 0.27	12.5	14.7	0.01	0.04
Cassava	276 762 059	13.6	20 393	Stalks	0.06 - 1	17.2	277	0.13	2.06
Sugarbeet	246 521 602	56.4	4 368	Leaves	0.4 - 0.4	98.6	98.6	0.01	0.01
Sugarcane	1 911 179 775	70.9	26 943	Bagasse	0.1 - 1.16	191	2 217	0.30	12.0
				Tops	0.1 - 0.3	191	573	0.38	2.50
Total						3 574	17 258	13.1	122

(FAO, WBA 2015). Retention rate of 50%

Africa has a potential of 0.89 EJ from agricultural residues (Table 28) while Asia has the highest potential of 5.26 EJ. With increasing yields, the volumes of agricultural residues would also increase.

Table 28: Energy potential of agricultural residues in 2013 (low potential)							
Major crop	By products	World	Africa	Americas	Asia	Europe	Oceania
Maize	Stalk	2.19	0.15	1.12	0.66	0.26	0.00
	Cob	1.36	0.09	0.70	0.41	0.16	0.00
	Husks	1.15	0.08	0.59	0.34	0.13	0.00
Rice	Straw	1.32	0.05	0.06	1.20	0.01	0.00
	Husk	0.81	0.03	0.04	0.73	0.00	0.00
Wheat	Straw	2.42	0.10	0.40	1.08	0.76	0.08
Barley	Straw	0.42	0.02	0.06	0.06	0.25	0.02
Millets/Rye/Oats	Straw	0.41	0.09	0.04	0.09	0.17	0.01
Sorghum	Straw	0.29	0.12	0.11	0.05	0.01	0.01
Olive oil	Kernels	0.04	0.01	0.00	0.01	0.03	0.00
Rapeseed/Canola	Straw	0.33	0.00	0.09	0.11	0.11	0.02
Soybean	Straw	1.45	0.01	1.27	0.14	0.03	0.00
Sunflower seed	Straw	0.28	0.01	0.03	0.04	0.20	0.00
Oil palm	Shell	0.05	0.00	0.00	0.04	-	0.00
	Fibre	0.06	0.00	0.00	-	0.05	0.00
	Bunch	0.03	0.00	0.00	-	0.02	0.00
Cassava	Stalks	0.13	0.07	0.01	0.04	-	0.00
Sugarbeet	Leaves	0.01	0.00	0.00	0.00	0.00	-
Sugarcane	Bagasse	0.30	0.02	0.16	0.12	0.00	0.00
	Tops	0.38	0.02	0.21	0.15	0.00	-
Total		13.4	0.89	4.91	5.26	2.21	0.15

(FAO, WBA 2015)

2.3 Forestry

Forestry

The forestry area globally has decreased by 1.6% during 2000 – 2013 (Table 29). The area in Africa, Americas and Oceania has decreased while the area has increased in Asia and Europe. 39% of all forest area is in Americas.

Table 29: Forest area data (in 1000 ha)

	World	Africa	Americas	Asia	Europe	Oceania
2000	4 085 169	708 564	1 609 819	570 164	998 239	198 381
2005	4 060 965	691 468	1 587 554	584 049	1 001 150	196 745
2010	4 033 060	674 419	1 569 744	592 512	1 005 001	191 384
2011	4 027 478	671 009	1 566 182	594 205	1 005 771	190 312
2012	4 021 911	667 620	1 562 619	595 898	1 006 534	189 240

(FAO 2015)

In 2012, Russia had the world's largest forest area. (Table 30). The forest area for China has increased by 20% since 2000.

Table 30: Forestry area in top 10 countries (in 1000 ha)

Country	Forest area in 2000	Forest area in 2012	% change
Russian Federation	809 269	809 210	-0.01%
Brazil	545 943	515 133	-5.64%
Canada	310 134	310 134	0.00%
USA	300 195	304 788	1.53%
China	177 001	212 387	20.0%
Democratic Republic of the Congo	157 249	153 512	-2.38%
Australia	154 920	147 452	-4.82%
Indonesia	99 409	93 062	-6.38%
India	70 491	68 724	-2.51%
Peru	69 213	67 692	-2.20%
Top 10	2 693 823	2 682 094	-0.44%
EU 28	153 580	159 795	4.05%
World	4 021 911	4 085 169	1.57%

(FAO 2015) . There has been a significant drop in deforestation rates in Brazil since the year 2004.

Roundwood is the major forestry product and its production has increased by 136 million m^3 in 13 years since 2000 (Table 31). The demand for increase has been from Africa and Asia.

Table 31: Production of roundwood (in million m^3)

	World	Africa	Americas	Asia	Europe	Oceania
2000	3 455	613	1 094	1 076	612	59.8
2005	3 584	663	1 110	1 074	676	61.2
2010	3 471	699	920	1 126	659	67.4
2011	3 549	706	964	1 126	683	70.1
2012	3 559	712	974	1 123	683	68.1
2013	3 591	720	981	1 126	694	70.2

(FAO 2015)

India is the world's largest producer of roundwood (Table 32). In 2013, the country produced 357 million m^3, which is 10% of the global supply of roundwood. The demand increased by 12.1% since 2000. The production has reduced the most in USA while the highest increase was in DR Congo.

Table 32: Production of roundwood in top 10 countries (in million m^3)

Country	Roundwood production in 2000	Roundwood production in 2013	% change
India	319	357	12.1%
China	322	346	7.4%
USA	467	334	-28.4%
Brazil	235	269	14.4%
Russian Federation	158	194	23.0%
Canada	202	148	-26.6%
Indonesia	138	115	-16.4%
Ethiopia	90	108	20.4%
Democratic Republic of the Congo	68.5	84.7	23.7%
Nigeria	68.8	73.8	7.4%
Top 10 (Total)	2 068	2 031	
EU - 28	432	411	-4.7%
World	3 591	3 455	-3.8%

(FAO 2015)

Woodfuel is wood used for cooking, heating or power production. It also includes wood used for charcoal production in kilns and ovens as well as chips and particles to be used as fuel. In 2013, 1 882 million m^3 of woodfuel was produced globally out of which almost 75% was produced in Africa and Asia (Table 33).

Table 33: Production of woodfuel (in million m^3)

	World	Africa	Americas	Asia	Europe	Oceania
2000	1 810	542	314	808	133	12.7
2005	1 855	589	324	792	139	11.5
2010	1 886	630	327	766	152	10.7
2011	1 872	639	329	758	134	10.7
2012	1 878	645	333	750	139	10.6
2013	1 882	652	335	742	143	10.6

(FAO 2015)

India is the world's largest producer of woodfuel (Table 34). In 2013, the country produced 308 million m^3. 86.1% of all round-wood produced in India is used for energy purposes. In African continent, Ethiopia, DRC, Nigeria utilize most of the round-wood for energy purposes unlike USA where the use of forestry is mainly for the production of wood products.

Table 34: Production of woodfuel in top 10 countries (in million m3)

Country	Woodfuel production in 2010	Woodfuel production in 2013	% change since 2000	Share of round-wood (%)
India	277	308	10.9%	86.1%
China	228	179	-21.4%	51.7%
Brazil	132	146	10.3%	54.2%
Ethiopia	87.5	105	20.4%	97.3%
Democratic Republic of the Congo	64.9	80.1	23.4%	94.6%
Nigeria	59.3	64.4	8.53%	87.2%
Indonesia	89.0	52.6	-40.9%	45.7%
Ghana	26.7	41.4	55.1%	96.3%
Uganda	34.1	41.3	21.1%	89.9%
USA	45.9	40.4	-12.0%	12.1%
Top 10 (Total)	1 045	1 058		
EU - 28	69.6	98.2	41.0%	23.9%
World	1 882	1 810	-3.83%	52.4%

(FAO 2015)

2.4 Waste

The third biomass supply source is waste.

Municipal waste consists of products that are combusted directly to produce heat and/or power and comprises of wastes from household, industry, hospitals and other sources, which are collected by local authorities for incineration. Industrial waste is of non-renewable origin and consists of solid and liquid products combusted directly, usually in specialized plants to produce heat and electricity. Americas and Europe have put a lot of emphasis on generating energy from waste. In the year 2012, 2.18 EJ of waste was used for energy – Americas and Europe share was 21% and 55% (Table 35, Table 36, Table 37).

Table 35: Production of waste for energy in the world (in EJ)

	World	Africa	Americas	Asia	Europe	Oceania
2000	1.26	-	0.52	0.12	0.61	0.01
2005	1.42	-	0.41	0.20	0.81	0.00
2010	1.91	-	0.44	0.42	1.04	0.00
2011	2.13	-	0.45	0.51	1.17	0.00
2012	2.18	-	0.45	0.53	1.20	0.00

(IEA 2015)

Table 36: Production of municipal waste for energy (in EJ)

	World	Africa	Americas	Asia	Europe	Oceania
2000	0.77	-	0.35	0.07	0.35	-
2005	1.01	-	0.30	0.14	0.57	-
2010	1.16	-	0.30	0.16	0.70	-
2011	1.23	-	0.30	0.19	0.74	-
2012	1.26	-	0.30	0.19	0.77	-

(IEA 2015)

Table 37: Production of industrial waste in the world (in EJ)						
	World	Africa	Americas	Asia	Europe	Oceania
2000	0.49	-	0.18	0.05	0.26	0.01
2005	0.41	-	0.11	0.06	0.24	0.00
2010	0.74	-	0.14	0.26	0.33	0.00
2011	0.90	-	0.15	0.32	0.43	0.00
2012	0.91	-	0.14	0.34	0.43	0.00

(IEA 2015)

Renewable municipal waste includes the biodegradable part of municipal waste products that are combusted directly for electricity or heating. It includes waste from residential, commercial, and public services collected by local authorities for disposal. Europe has a sophisticated waste to energy conversion system and produced 0.4 EJ of energy from renewable municipal waste (Table 38).

Table 38: Production of renewable municipal waste for energy (in EJ)						
	World	Africa	Americas	Asia	Europe	Oceania
2000	0.39	0.00	0.17	0.04	0.18	0.00
2005	0.52	0.00	0.17	0.07	0.28	0.00
2010	0.61	0.00	0.17	0.08	0.36	0.00
2011	0.63	0.00	0.15	0.09	0.38	0.00
2012	0.64	0.00	0.16	0.09	0.40	0.00

(IEA 2015)

Table 39: Production of waste in top 10 countries	
Country	Waste production (in EJ)
USA	0.44
Germany	0.28
China	0.20
Russian Federation	0.18
Belgium	0.12
South Korea	0.13
France	0.11
Japan	0.10
Italy	0.02
Switzerland	0.06
Total (Top 10)	1.61
EU 28	0.95
World	2.18

(IEA 2015)

CHAPTER 3: BIOMASS TO ELECTRICITY

1. 439 TWh of electricity was generated from biomass sources in the year 2012
2. In 2012, Europe contribution to bioelectricity from CHP plants was at 64%.

439 TWh of electricity was generated from biomass sources in the year 2012 (Table 40). The biomass sources were predominantly solid biomass (forest and agricultural products and residues) followed by biogas, municipal wastes and biofuels.

Table 40: Global production of electricity from biomass (in TWh)

	World	Africa	Americas	Asia	Europe	Oceania
2000	170	1.26	93.9	22.2	51.2	1.72
2005	237	1.49	103	38.8	89.4	4.33
2010	381	1.82	131	95.8	149	3.38
2011	409	1.79	135	110	159	2.73
2012	439	1.77	141	117	176	2.97

(IEA 2015)

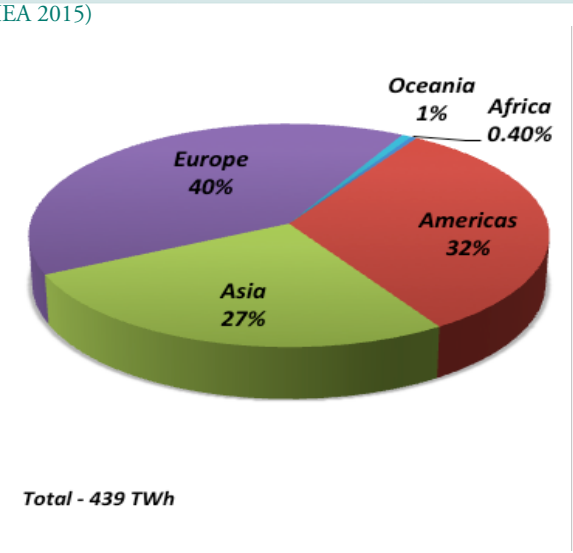

Figure 5 Electricity generation from biomass in 2012

The production of electricity from biomass can be classified as via electricity only plants or cogeneration units (Combined heat and power plants). Out of 56.2 EJ of biomass supply, 10% was used for electricity generation in 2012 (Table 41). This increased from 5% in 2000.

Table 41: Global overview of electricity generation from biomass

	Total PES (in EJ)	% PES to electricity	Biomass used for electricity (in EJ)		
			Total	Electricity only	CHP
2000	43.1	5.07%	2.18	1.13	1.06
2005	47.2	6.63%	3.13	1.77	1.37
2010	53.9	8.63%	4.66	2.89	1.76
2011	55.0	9.18%	5.05	3.20	1.85
2012	56.2	9.99%	5.62	3.42	2.20

(IEA 2015)

Europe uses most of its biomass for electricity production (33.7%) while Africa uses the least (Table 42).

Table 42: Continental overview of electricity generation from biomass

	Total PES (in EJ)	% PES to electricity	Biomass used for electricity (in EJ)		
			Total	Electricity only	CHP
Africa	14.7	0.27%	0.04	0.04	-
Americas	9.73	17.4%	1.70	0.94	0.75
Asia	25.0	6.68%	1.67	1.65	0.02
Europe	6.46	33.7%	2.18	0.77	1.40
Oceania	0.26	13.3%	0.03	0.01	0.03
World	56.2	9.99%	5.62	3.42	2.20

(IEA 2015)

3.1 Electricity only plants

Asia produces most of its bioelectricity via electricity only plants (Table 43). In Asia, China, India and Japan make up 3 of the top 5 countries producing bioelectricity in electricity only plants (Table 44).

Table 43: Electricity generation from biomass in electricity only plants (in TWh)

	World	Africa	Americas	Asia	Europe	Oceania
2000	100	2.10	50.8	21.7	25.4	0.07
2005	157	2.62	64.7	43.3	44.6	1.69
2010	257	3.53	73.2	118	61.5	1.29
2011	284	3.56	76.4	137	65.9	1.30
2012	304	3.49	83.9	147	68.7	0.86

(IEA 2015). A conversion efficiency of 32% is used for electricity only plants.

Table 44: Electricity generation from biomass in electricity only plants in top 5 countries (in TWh)

Country	Electricity generation in 2000	Electricity generation in 2012
China	3.10	57.2
USA	6.54	52.8
India	3.17	42.7
Japan	11.0	27.3
Germany	3.51	18.7
Total (Top 5)	27	199
World	100	304

(IEA 2015) A conversion efficiency of 32% is used for electricity only plants.

3.2 CHP plants

Europe is the world leader in combined heat and power generation where the total efficiency of conversion from biomass to energy is higher than electricity alone or heat alone plants. In 2012, Europe contribution to bioelectricity from CHP plants was at 64% (Table 45). Since 2000, apart from USA, the rest of the top 5 countries have increased the production of bioelectricity (Table 46).

Table 45: Electricity generation from biomass in CHP plants (in TWh)						
	World	Africa	Americas	Asia	Europe	Oceania
2000	67.6	-	37.1	0.07	28.2	2.21
2005	87.4	-	36.5	0.30	46.2	4.42
2010	113	-	37.3	0.76	72.9	1.45
2011	118	-	38.5	1.17	77.5	1.10
2012	141	-	48.0	1.29	89.7	1.62

(IEA 2015) A electrical conversion efficiency of 23% is used for CHP plants

Table 46: Electricity generation from CHP plants in top 5 countries (in TWh)		
Country	Electricity generation in 2000	Electricity generation in 2012
USA	31.9	21.0
Germany	1.5	19.1
Brazil	4.2	16.7
Sweden	5.6	11.7
Finland	4.26	6.99
Total (Top 5)	47.4	75.5
World	67.6	141

(IEA 2015) A electrical conversion efficiency of 23% is used for CHP plants

CHAPTER 4: BIOMASS TO HEAT

1. Africa and Asia have high dependence on biomass sources for direct heat.
2. The use of biomass for producing heat in heat only and CHP plants has more than doubled in the last 12 years.

The use of biomass for heating has increased rapidly as it is a sustainable alternative to the use of fossil fuels. In the global production of heat, Asia and Africa have high dependence on traditional biomass sources (Table 47).

Table 47: Global production of heat from biomass (in EJ)

	World	Africa	Americas	Asia	Europe	Oceania
2000	38.3	9.10	5.35	21.0	2.68	0.22
2005	40.5	10.2	5.62	21.6	2.95	0.18
2010	43.7	11.6	5.80	22.4	3.69	0.17
2011	44.2	12.0	5.80	22.6	3.68	0.17
2012	44.7	12.3	5.63	22.7	3.81	0.21

(IEA 2015)

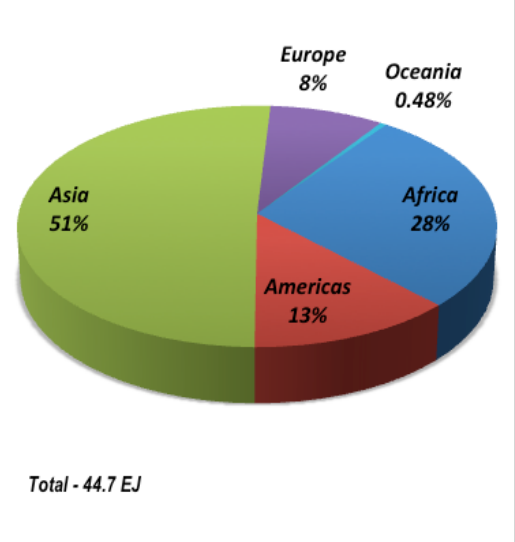

Figure 6 Global production of heat from biomass in 2012

The conversion of biomass to heat occurs in CHP plants, heat only plants and the direct use of biomass in end-use sectors. Most of the biomass is utilized in the end sectors without undergoing transformation in the energy industry. In 2012, 44 EJ of biomass was consumed in the end-use sectors and 2.67 EJ of biomass was used in the energy industry to produce 44.7 EJ of heat (Table 48). The conversion of biomass in end sector is not considered.

Table 48: Global overview of heat production from biomass (in EJ)

	Total heat production	Consumption of biomass for heat		
		CHP plants	Heat only plants	Direct heat
2000	38.3	1.06	0.24	38.0
2005	40.5	1.37	0.31	40.1
2010	43.7	1.76	0.45	43.0
2011	44.2	1.85	0.45	43.6
2012	44.7	2.20	0.47	44.0

(IEA, WBA 2015)

Consumption of biomass in Africa is predominantly at the end-use sectors – mostly in residential sector (Table 49).

Table 49: Continental overview of heat production from biomass (in EJ)				
	Total heat production	Consumption of biomass for heat		
		CHP plants	Heat only plants	Direct heat
Africa	12.3	-	-	12.3
Americas	5.63	0.75	0.00	5.59
Asia	22.7	0.02	0.09	22.7
Europe	3.81	1.40	0.38	3.21
Oceania	0.21	0.03	0.00	0.21
World	44.7	2.20	0.47	44.0

(IEA, WBA 2015)

4.1 Derived heat

In 2012, 860 PJ of heat was generated in the energy transformation sector (derived heat). 86% of the heat was in Europe.

Table 50: Global production of derived heat from biomass (in PJ)						
	World	Africa	Americas	Asia	Europe	Oceania
2000	416	-	29.1	15.7	371	-
2005	531	-	18.7	20.2	492	-
2010	770	-	46.2	54.3	670	-
2011	773	-	44.6	61.0	667	-
2012	860	-	46.7	74.1	739	-

(IEA, WBA 2015)

European countries produce the most derived heat from biomass. Sweden leads the way with 142 PJ of bio heat produced in year 2012 (Table 51). Derived heat production from biomass more than doubled in many European countries.

Table 51: Production of derived heat from biomass in top 5 countries in 2012 (in PJ)		
Country	Derived heat production in 2012 (in PJ)	% change since 2000
Sweden	142	57.3%
Russia	114	2.21%
Germany	89.9	364%
Finland	75.8	112%
Denmark	65.6	111%
Total (Top 5)	488	
World	860	

(IEA, WBA 2015)

4.2 Direct heat

The majority of biomass used globally is for the purpose of direct heating – cooking, room heating etc. Although the developed countries use the most biomass in heat plants for energy generation, Asia and Africa use the most biomass for direct heating. This can be in terms of fuel wood, charcoal, and other forms of traditional biomass. Asia uses close to 50% (~ 23.6 EJ) of all biomass used for direct heating (Table 52). China and India are top biomass users for direct heat (Table 53).

Table 52: Global production of direct heat from biomass (in EJ)						
	World	Africa	Americas	Asia	Europe	Oceania
2000	38.0	9.1	5.32	21.0	2.36	0.22
2005	40.1	10.2	5.61	21.6	2.55	0.18
2010	43.0	11.6	5.76	22.4	3.15	0.17
2011	43.6	12.0	5.77	22.5	3.13	0.17
2012	44.0	12.3	5.59	22.7	3.21	0.21

(IEA, WBA 2015)

Table 53: Production of direct heat from biomass in top 5 countries in 2012 (in EJ)		
Country	Derived heat production in 2012 (in PJ)	% change since 2000
China	8.34	-1.58%
India	7.26	17.1%
Nigeria	4.16	48.2%
USA	2.78	27.3%
Brazil	2.37	61.7%
Total (Top 5)	24.9	
World	44.0	

(IEA, WBA 2015)

4.3 District heating

There is a lack of statistics on the global use of biomass for district heating networks. According to district heating statistics in general, Russia has the largest DH network, though most of it is via the use of fossil gas. Among the top 10 countries with large district heating sales, EU countries use of district heat is via recycled heat (Table 54).

Table 54: Overview of district heating statistics for top 10 countries					
Country	Total DH sales (2011, TJ)	Average DH price (Euro/GJ)	Recycled	Direct renewables	Others
Russia	6 891	-	-	-	-
China	2 810	-	-	-	-
USA	355	13.85 steam /8.64 water	-	-	-
Germany	280	20.28	90%	0%	10%
Poland	235	10.73	70%	1%	29%
Korea	187	12.20	-	-	-
Sweden	183	20.63	70%	23%	7%
Finland	112	14.80	77%	6%	17%
Denmark	102	27.80	70%	19%	11%
Czech Republic	88.2	19.10	68%	2%	30%

(Euroheat and power 2013)

CHAPTER 5: BIOMASS TO BIOFUELS

1. In 2012, 79% of all the biofuels produced globally were produced in Americas – predominantly in USA and Brazil.
2. In 2012, the protein production associated with conventional biofuels delivered 67 million tonnes. In comparison, 81.6 million tonnes of biofuels were co produced.

Biofuels for transport are part of important strategy to improve fuel security, mitigate climate change and support rural development. In 2012, Americas were the largest producers of liquid biofuels – bioethanol, biodiesel and other liquid biofuels (Table 55). 73% of all the biofuel produced globally is produced in Americas – predominantly in USA and Brazil. In the year 2012, 82.3 billion litres was produced in Americas which is a 4.8 times increase since 2000. However, the highest increase in biofuel production was in Europe with a 23 times increase during 2000 – 2012. Africa and Oceania have negligible biofuels production.

Table 55: Global production of liquid biofuels (in billion litres)

	World	Africa	Americas	Asia	Europe	Oceania
2000	18.0	-	16.9	0.14	0.95	-
2005	37.0	-	32.2	0.29	4.47	0.04
2010	103	0.01	82.9	2.49	16.65	0.52
2011	104	0.01	83.8	4.08	15.01	0.62
2012	105	0.01	82.3	5.28	16.39	0.60

(IEA, WBA 2015) An average biofuel energy content of 29.3 MJ/l and density of 0.84 kg/l is used.

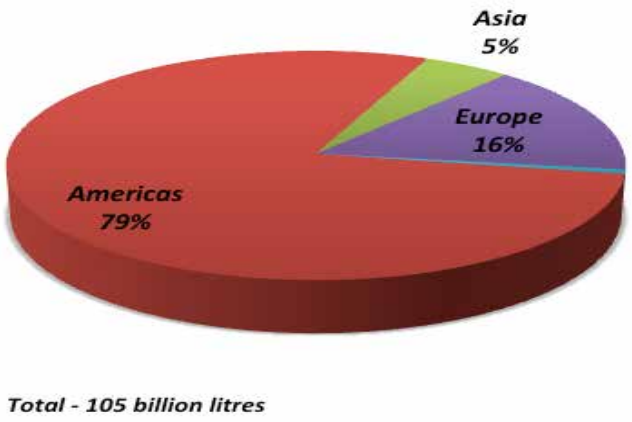

Figure 7 Global liquid biofuels production in 2012

In 2012, 5.11 EJ of biomass was used for liquid biofuels production which is 9% of all biomass supply.

Table 56: Global overview of liquid biofuel production

	Total PES (in EJ)	Biofuels		Bioethanol		Biodiesel		Other biofuels	
		Billion litres	PJ	Billion litres	PJ	Billion litres	PJ	Billion litres	PJ
2000	0.88	18.0	527	13.2	387	0.84	29.5	3.92	115
2005	1.81	37.0	1 084	25.5	748	3.40	120	8.09	237
2010	5.01	103	3 005	65.3	1 914	19.8	695	19.7	577
2011	5.06	104	3 034	69.0	2 022	23.0	810	13.8	403
2012	5.11	105	3 064	68.2	1 997	24.9	877	13.8	403

(IEA, WBA 2015)To calculate TPES, an average conversion efficiency of 60% is used.

Table 57: Continental overview of liquid biofuel production in 2012									
	Total PES (in EJ)	Biofuels		Bioethanol		Biodiesel		Other biofuels	
		Billion litres	PJ	Billion litres	PJ	Billion litres	PJ	Billion litres	PJ
Africa	0.00	0.01	0.33	0.01	0.27	-	-	-	-
Americas	4.02	82.3	2 411	60.4	1 413	8.88	313	13.0	10.9
Asia	0.26	5.28	155	1.16	27	4.06	143	0.06	0.05
Europe	0.80	16.4	480	3.99	93	11.7	413	0.68	0.57
Oceania	0.03	0.60	17.6	0.51	12	0.09	3.12	-	-
World	5.11	105	3 064	66.1	1 546	24.8	872	13.8	11.6

(IEA, WBA 2015)

5.1 Bioethanol

Raw materials for production of bioethanol include sugarcane, sugar beet, sweet sorghum, cassava, or cereals etc. In 2012, 66.1 billion litres of bioethanol were produced – predominantly from corn in USA and sugarcane in Brazil (Table 58, Table 59). During 2000 - 2012, there has been a 5 times increase in the bioethanol output.

Table 58: Bioethanol production (in billion litres)						
	World	Africa	Americas	Asia	Europe	Oceania
2000	13.2	-	13.0	0.1	0.1	-
2005	25.5	-	24.3	0.3	0.9	0.0
2010	63.3	0.0	58.5	0.5	3.8	0.4
2011	66.9	0.0	62.0	1.0	3.4	0.5
2012	66.1	0.0	60.4	1.16	4.0	0.5

(IEA, WBA 2015). An average energy content of 23.4 MJ/l and density of 0.79 kg/l is used for bioethanol.

Table 59: Bioethanol production in top 6 countries in 2012		
Country	Ethanol production	
	Billion litres	PJ
United States	50.3	1 177
Brazil	25.5	597
China	2.0	47
Canada	1.8	42
France	1.0	23
Thailand	1.0	23
Total (Top 6)	81.6	
World	87.2	2 040

(REN21 2014)

5.2 Biodiesel

Biodiesel is produced from vegetable oils extracted from seeds or fruit kernels of canola, soybean, oil palm, jatropha, and sunflower etc. Oil rich and fatty wastes from kitchen oil are also an important source. In 2012, 24.9 billion litres of biodiesel were produced globally. Europe accounted for almost half of the production (Table 60)

Table 60: Biodiesel production (in billion litres)						
	World	Africa	Americas	Asia	Europe	Oceania
2000	0.84	-	0.02	-	0.81	-
2005	3.40	-	0.36	0.01	3.02	-
2010	19.8	-	6.16	2.00	11.4	0.07
2011	23.0	-	8.80	3.01	11.0	0.10
2012	24.9	-	8.88	4.06	11.7	0.09

(IEA, WBA 2015). An average energy content of 35.2 MJ/l and density of 0.88 kg/l for biodiesel is used.

Table 61: Biodiesel production in top 6 countries in 2012		
Country	Biodiesel production	
	Billion litres	PJ
United States	4.8	169
Germany	3.1	109
Brazil	2.9	102
Argentina	2.3	81.0
Indonesia	2.0	70.4
France	2.0	70.4
Total (Top 6)	17.1	
World	26.3	926

(REN21 2014)

5.3 Other liquid biofuels

Apart from bioethanol and biodiesel, biomass can be converted to other liquid fuels. All those biofuels that are not classified into bioethanol and biodiesel (for example: advanced biofuels, butanol, green diesel, vegetable oils) are classified in this category. Majority of these biofuels are produced in Americas (Table 62). These contribute 13% of the total biofuels production.

Table 62: Other liquid biofuels production (in billion litres)						
	World	Africa	Americas	Asia	Europe	Oceania
2000	3.92	-	3.90	-	0.02	-
2005	8.09	-	7.52	0.00	0.56	-
2010	19.7	-	18.3	0.00	1.44	-
2011	13.8	-	13.0	0.09	0.63	-
2012	13.8	-	13.0	0.06	0.68	-

(IEA 2015). An average energy content of 29.3 MJ/l and density of 0.84 kg/l was used for other liquid biofuels

5.4 Biofuels: Land use and protein production

Conventional biofuel production not only delivers ethanol and biodiesel but also protein feed, with the quantities of these both being produced on a similar scale. In 2012, the protein production associated with conventional biofuels based on corn, cereals, canola and soybeans delivered 67 million tonnes (Table 64). In comparison, 81.6 million tonnes of biofuels were co produced. Hence, conventional biofuel production chains are a vital part of both global fuel and protein supplies. Also, 28 Mha of land was used for biofuel production – a small fraction of the additional land available by grains in yields.

Table 63: Global production of biofuels and feedstock use		
Biofuel	**Feedstock**	**Biofuel production (in billion litres)**
Bioethanol	Wheat	2.48
	Corn	56.7
	Sugarcane	19.8
	Sugarbeet	1.41
	Others	1.51
Biodiesel	Rapeseed	6.45
	Soybean	9.13
	Oil palm	4.99
	Others	4.34

(OECD FAO 2014)

Table 64: Land needed, protein and biofuel production in 2012			
Feedstock	**Land needed (in Mha)**	**Protein production (in Mt)**	**Biofuel production (in Mt)**
Wheat	1.68	2.04	1.96
Corn	18.8	41.0	44.8
Sugarcane	3.76	-	15.6
Sugarbeet	0.22	-	1.11
Rapeseed	5.99	4.12	5.68
Soybean	17.7	20.0	8.03
Oil palm	1.20	-	4.39
Total	49.4	67.1	81.6

(OECD FAO WBA 2014)

CHAPTER 6: SPECIAL SECTORS

1. Europe is currently the largest biogas producer in the world (42.2% of global production).
2. In the year 2013, Americas and Europe accounted for production of 97% of the global production of pellets.
3. 60% of global charcoal production is in Africa and the top 10 countries producing charcoal are either in Africa or Asia

6.1 Biogas

Biogas is a gas produced by anaerobic fermentation of different forms of organic matter and is composed mainly of methane (CH¬4) and carbon dioxide (CO2). Typical feedstock for biogas production includes manure, sewage, crop residues and organic wastes from municipal and industrial sources.
In the year 2012, 1 212 PJ of biogas was produced in the world (Table 65), which is an estimated 56.1 billion m^3 of biogas. It is important in replacing other energy sources including charcoal, fuelwood, petroleum gas, oil etc. in cooking and transportation sector. In Africa, biogas is a sustainable alternative for replacing the use of fuelwood and charcoal, thereby reducing deforestation. In the recent years, the production of biogas in Africa is visible. Europe is currently the largest biogas producer in the world.

Table 65: Production of biogas (in PJ)

	World	Africa	Americas	Asia	Europe	Oceania
2000	285	-	132	50.5	95.1	7.11
2005	500	-	169	150	171	9.94
2010	939	0.08	236	325	362	15.7
2011	1 100	0.12	247	397	439	16.5
2012	1 212	0.30	282	398	511	20.2

(IEA, WBA 2015) An average energy content of 21.6 MJ/Nm3 is used.

Germany is the world leader in the installation and production of biogas. There are currently more than 10 000 biogas plants in operation in Germany with a combined electricity and heat production of 148 PJ (Table 66).

Table 66: Production of biogas in top 5 countries

	Biogas production		Energy production (in PJ)	Plants (-)	Year
	in PJ	in billion m^3			
Germany	291	13.5	148	10 020	2013/14
UK	68.3	3.16	23.9	634	2013
The Netherlands	11.2	0.52	0.89	252	2012
Korea	9.28	0.43	9.28	82	2013
Brazil	6.31	0.29	2.21	25	2013

(IEA Bioenergy 2014)

Biogas is predominantly used for generation of electricity followed by heat (Table 67). Recently, bio methane (upgraded biogas to increase methane content) is being used in the transportation sector.

Table 67: Utilization of biogas in top 5 countries (in %)

	Electricity	Heat	Transport	Others
Germany	68.0%	31.1%	0.8%	0.0%
UK	-	-	-	-
The Netherlands	34.7%	63.0%	0.0%	2.3%
Korea	58.8%	24.0%	1.0%	16.2%
Brazil	-	-	-	-

(IEA Bioenergy 2014)

Pellets

Pellets are one of the fastest growing energy commodities in the world. They are a solid biomass fuel produced predominantly from wood residues, but also from agricultural wastes such as straw. The high energy content of the fuel, standardized properties and the ease of storage and transportation are driving the demand for pellets. They are a sustainable alternative to replace the dependence of the residential heat market on fossil fuels. Pellets are also being used in large power plants to produce heat and electricity.

Pellets production

The production of pellets has picked up pace in the recent years. In the year 2014, 27 million tonnes of pellets were produced. In the year 2013, Americas and Europe accounted for production of 97% of the global production of pellets.

Table 68: Global production of pellets (in million tonnes)

	World	Africa	Americas	Asia	Europe	Oceania
2012	19.5	0.09	6.71	0.30	12.4	0.00
2013	22.1	0.10	7.62	0.62	13.8	0.00
2014	27.0	-	-	-	-	-

(FAO 2015) (Gauthier 2015)

USA is the world leader in pellet production. In 2013, the production was at 5.7 million tonnes, which is more than a quarter of the global production. The top 10 producers accounted for 73% of global production.

Table 69: Pellet production in top 10 countries in 2013 (in million tonnes)

Country	Production
USA	5.70
Germany	2.21
Canada	1.80
Sweden	1.31
Latvia	1.09
Austria	0.96
Portugal	0.90
France	0.89
Russian Federation	0.81
Poland	0.60
Total (Top 10)	16.3
World	22.1

(FAO 2015)

In 2012, there were 749 pellet-producing plants globally (Table 70). The combined capacity of all these plants was 48.4 million tonnes (4 million tonnes under planning and 1 million tonnes under construction). In terms of individual capacity, the Vyborskay Cellulose plant in Russia is the world's largest pellet producing plant. However, the production volume for the Russian plant was well under capacity the last time information was available.

Table 70: Overview of pellet production plants

	World	Africa	Americas	Asia	Europe	Oceania
Number of plants (-)	749	4.00	189	118	433	5.00
Production capacity (Mt)	48.4	0.19	20.0	5.88	22.0	0.33
Average capacity per plant (in 1000 t)	64.6	47.5	105.7	49.9	50.9	65.6

(Bioenergy International 2014).

Table 71: Major pellet producing plants globally (capacity in 1000 tonnes, 2013)		
Company	**Country**	**Capacity**
Vyborskay Cellulose, Leningrad Region, pos. Sovetsky	Russia	900
Georgia Biomass (RWE), Waycross GA	USA	750
German Pellets Texas, Woodville, TX	USA	578
Protocal Biomass, Marathon	Canada	500
Enviva Pellets Northampton (Envivia LP) Garysburg	USA	500

(Bioenergy International 2014)

Pellet consumption

Europe is the world's largest consumer of pellets. 74% of the global consumption of pellets occurs in European countries with UK, Denmark and Italy being the top consumers (Table 72, Table 73).

Table 72: Consumption of pellets (in million tonnes)						
	World	**Africa**	**Americas**	**Asia**	**Europe**	**Oceania**
2012	18.5	-	3.56	0.42	14.5	0.00
2013	21.7	0.04	3.26	0.89	17.5	0.00
2014	27.0	-	-	-	20.0	-

(FAO 2015) (Gauthier 2015)

Table 73: Wood pellet consumption in top 10 countries in 2013 (in million tonnes)	
Country	**Consumption**
United Kingdom	3.63
USA	2.97
Denmark	2.24
Italy	2.04
Germany	2.03
Sweden	1.86
Belgium	0.89
Austria	0.86
France	0.83
Netherlands	0.68
Total (Top 10)	18.0
World	21.7

(FAO 2015)

Pellets trade

Europe is a major player in the import and export of pellets. During 2012 – 13, the import of pellets has increased by 3 million tonnes, while exports increased by 1.3 million tonnes (Table 74, Table 75). The major inter continental trade occurs between USA, Canada and Europe. The decrease in demand for fibre wood in USA due to decreased demand for paper has opened up large volumes of raw material for pellets. European climate policy that incentivizes renewable energy use is another factor. In the near future, Russia and China could become a major supplier of pellets to the European and Asian markets.

Table 74: Import and export of pellets (in million tonnes)										
	Africa		Americas		Asia		Europe		Oceania	
	Import	Export	Import	Export	Import	Export	Import	Export	Import	Export
2012	0.00	0.12	0.13	3.28	0.20	0.09	8.45	6.30	0.00	0.00
2013	0.01	0.06	0.18	4.54	0.58	0.30	11.4	7.68	0.00	0.00

(FAO 2015)

Table 75: Top 10 pellet exporting countries in 2013 (in million tonnes)		
Country	Exports	Imports
United States of America	2.88	0.15
Canada	1.64	0.02
Latvia	1.06	0.04
Portugal	0.78	0.03
Russian Federation	0.74	0.00
Germany	0.72	0.55
Estonia	0.62	0.07
Austria	0.48	0.39
Romania	0.46	0.01
Belgium	0.39	0.90
Total (Top 10)	9.78	2.15
World	12.6	12.2

(FAO 2015)

6.3 Charcoal

Charcoal is a black product, which is obtained by heating wood in the absence of oxygen to eliminate water and other volatile matter. One of the major uses for charcoal is in the metallurgy industry, e.g. in Brazil. It is also used in large quantities as cooking fuel in developing countries. However, the inefficient use of wood for producing charcoal is one of the major causes of deforestation. Charcoal is usually traded locally or in some cases, illegally which creates challenge in collecting accurate data on the actual production and use. During 2000 – 13, the global production of charcoal has increased by 29% to 51.9 million tonnes (Table 76). 60% of the production is in Africa and the top 10 countries producing charcoal are either in Africa or Asia. Brazil is the world's largest producer of charcoal with production at 6.26 million tonnes in 2013 (Table 77).

Table 76: Global production of charcoal (in million tonnes)						
	World	Africa	Americas	Asia	Europe	Oceania
2000	37.0	20.4	9.67	6.58	0.30	0.04
2005	46.2	24.5	13.2	8.01	0.51	0.03
2010	49.5	29.5	10.8	8.61	0.51	0.04
2011	51.1	30.2	11.5	8.84	0.44	0.04
2012	51.9	30.9	11.6	8.90	0.46	0.05

(FAO 2015)

Table 77: Charcoal production in top 10 countries in 2013 (in million tonnes)		
Country	Production in 2013	% change since 2000
Brazil	6.26	-1.4%
Nigeria	4.19	35.9%
Ethiopia	4.02	38.2%
India	2.88	73.4%
Democratic Republic of the Congo	2.24	56.7%
Ghana	1.77	70.5%
United Republic of Tanzania	1.76	51.3%
China, mainland	1.68	-5.5%
Thailand	1.41	17.4%
Egypt	1.40	16.4%
Total (Top 10)	27.62	
World	51.9	

(FAO 2015)

Charcoal is a major energy source for rural communities in many countries. However, the unsustainable production and use of charcoal has to be changed. This can be in terms of improving the conversion efficiency, use of improved cookstoves and/or replacing charcoal with other renewable alternatives like biogas and renewable electricity.

According to Table 21, charcoal as biomass source contributed 3.94 EJ of primary energy globally. This translates to 131 million tonnes (Energy content of 30 MJ/kg) while the actual production quantities estimated according to Table 76 is 51.9 million tonnes. According to WBA calculations, Kenya alone produced 5 million tonnes of charcoal in 2013.

WBA sees an urgent need to better understand the role of charcoal, especially in Africa and Latin America and its contribution to the energy system and its impact on use of forest. The first step is to gather accurate and updated statistics on charcoal production and use.

6.4 Traditional biomass

Traditional biomass use refers to the use of wood, charcoal, agricultural residues and animal dung for cooking and heating in the residential sector. The efficiencies are usually low, about 10 – 20% and the supply is often unsustainable. Most of it is traded informally and non-commercially. This hinders accurate data collection and estimation on the actual production and use of traditional biomass. The use of traditional biomass in 2010 (updated statistics were not available) was 31.7 EJ, which is 9.6% of the global energy consumption. In terms of population, more than 800 million people are dependent on traditional biomass for cooking and heating.

Table 78: Use of traditional biomass in 2010 (in PJ)						
	World	Africa	Americas	Asia	Europe	Oceania
Traditional biomass use	31 664	10 788	1 122	19 029	411	166
Share in final energy (%)	9.60%	53.0%	1.30%	14.0%	0.60%	4.30%

(SE4All 2011)

Traditional biomass accounts for more than 80% of the final energy use for many African countries (Table 79). For example, traditional biomass share in final energy for Ethiopia is 92.7% (1.2 EJ). Almost all the energy use in sectors including residential, commercial, industrial, transport etc. is via the use of traditional biomass.

Table 79: Use of traditional biomass in top 10 countries in 2010			
Country	Share in final energy (%)	Traditional bio-mass use (in PJ)	Use per capita (GJ per capita)
Burundi	95.7	80.4	7.91
Ethiopia	92.7	1 214	12.9
Liberia	92.5	68.5	16.0
Chad	91.1	74.7	5.81
Guinea	87.3	100	8.47
Rwanda	86.8	44.3	3.76
Uganda	85.5	333	8.87
Mali	85.4	52.9	3.46
Nepal	84.3	357	12.9
Burkina Faso	84.1	105	6.21
Total (Top 10)		2 431	
World		31 664	4.50

(SE4All 2011) *Order based on share of traditional biomass in final energy

CHAPTER 7: BIOENERGY DEVELOPMENTS

1. Canada was one of the earliest countries to experiment with fast pyrolysis bio oil production.
2. Over 50 companies are developing torrefaction technologies – predominantly in North America and Europe
3. The production capacity of all advanced biofuels plants stood at 4.5 billion litres by end of 2012

7.1 Pyrolysis oil

Pyrolysis oil – also referred to as biocrude or bio-oil – is a synthetic fuel produced from woody or other biomass via fast pyrolysis. It is an alternative green fuel which can be used for heating and/or in transportation as a substitute for petroleum.

Current market status

Canada was one of the earliest countries to experiment with fast pyrolysis bio oil production. Dynamotive had couple of plants in Ontario which had a combined capacity of more than 200 tonnes per day. Currently, the plants are non-operational. Recently, Finland has taken initiative with Fortum commissioning a pyrolysis oil plant in Joensuu, Finland. The oil is used within the plant as well as to fuel a nearby CHP unit. In Canada, Ensyn upgraded their plant in Ontario to full capacity. They recently announced two bio-oil supply contracts to hospitals in USA for supply of 550 000 gallons of pyrolysis oil per year. Finally, the Empyro project (the Netherlands) is nearing completion with a full capacity of 20 million litres per year.

Table 80: Commercial pyrolysis plants

Plant	Location	Production capacity (million litres)*	Feedstock	Operational since
Fortum Joensuu	Joensuu, Finland	41.7	Forest residues, sawdust etc.	2013
Ensyn Renfrew	Ontario, Canada	11.3	-	2006
Empyro	Hengelo, The Netherlands	20	Residual wood	2014

*Conversion factors used (Density - 1.2 kg/l)

7.2 Torrefied biomass

Torrefaction is the thermal treatment of various woody and agricultural residue feedstock. Biomass is heated to 250 – 300 °C and at atmospheric pressures. The biomass decomposes to a solid, dry material referred to as torrefied biomass or biocoal. The properties are similar to coal with the added advantage of being a renewable fuel. Other advantages include: homogenous product, durability, hydrophobic nature etc. Reports suggest that over 50 companies are developing torrefaction technologies – predominantly in North America and Europe. Table 81 provides an overview of the various commercial plants.

Table 81: Commercial torrefaction plants

Developer	Location	Capacity (tonnes/year)	Remarks
Stramproy Green	Steenwijk, the Netherlands	90 000	Declared bankrupt
Renogen/4EnergyInvest	Amel, Belgium	42 000	
Topell Energy	Duiven, the Netherlands	60 000	Filed for bankruptcy
Solvay Biomass Energy/ New Biomass Energy	Quitman, USA	80 000	Expansion to 250 000 tpa
Thermya	Urnieta, Spain	20 000	Company bought by Areva
	Mazingarbe, France	20 000	
Integro Earth Fuels	Greenville, USA	11 000	
River Basin Energy	Wyoming, USA	48 000	Pilot stage
Torr Coal	Dilsen Stokkem, Belgium	35 000	
BioEndev	Holmsund, Sweden	16 000	To be completed in 2015
Bio Energy Development North AB/Metso	Övik, Sweden	30 000	

Commercial and operational plants with a capacity above 10 000 tonnes per annum.

7.3 Advanced biofuels

Advanced biofuels – generally referred to as 2nd or 3rd generation biofuels – represent an important step forward as the world advances towards a sustainable bio – economy. These fuels are produced from a broad spectrum of predominantly non-edible biomass feedstock. These include lignocellulose based ethanol, methanol, dimethyl ether – DME, bioSNG, synthetic diesel, hydrogenated vegetable oil – HVO, algae based biofuels and biogas. Advanced biofuels open up a diverse range of biomass sources available for biofuel production. Some of these biofuels provide the benefit of complete compatibility with existing fossil fuels transport infrastructures, which will increase the efficiency of transporting to commercial markets.

While commercial-scale production of advanced biofuels has been limited compared to conventional biofuels, several facilities have begun operation in the past decade. Neste Oil started producing renewable diesel in Finland since 2007 while Beta Renewables plant in Italy started production of ethanol from cellulosic feedstock in October 2013 (Neste Oil 2015, Beta Renewables 2015). The production capacity of all advanced biofuels plants stood at 4.5 billion litres by end of 2012 (IEA 2013). However, due to uncertainty in biofuel and fossil oil markets, and in policy domains, a number of large scale facilities are reportedly idle at the current time.

Table 82: Advanced biofuel plants

Company	Location	Start of production	Capacity (million litres)	Capital costs ($ msillion)	Feedstock (1000 tons per year)	Feedstock
POET DSM	Emmetsburg, Iowa, US	Sep – 14	Ethanol, 95	275	285	Corn cobs, leaves, husk and stalk
Abengoa	Hugoton, Kansas, USA	Oct – 14	Ethanol, 95	500	365	Corn stover, wheat straw, milo stubble, switch grass
Göteborg Energi	Gothenburg, Sweden	Dec – 14	Biomethane, 20 MW	170	50	Wood pellets
GranBio	Sao Miguel dos Campos, Brazil	Sep – 14	Ethanol, 82	265	400	Sugarcane straw and bagasse
DuPont	Nevada, Iowa, USA	Dec – 14	Ethanol, 113	225	700	Corn stover
Enerkem	Edmonton, Canada	June – 14	Methanol, 38	75	100	Municipal waste
UPM	Lappeenranta, Finland	Dec – 14	Biodiesel, 120	210	Not disclosed	Tall oil
Quad county corn processors	Galva, Iowa, USA	Sep - 14	Bioethanol, 8 000 m3	8.5	-	Corn kernel fibre

CHAPTER 8: JOBS IN RENEWABLE ENERGY

1. Among renewable sources, biomass industry has the largest number of jobs (2.5 million jobs) – mostly in feedstock sector.

The growth of renewable energy technologies in the past couple of decades has led to numerous 'green jobs'. According to UNEP, green jobs are: '… work in agricultural, manufacturing, research and development (R&D), administrative, and service activities that contribute substantially to preserving or restoring environmental quality. Specifically, but not exclusively, this includes jobs that help to protect ecosystems and biodiversity; reduce energy, materials, and water consumption through high- efficiency strategies; de-carbonize the economy; and minimize or altogether avoid generation of all forms of waste and pollution'.

The renewables sector has employed millions in the design, installation, construction, operation and maintenance of renewable energy systems. However, the statistics on jobs in this sector are far from accurate due to various issues: data inconsistency, methodological issues etc. The annual review of their report 'Renewable Energy and Jobs', IRENA estimated that 6.5 million people are employed in the renewables sector (Table 83). Among renewable sources, bioenergy industry has the largest number of jobs – mostly in biomass feedstock sector. However, these statistics do not include data for large hydro or traditional biomass.

Table 83: Global employment figures in renewable energy in 2012 - 13

	World	Asia	Americas	Europe
Bioenergy	2 499	541	1 208	486
Geothermal	184	-	35	100
Small hydro	156	17	20	33
Solar	2 819	2 183	173	292
Wind	834	404	83	328
Total	6 492	3 145	1 519	1 238

(IRENA 2014)

Most of the employees in the bioenergy field were in the biofuels sector. The sugarcane dominated biofuels sector in Brazil itself is estimated to have 820 000 people.

Table 84: Employment figures in bioenergy sector in 2012 - 13 (in 1000's)

	World	Brazil	China	India	USA	EU
Solid biomass	753		266	58	152	274
Biofuels	1 379	804	24	35	217	109
Biogas	266		90	85	-	71
Bioenergy	2 398	804	380	178	369	454

(IRENA 2014)

CHAPTER 9: COUNTRY STATISTICS

1. Kenya used 76.1 million m3 of wood in 2014 – 70% of it for producing charcoal for cooking.
2. In 2014, 243 GWh of bioelectricity was generated in Malaysia from biogas, solid biomass and waste.
3. In Sudan, biomass is used for producing 45 GWh of electricity, 65 million litres of ethanol and 64 m3 of biogas.

One of the objectives of the WBA Global Bioenergy Statistics project is to improve the national statistics on production, transformation and consumption of biomass resources. The focus is on countries with high dependence on biomass and which lack accurate, reliable and updated data. As a case study, we compiled the available information on Kenya, Malaysia and Sudan. Contact was made with local representatives from each country to obtain updated statistics on biomass use. Initially, official statistics are presented followed by data obtained by WBA.

9.1 Kenya

Table 85: Primary energy supply of energy sources in Kenya (in TJ)

	Total	Coal	Oil	Natural gas	Nuclear	Renewables
2000	588 413	2 763	104 126	-	-	480 812
2005	677 927	3 726	100 902	-	-	573 299
2010	829 321	6 908	156 586	-	-	665 827
2011	849 041	9 881	155 330	-	-	683 872
2012	859 927	8 834	143 733	-	-	707 360

(IEA 2015)

Table 86: Total imports and exports of energy sources in Kenya in 2012 (in TJ)

	Total	Coal	Oil	Natural gas	Renewables
Imports	185 392	8 834	176 390	-	-
Exports	1 968	-	1 842	-	-

(IEA 2015)

Table 87: Overview of primary energy to final energy for all energy sources in Kenya in 2012 (in TJ)

	Primary energy	Final energy			
		Total	Electricity	Heat	Transportation
Fossils	152 567	119 249	6 037	46 390	66 821
Nuclear	-	-	-	-	-
Hydro	15 491	12 600	12 600	-	-
Biomass	634 258	419 020	926	418 094	-
Other renewables	57 610	4 733	4 733	-	-
Total	859 927	579 968	24 296	488 851	66 821

(IEA 2015)

Wood fuel statistics in Kenya

WBA made a study tour in Kenya and attended the Low carbon development in Africa workshop in June 2015. Wood fuel and charcoal statistics were collected during the tour. In Kenya, the use of fuel is divided as: Charcoal (40%), Fuelwood (40%) and other fuels including LPG, Kerosene etc. (20%). Based on certain assumptions (Table 108), wood consumption for production of charcoal and wood fuel was calculated as 45.7 million tonnes out of which 32.2 million tonnes of wood is used for producing 5.04 million tonnes of charcoal.

Table 88: Wood fuel consumption in Kenya		
Annual charcoal consumption	5.04	million tonnes
Annual wood fuel consumption for charcoal	32.2	million tonnes
Annual wood consumption	13.4	million tonnes
Total wood consumption	45.7	million tonnes
	76.1	million m^3

Table 89: Wood in the energy balance in Kenya			
Primary energy	GJ/tons	Quantity (million tonnes)	Energy (in PJ)
Wood for charcoal consumption	14.0	32.2	451
Wood for wood fuel consumption	14.0	13.4	188
Total wood consumption - primary energy			639
Final energy			
Charcoal consumption	30.0	5.04	151
Wood fuel consumption	13.4	13.4	180
Total wood consumption - final energy			332
Conversion losses from wood to charcoal			308
			51.9%

The WBA calculation on the use of wood for charcoal and cooking delivers 639 PJ of primary energy from biomass (Table 89), which is similar to IEA statistics of 634 PJ for biomass primary energy. Yet, there is a significant difference concerning final energy. WBA calculates the final energy use of wood to be 308 PJ while the use of biomass for 419 PJ. This might be due to higher conversion factors used for wood to charcoal conversion. According to WBA, Kenya uses 76.1 million m3 of wood in 2014. FAO reports that the use of woodfuel in 2013 to be 26.4 million m3. This is a significant gap. Finally, the inefficient charcoal production causes significant losses in energy. Kenya is an extreme low carbon society with emissions of 0.3 tons/capita in comparison to the global average of 4.5 tons/capita.
The calculations in this section are estimation and further research is required to obtain good data. The assumptions used have to be cross verified via field trials as for example: conversion of wood to charcoal data, use of wood fuel and charcoal efficiencies etc. It is important to analyse the consequences of wood removal from forestry and sustainable forestry management. A new carbon neutral pathway for use of wood and other biomass for cooking has to be developed.

Malaysia

Table 90: Primary energy supply of energy sources in Malaysia (in TJ)						
	Total	Coal	Oil	Natural gas	Nuclear	Renewables
2000	2 072 424	96 631	1 091 708	1 035 061	-	141 598
2005	2 787 027	288 387	1 210 697	1 333 956	-	147 208
2010	3 167 607	611 315	1 089 489	1 305 695	-	161 652
2011	3 312 010	652 387	1 163 805	1 325 080	-	169 440
2012	3 401 105	661 347	1 319 554	1 356 649	-	177 353

(IEA 2015)

Table 91: Total imports and exports of energy sources in Malaysia in 2012 (in TJ)					
	Total	Coal	Oil	Natural gas	Renewables
Imports	1 943 345	595 405	1 018 188	329 250	167
Exports	2 201 713	9 755	1 063 112	1 126 542	2 261

(IEA 2015)

Table 92: Overview of primary energy to final energy for all energy sources in Malaysia in 2012 (in TJ)					
	Primary energy	Final energy			
		Total	Electricity	Heat	Transportation
Fossils	3 337 549	1 477 217	364 742	504 384	608 091
Nuclear	-	-	-	-	-
Hydro	32 615	26 541	26 541	-	-
Biomass	144 570	80 801	2 424	73 562	4 815
Other renewables	167	138	138	-	-
Total	3 401 105	2 019 077	393 845	1 011 447	613 785

(IEA 2015)

Biomass statistics for Malaysia – WBA

WBA contacted government representatives and board members from Malaysia to obtain updated information on the use of biomass for energy. In 2014, 243 556 MWh of bioelectricity was generated from biogas, solid biomass and waste.

Table 93: Power generation from biomass in Malaysia (in MWh)						
	Biogas	Biogas (Landfill/ agri waste)	Biomass	Biomass (solid waste)	Total (in MWh)	Total (in TJ)
2012	98	7 465	101 310	3 235	112 108	403.6
2013	12 217	9 478	209 408	11 144	242 247	872.1
2014	18 522	27 703	192 984	4 348	243 556	876.8
2015	1 509	2 286	58 775	-	62 570	225.3

(SEDA Malaysia 2015)

Sudan

Table 94: Primary energy supply of energy sources in Sudan (in TJ)						
	Total	Coal	Oil	Natural gas	Nuclear	Renewables
2000	557 054	-	97 887	-	-	459 166
2005	627 141	-	149 092	-	-	480 938
2010	699 070	-	216 709	-	-	482 361
2011	698 526	-	206 786	-	-	491 740
2012	697 479	-	197 031	-	-	500 448

(IEA 2015)

Table 95: Total imports and exports of energy sources in Sudan in 2012 (in TJ)					
	Total	Coal	Oil	Natural gas	Renewables
Imports	48 358	-	171 366	-	-
Exports	57 192	-	18 673	-	-

(IEA 2015)

Table 96: Overview of primary energy to final energy for all energy sources in Sudan in 2012 (in TJ)					
	Primary energy	Final energy			
		Total	Electricity	Heat	Transportation
Fossils	197 031	170 160	8 256	41 491	120 412
Nuclear	-	-	-	-	-
Hydro	23 823	19 399	19 399	-	-
Biomass	476 625	282 693	-	282 693	-
Other renewables	-	-	-	-	-
Total	697 479	499 633	27 655	351 566	120 412

(IEA 2015)

Biomass statistics for Sudan – WBA

Country statistics from Sudan were obtained from WBA board member (Dr Hazir Farouk, Sudan University of Science and Technology). The highest production in quantity is for sorghum and sugarcane (Table 97). The average yields are the low in comparison to global averages except for sugarcane. The information gathered are not available in online sources.

Table 97: Crop production data for Sudan in 2014				
Crop	Area harvested (1000 ha)	Yield (t/ha)	Production (1000 tonnes)	Global average yield 2013 (t/ha)
Maize	26.9	1.60	43.00	5.50
Sorghum	7 137	0.63	4 524	1.48
Cassava	8.17	2.19	17.88	13.6
Sugarcane	69.8	97.4	6 798	70.9
Sunflower	63	0.96	60.0	1.75
Millet	1 488	0.24	360	0.90
Wheat	125	1.92	240	3.27

In terms of bioelectricity generation, Kenana Sugar mill uses biomass to produce approx. 45 GWh of bioelectricity. The same mill also produces ethanol from sugarcane with an annual capacity of 65 million litres. 90% of the ethanol produced is exported to European Union. The remaining ethanol is sold as E10 in petrol stations in Khartoum.

There are currently 15 biogas digesters (capacity of 3.6 m^3) installed in 2014 in rural area of North Kordofan for lighting and cooking applications. The feedstock is cow manure. Also, a 12 m^3 biogas unit has started operation at Sudan University, Agriculture faculty campus in Khartoum.

Table 98: Overview of energy system in Kenya, Malaysia, Sudan in 2012 (in TJ)											
	Primary energy	Final energy			Final energy transformation						
		Electric-ity only	CHP	Heat only	Total	Industry	Transport	Residential	Commercial	Others	Electricity
Kenya	859 927	71 720	-	-	579 968	43 208	66 821	439 447	3 601	2 596	24 296
Malaysia	3 401 105	766 101	-	-	2 019 077	597 917	613 785	192 551	176 892	44 087	393 845
Sudan	697 479	15 198	-	-	499 633	53 382	120 412	219 137	71 887	7 159	27 655

(IEA 2015)

Table 99: Overview of biomass supply and consumption in Kenya, Malaysia, Sudan in 2012 (in TJ)											
	Primary energy	Final energy			Final energy transformation						
		Electric-ity only	CHP	Heat only	Total	Industry	Transport	Residential	Commercial	Others	Electricity
Kenya	634 258	3 810	-	-	419 020	-	-	418 094	-	-	926
Malaysia	144 570	11 891	-	-	80 801	-	4 815	73 562	-	-	2 424
Sudan	476 625	-	-	-	282 693	30 647	-	194 519	57 527	-	-

(IEA 2015)

Table 100: Overview of crop area, production quantity and crop yields (in 2013)								
			Kenya		Malaysia		Sudan	
			2000	2013	2000	2013	2000	2013
Cereal crops	Maize/corn	Area (Mha)	1 500	2 028	27.0	9.8	-	-
		Yield (t/ha)	1.44	1.67	2.41	8.97	-	-
		Production (Mt)	2.16	3.39	0.07	0.09	-	-
	Rice, paddy	Area	13.9	30.4	699	688	-	-
		Yield	3.77	4.83	3.06	3.82	-	-
		Production	0.05	0.15	2.14	2.63	-	-
	Wheat	Area	132	131	-	-	-	-
		Yield	1.55	3.70	-	-	-	-
		Production	0.20	0.49	-	-	-	-
	Barley	Area	20.3	22.7	-	-	-	-
		Yield	2.22	3.41	-	-	-	-
		Production	0.05	0.08	-	-	-	-
	Millet	Area	93.2	88.0	-	-	-	-
		Yield	0.48	0.73	-	-	-	-
		Production	0.04	0.06	-	-	-	-
	Oats	Area	3.00	4.00	-	-	-	-
		Yield	1.17	1.00	-	-	-	-
		Production	0.00	0.00	-	-	-	-

			Kenya		Malaysia		Sudan	
			2000	2013	2000	2013	2000	2013
	Rye	Area	-	-	-	-	-	-
		Yield	-	-	-	-	-	-
		Production	-	-	-	-	-	-
	Sorghum	Area	122	189	-	-	-	-
		Yield	0.67	0.73	-	-	-	-
		Production	0.08	0.14	-	-	-	-
Oil crops	Olives	Area	-	-	-	-	-	-
		Yield	-	-	-	-	-	-
		Production	-	-	-	-	-	-
	Rapeseed	Area	-	-	-	-	-	-
		Yield	-	-	-	-	-	-
		Production	-	-	-	-	-	-
	Soybeans	Area	2.61	1.95	56 600	95 729	-	-
		Yield	0.91	1.54	-	-	-	-
		Production	0.00	0.00	-	-	-	-
	Sunflower	Area	13.0	14.0	-	-	5.46	106
		Yield	1.00	1.00	-	-	0.73	0.81
		Production	0.01	0.01	-	-	0.00	0.09
	Oil palm	Area	120	81.7	-	-	-	-
		Yield	308	455	-	-	-	-
		Production	0.18	0.21	-	-	-	-
Sugar crops	Cassava	Area	60.3	72.5	8.50	2.97	5.75	8.00
		Yield	6.95	15.35	14.1	27.6	1.74	2.19
		Production	0.42	1.11	-	-	0.01	0.02
	Sugar beet	Area	-	-	-	-	-	-
		Yield	-	-	-	-	-	-
		Production	-	-	-	-	-	-
	Sugar cane	Area	57.2	85.0	21.4	4.52	63.5	69.8
		Yield	68.86	69.41	51.45	47.35	78.41	97.39
		Production	3.94	5.90	1.10	0.21	4.98	6.80

(FAO 2015)

APPENDIX

A.1: Geographical classification

Africa: Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Cote d'Ivoire, Democratic Republic of the Congo, Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Ghana, Guinea, Guinea – Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Reunion, Rwanda, Sao Tome and Principe, Senegal , Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, Togo, Tunisia, Uganda, United Republic of Tanzania, Western Sahara, Zambia, Zimbabwe.
Americas:Antigua and Barbuda, Argentina, Aruba, Bahamas, Barbados, Belize, Bermuda, Bolivia, Brazil, British Virgin Islands, Canada, Cayman Islands, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, Falklands Islands , French Guiana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Mexico, Montserrat, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, Saint Kitts and Nevis, Saint Lucia, Saint Pierre and Miquelon, Saint Vincent and the Grenadines, Suriname, Turks and Caicos Islands, United States of America, Uruguay, Venezuela.
Asia: Afghanistan, Bahrain, Bangladesh, Bhutan, Brunei Darussalam, Cambodia, China, China, Hong Kong SAR, China, Macao SAR, Democratic People's Republic of Korea, India, Indonesia, Iran (Islamic Republic of), Iraq, Israel, Japan, Jordan, Korea Democratic Republic, Kuwait, Lao People's Democratic Republic, Lebanon, Malaysia, Maldives, Mongolia, Myanmar, Nepal, Oman, Pakistan, Philippines, Qatar, Saudi Arabia, Singapore, Sri Lanka, Syrian Arab Republic, Thailand, Turkey, United Arab Emirates, Viet Nam, Yemen.
Europe: Albania, Austria , Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Gibraltar, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Montenegro, Netherlands, Norway, Poland, Portugal, Republic of Moldova, Romania, Russian Federation, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, The Former Yugoslav Republic of Macedonia, Ukraine, United Kingdom.
Oceania: Australia, New Zealand

A.2: Glossary

Advanced biofuels: Advanced biofuels or second generation biofuels are liquid fuels with the conversion technology still in R&D, pilot or demonstration phase. However, in the past few years, commercial plants have started production. They include hydro treated vegetable oil, biofuels from lignocellulosic biomass and algae based biofuels.
Agriculture area: Agricultural area, this category is the sum of areas under a) arable land - land under temporary agricultural crops (multiple-cropped areas are counted only once), temporary meadows for mowing or pasture, land under market and kitchen gardens and land temporarily fallow (less than five years).
Arable land: Arable land is the land under temporary agricultural crops (multiple-cropped areas are counted only once), temporary meadows for mowing or pasture, land under market and kitchen gardens and land temporarily fallow (less than five years).
Biodiesel: Biodiesel is a liquid fuel produced predominantly from vegetable oil or animal fats.
Bioenergy: Bioenergy is energy produced from biomass (including biological origin fraction of municipal waste) and used directly as fuel or processed into liquids or gases.
Bioethanol: Bioethanol is ethanol produced from biomass and/or biodegradable fraction of waste.
Biogas: Biogas is the gas obtained from anaerobic fermentation of biomass in landfills, sewage etc. – comprising primarily of methane and carbon dioxide.
Biomass: Biomass is any organic matter derived from plants, animals or algae.
Combined Heat and Power (CHP): CHP plants are designed to cogenerate heat and electricity from a variety of plants, sizes and technologies.
Derived heat: Derived heat covers the total heat production in heating plants and in combined heat and power plants.
Direct heat: Direct heat from biomass is the heat produced and used from direct combustion of biomass. It excludes the heat production from power plants. It is calculated as:
Biomass for direct heating=Total primary energy supply of biomass-Biomass use for electricity-Biomass use for biofuels
District heat: District heating is the concept of using surplus heat from power plants for heating residential, public and/or commercial buildings as well as meeting industrial demands for low temperature heat.
Electricity only: Electricity plants refers to plants which are designed to produce electricity only.
Forest area or forest land: Forest area is the land spanning more than 0.5 hectares with trees higher than 5 metres and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ.
Gross Final Energy Consumption: GFEC (Gross Final Energy Consumption): It is the sum of: Total final energy consumption, Consumption of electricity and heat by the transformation sector, including the energy industry own use, Losses in transmission and distribution of electricity and heat
Heat only: Heat plants, refers to plants (including heat pumps and electric boilers) designed to produce heat only.
Industrial waste: Industrial waste of non-renewable origin consists of solid and liquid products (e.g. tyres) combusted directly, usually in specialized plants, to produce heat and/or power.

Land area: Land area is the total area of the country excluding area under inland water bodies.
Liquid biofuels: Liquid biofuels includes bioethanol, biodiesel and other liquid biofuels.
Municipal wastes: Municipal waste consists of products that are combusted directly to produce heat and/or power and comprises of wastes from household, industry, hospitals and other sources which are collected by local authorities for incineration.
Other land: Other land is the land not classified as Agricultural land and Forest area. It includes built-up and related land, barren land, other wooded land, etc.
Pellets: Wood pellets are mostly produced from sawdust and wood shavings compressed under high pressure. They are cylindrical in shape and usually 6-10 mm in diameter.
Permanent crops: Permanent crops are sown or planted once, and then occupy the land for some years and need not be replanted after each annual harvest, such as cocoa, coffee and rubber.
Permanent meadows and pastures: Permanent meadows and pastures is the land used permanently (five years or more) to grow herbaceous forage crops, either cultivated or growing wild (wild prairie or grazing land).
Pyrolysis oil: Pyrolysis Oil is a dark-brown, free-flowing liquid made from plant material by a process called fast pyrolysis, whereby biomass particles are rapidly heated to ~500 °C in the absence of oxygen, vapourized, and the vapours then quenched into the Pyrolysis Oil liquid, also known as bio-oil.
Renewable municipal waste: Municipal waste – renewable consists of the biodegradable part of municipal waste products that are combusted directly to produce heat and/or electricity. It comprises waste produced by the residential, commercial and public services sectors that is collected by local authorities for disposal in a central location, including biodegradable hospital waste.
Roundwood: Roundwood comprises all wood obtained from removals, i.e. the quantities removed from forests and from trees outside the forest, including wood recovered from natural, felling and logging losses during the period, calendar year or forest year.
Torrefaction or torrefied biomass: Torrefaction is the thermal treatment of various woody and agricultural residue feedstock in which biomass is heated to 250 – 300 °C and at atmospheric pressures.
Total Primary Energy Supply or Primary energy supply: TPES (Total Primary Energy Supply): It is the energy content of the energy sources and is calculated as production + imports – exports +/- international bunkers +/- stock changes.
Traditional biomass: Traditional biomass refers to the use of fuel wood, charcoal, animal dung and agricultural residues in stoves with low efficiencies.
Vegetable oils: It includes the production and consumption of coconut oil, cottonseed oil, olive oil, palm oil, palm kernel oil, peanut oil, rapeseed oil, soybean oil and sunflower seed oil.
Vegetal waste: Mainly crop residues (cereal straw from maize, wheat, paddy rice, etc.) and food processing wastes (rice hulls, coconut husks, ground nut shells, etc.) used for fuel. Bagasse is excluded.
Wood charcoal: Wood charcoal is wood carbonised by partial combustion or the application of heat from external sources.
Wood Fuel: Roundwood that will be used as fuel for purposes such as cooking, heating or power production. It includes wood harvested from main stems, branches and other parts of trees (where these are harvested for fuel) and wood that will be used for charcoal production (e.g. in pit kilns and portable ovens). It also includes wood chips to be used for fuel that are made directly (i.e. In the forest) from roundwood. It excludes wood charcoal. It is reported in cubic metres solid volume underbark (i.e. excluding bark).

A.3: General data

Table 101: General global, continental and country information

	Population (in millions)	GDP (billion USD)	CO_2 emissions (Mt CO_2)
World	7 037	54 588	31 734
Africa	1 083	1 331	1 032
Americas	951	19 086	7 269
Asia	3 938	14 915	14 141
Europe	824	16 776	6 146
Oceania	27.6	1 051	418
China	1 351	4 522	8 206
USA	314	14 232	5 074
India	1 237	1 389	1 954

	Population (in millions)	GDP (billion USD)	CO_2 emissions (Mt CO_2)
Russia	144	981	1 659
Japan	128	4 694	1 223
Germany	81.9	3 074	755
Brazil	199	1 137	440
South Korea	50.0	1 078	593
France	65.4	2 249	334
Canada	34.9	1 293	534
Nigeria	314	14 322	5 074
Indonesia	247	427	435
Ethiopia	91.7	24.7	7.93
Pakistan	179	138	137
Thailand	66.8	224	257
Burundi	10.2	1.51	0.31
Ethiopia	94.1	24.7	7.93
Liberia	4.29	1.16	0.80
Chad	12.9	9.18	0.47
Guinea	11.7	3.53	1.24
Rwanda	11.8	4.51	0.59
Uganda	37.6	15.2	3.78
Mali	15.3	7.13	0.62
Nepal	27.8	11.0	4.89
Burkina Faso	16.9	8.29	1.68
EU 28	507	14 614	3 505

(World Bank 2015, IEA 2015)

A.4: Conversions

Table 102: Unit conversions					
To:	**TJ**	**Gcal**	**Mtoe**	**MBtu**	**GWh**
From:	**(Multiply by)**				
TJ	1	238.8	2.39E-05	947.8	0.2778
Gcal	4.19E-03	1	1.00E-06	3.968	1.16E-03
Mtoe	4.19E+04	1.00E+08	1	3.97E+07	11 630
Mbtu	1.06E-03	0.252	2.52E-08	1	2.93E-04
GWh	3.60	860	8.60E-05	3,412	1

Table 103: Energy content and density of liquid fuels		
Fuel	**Energy content (MJ/l)**	**Density (kg/l)**
Gasoline	35.2	0.75
Ethanol	23.4	0.79
Diesel	37.3	0.83
Biodiesel	35.2	0.88
Biofuels average	29.3	0.84
Biogas average	21.6	MJ/Nm^3

Table 104: Average efficiencies of conversion		
	Electrical efficiency (%)	**Thermal efficiency (%)**
Electrical only	32%	0%
CHP	23%	60%
Heat only	0%	80%
Biofuels	60%	

Table 105: Energy content of biogas and biomethane			
	Unit	**kWh**	**MJ**
Biogas (Average)	1 Nm^3	6.0	21.6
Bio methane	1 Nm^3	9.97	35.9
Bio methane	1 kg	13.9	50.0

Table 106: Average composition of biogas		
	Forumula	**Composition (%)**
Methane	CH_4	50 – 75%
Carbon dioxide	CO_2	25 – 45%
Water vapor	H_2O	2 – 7%
Nitrogen and oxygen	N_2, O_2	< 2% each
Others	NH_3, H_2, H_2S, trace gases	-

Table 107: Examples of biogas yields		
Type		**Biogas yield (in Nm^3)**
1 milking cow	20 m^3 liquid manure per year	500
1 pig	1.5 – 6 m^3 liquid manure per year	42 – 168
1 cattle (beef)	2 – 11 tonnes solid manure per year	240 – 880
100 chicken	1.8 m^3 dry litter	242
Maize silage	40 – 60 green weight per ha	7040 – 10560
Grass	24 – 43 tonne fresh matter per ha	4118 – 6811

Table 108: Key properties of pellets	
Property	**Value**
Pellet size	20 – 30 mm length
	6 – 12 mm diameter
Moisture content	< 10%
Calorific value	4.7 – 4.9 kWh/kg
Bulk density	600 kg/m^3
Ash content	< 1%

Table 109: Conversion factors assumptions for woodfuel use in Kenya		
Population	46	million
Charcoal consumption	0.75	kg/person/day
Wood consumption	2	kg/person/day
Energy content - charcoal	30	GJ/ton
Energy content - dry wood	14	GJ/ton
Energy content - green wood	11	GJ/ton
Density - dry wood	600	kg/m^3
Wood fuel to charcoal conversion coefficient	6.4	t charcoal/t wood
Average charcoal production efficiency	30%	%
Average charcoal conversion in cookstoves efficiency	20%	%
Average wood burning efficiency	15%	%

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ANDRITZ

SILVER SUPPORTER OF WBA

AGRANA

SUPPORTERS OF WBA STATISTICS

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