WBA fact sheet

GLOBAL BIOMASS POTENTIAL TOWARDS 2035

SUMMARY

Climate change is the most signficant challenge for humanity today. An important solution is replacement of fossil fuels with renewables and improved energy efficiency. Among renewables, biomass will play a major role in satisfying the human energy needs.

Biomass for energy originates from a variety of sources classified into forestry, agriculture and waste streams. Some of the potential sources include: crops for biofuels, energy grass, short rotation forests, woody biomass and residues, herbaceous by-products and municipal solid waste. Globally, in 2012, the biggest share of biomass for energy came from forests - almost 49 EJ out of a total supply of 56.2 EJ. The current global energy supply is about 560 EJ.

Land is an important basis for biomass production. The future potential of biomass for energy depends on protection of agricultural land against desertification, degradation, limitless urbanization as well as protection and increase of forest area. Permanent innovation in agricultural yields plays a major role in increasing potential for food and fuel production. As an example, increase in corn yields between years 2000 and 2012 has saved 50 million ha of land area. Given good policies, WBA estimates that by 2035, about 5% of the agricultural area (240 milliona ha) can be used for growing dedicated energy crops for biofuels and solid biomass for energy.

A conservative estimate of the energy potential of biomass from agriculture, forestry and waste sectors totals 150 EJ in the next 20 years. About 43% coming from agriculture (residues, by-products and energy crops), 52% from forests (wood fuel, forest residues and by-products of the forest industry) and 5% from waste streams. Biomass can play an important role in the transformation to a new energy system based on renewable energies.

INTRODUCTION

Climate change threatens continued global development led by the excessive use of fossil fuels. The rapid replacement of fossil fuels by renewable energies is the best strategy against climate change. Biomass is currently the dominating renewable energy source for multiple uses in heat, power and transportation fuels. A step-by-step substitution of fossil fuels by renewable energies in the coming decades requires the rapid growth of all renewable energy carriers such as wind, solar, hydro, geothermal and bioenergy.

Biomass is the biological matter from living organisms. Green plants capture carbon from the atmosphere through photosynthesis and release it back to the atmosphere by decay or use. Every year, plants convert 4,500 EJ of solar energy (1) and 120 Giga Tonnes of carbon (2) from the atmosphere into biomass - eight times as much as the global energy need. Animals and microorganisms break down most of the plant biomass to Carbon Dioxide (CO_2) and water as part of the natural carbon cycle, while the rest of the biomass can be used to satisfy human needs.

Plants consist of different parts like roots, stems, stalks, branches, leaves, fruits, and fruit shells. Different parts of the plants can be used for different purposes: fruits for food, fruit shells, stalk and straw for energy, strong stems of trees for the saw mill and pulp industry, and small stems, branches, tops of trees for energy etc.

Photo: SLU

Figure 1: Picture illustrates different ecological systems for biomass origins: short rotation forestry, corn and sugarcane and managed forestry

Plants contain different substances like starch, sugars, (vegetable) oils, proteins, cellulose and lignin. These can be used for different purposes such as proteins for food and feed and starch for cooking or biofuels or other products, or cellulose for pulp and paper, and lignin for energy or chemicals. Also, plants dedicated for energy purposes can be cultivated such as miscanthus, energy grasses, short rotation trees, such as poplars, willows, eucalyptus to mention a few. In this paper, we do not consider aquatic systems.

Hence, many forms of plant material can be used for energy. This fact sheet explains how much of biomass can be supplied in a sustainably for energy by 2035 taking into account the other uses such as food, feed or material use. In human history, plants have always served different human needs: food, energy, medicine, material use and animal feed. As the fossil fuel age declines, biomass regains a new importance.

Photo: iStock

Figure 2: Tropical landscape can have high production of both agricultural and forestry products: Volcanic Cinder Cone and Tropical Agriculture Mudende, Rwanda

DEFINITIONS

Four types of biomass potential

The type of biomass potential is an important parameter in biomass resource assessments as it determines to a large extent the approach and methodology as well as the data requirements. Four types of biomass potentials are commonly distinguished: theoretical potential, technical potential, economic potential, and implementation potential (2).

Theoretical potential is the maximum potential of biomass available globally or in a given system. The technical potential is the fraction of the theoretical potential that is available under the regarded techno-structural framework conditions with the current technological possibilities (such as harvesting techniques, infrastructure and accessibility, processing techniques). It also takes into account spatial confinements due to other land uses (food, feed and fibre production) as well as ecological (e.g. nature reserves) and possibly other non-technical constraints.

Economic potential is the share of the technical potential, which meets criteria of economic profitability within the given framework conditions. Implementation potential is the fraction of the economic potential, which can be implemented within certain time frame and under concrete socio-political framework conditions, including institutional and social constraints and policy incentives. In this study, the techno-economical potential will be assessed.

Sources of biomass for energy

Biomass for energy originates from different sources such as agriculture, forests and waste. Table 1 gives an overview about these sources and the different forms of biomass usable for energy.

The biomass feedstock is used directly for heat generation such as wood fuel or processed to different products for end users such as chips, pellets, charcoal, ethanol, biodiesel, and biogas. These products are converted to heat, electricity or transport services. The current composition of the supply of biomass for primary energy is shown in Table 2.

In 2012, the biggest share of biomass for energy came from forests – almost 49EJ (3).

TABLE 2: GLOBAL COMPOSITION OF BIOMASS SUPPLY FOR ENERGY IN 2012

Main sector	Biomass supply (EJ)
Agriculture	5.6
Forestry	48.9
Organic waste	1.7
Total	56.2

TABLE 1: CLASSIFICATION OF THE DIFFERENT SOURCES OF BIOMASS FOR ENERGY

Main sector	Sub sector	Examples
Agriculture	Dedicated crops - main products	Crops for biofuels (corn, sugarcane, rapeseed, oilpalm, jatropha, sorghum, cassava etc.), energy grasses (miscanthus, switchgrass), short rotation forests, other dedicated crops for energy
	By - products and residues	Herbaceous by - products: Straw from cereals, rice, corn, bagasse, empty fruit bunch from oil palm, prunings from stover, empty corn cobs etc.
		Woody biomass, regeneration orchards, vineyards, olive and oil palm plantations
		Other forms: Processing residues such as kernels, sunflower shells, rice husks, animal manure
Forestry	Main product	Stems, wood fuel from forests or trees outside forests, woody biomass from landscape cleaning
	By - product and residues	Residues of forest harvest (branches, tops, stumps), residues of wood industry (bark, sawdust, other wood pieces, black liquor, tall oil, recycled wood)
Organic waste		Municipal solid waste (MSW), food waste from stores, restaurants and households, used kitchen oil, waste from the food industries (from dairy, sugar, beer, wine, fruit juice industry, from slaughterhouses), sewage sludge

LAND AS BASIS FOR BIOMASS PRODUCTION

The availability of fertile land is crucial for biomass production. The global land mass without counting the water bodies (lakes, rivers) has a size of 13 000 Million ha. About 37% of this is used for different agricultural purposes and 30% is forest area as shown in Table 3 (4).

Today's use of land

About 1 400 million ha – 10.7% of the land area - is used as arable land for crop production such as corn, wheat, rice, soybeans and other plants. Orchards, vineyards, olive plantations are summarized under permanent crops. The vast majority of the agricultural land (68%) is used in a rather extensive way as meadows and pastures for cattle and sheep production. This area offers potential for additional rain fed arable land. Other areas comprise urban regions including (approx. 400 million ha) roads, railroads, airports, deserts and glaciers and other non-used land. Deserts make up by far the biggest share among the category of other land.

The use of land is permanently changing. FAO (2006a) reports for the period 2000 – 2005 that average annual gain of forest area was 5.7 million ha (5). These gains appear either as planted forests or as naturally expanding forests (typically on abandoned agricultural land). Most gains occur on former agricultural land, but considerable planting of woodlands/grasslands are also done. Another improvement is forest plantation in degraded land, for e.g. China. At the end, the cropland area was increasing and the forest area decreasing by 7.3 million ha (4). In terms of growth and deforestation, the global net growth of forests is 2 - 3 times as large as forest loss (deforestation). Forests are showing a net growth in developed countries while the rate of deforestation has decreased (6)

Future opportunities

The future potential of biomass for energy depends on the protection of agricultural land against desertification, degradation, and limitless urbanization as well as on the protection of forests and the increase of the forest area.

Permanent innovation in agriculture by improving crop yields also plays a decisive role in increasing the potential for food and biomass production. A study by Max Roser shows that, in 2011, the world used 68% less land than 50 years before to produce the same amount of food due to improved agricultural yields.

In a recent analysis, WBA could demonstrate that the increase of corn yields between 2000 and 2012 saved 50 million ha of land (3).

TABLE 3: OVERVIEW OF GLOBAL LAND AREA IN 2012 (IN MILLION HA)

Agricultural area	4 922		
		Arable land	1 396
		Permanent crops	164
		Meadows and pastures	3 362
Forest area	4 022		
Other land	4 075		
Total Global land area	**13 019**		

In another study, it was reported that more than 800 million ha land could be accommodated to rain fed agriculture and new forests.

In summary, additional land for biomass production is provided if:

- The average yields on arable land can be further improved
- Less agricultural land is abandoned
- The pasture land is used in a better way and partly converted to cropland
- The loss of arable land due to desertification or urbanization is reduced
- Abandoned agricultural land is brought back to production.

Given good governance, WBA estimates that by 2035, about 5% of the agricultural area - 240 million ha of land - can be used for dedicated energy crops. There is enough land on the globe to feed 9 billion people and to produce more biomass for energy and material use. But the available land has to be protected and well managed. Protecting and regaining arable land is an important part of sustainable governance.

POTENTIAL OF BIOMASS FROM AGRICULTURE, FORESTRY AND WASTE STREAMS

Biomass from agriculture

Dedicated energy crops

In 2012, crops used for both food and for bioenergy include: sugarcane, corn, sugar beets, cereals, canola, oil palm, jatropha soybean, sorghum and cassava.

Plants only used for bioenergy or material purposes are: energy grasses, miscanthus, switchgrass and short rotation coppices.

Crops like corn, canola and soybean deliver not only feedstock for biofuels but also proteins. The use of land for energy crops in 2012 not including the share for protein production can be estimated as 30 million ha delivering about 3.5 EJ. This land is mainly used for crops for biofuels and a small portion for solid biomass production (miscanthus and short rotation forests). Crops like sugarcane and oilpalm deliver feedstock

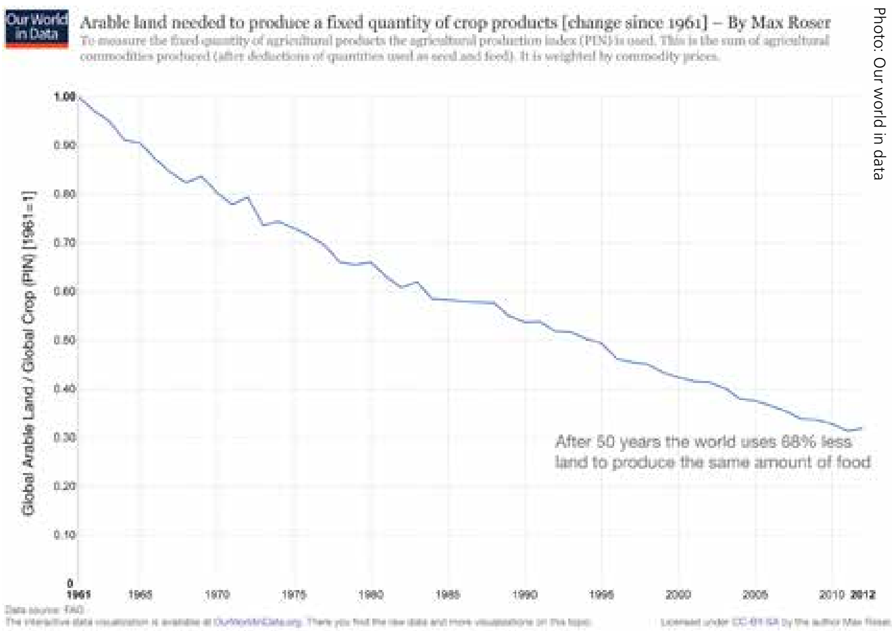

Photo: Our world in data

Figure 3: Arable land needed to produce a fixed quantity of crop products

Photo: iStock

Figure 4: An agricultural system in rural areas

for biofuels in large quantities globally. Sugarcane has one of the highest yields for any crop and produces multiple products like cane juice and molasses for ethanol and bagasse for electricity and heat generation. Oil palm is a very productive crop if grown on the right type of land (not on drained peat or deforested areas) and used in a sustainable way.

For the future, on an average, the energy yield can be estimated as 70 – 90 GJ per hectare for biofuels and 150 - 200 GJ for dedicated crops for solid biomass. The yields differ widely between crops and growing regions. In particular, Africa has a great potential to increase the yields. Investments in agriculture have been held back in the past few decades leading to low productivity in comparison to global averages. On the basis of 240 Million ha land for dedicated energy purposes by 2035, the energy output can be estimated with 26 - 34 EJ per year.

By-products of agriculture:

By products and residues of agriculture used for bioenergy can be classified into 3 categories: herbaceous, woody and other forms of by products as explained in Table 1. Herbaceous by-products and residues such as straw from cereal and rapeseed, rice straw, corn stalks, and various by-products of other crops are partly used on farms or remain on the fields to rot or are burned on the fields. Woody by-products and residues are those produced as consequence of pruning and regenerating orchards, vineyards, olive plantations and oil palm plantations. Oil palm delivers various forms of by-products such as empty fruit bunches, effluents and woody material. Normally, herbaceous crops are cultivated in arable land, whereas orchards, vineyards are considered as permanent crops.

Differences in growth conditions, soil quality and soil type and texture complicates estimates of residue potential. However, in general, 20–30% of the available straw could be used for bioenergy.

Worldwide, corn, wheat, rice, sugar cane and soybean offer the biggest potential of residues. Sunflower shells, rice husks, olive kernels add to this potential. WBA estimated the technical potential of these residues as 122 EJ (upper limit). Due to economic, ecological, market and institutional reasons, only a small part of this potential will be usable by 2035. WBA estimated the techno economical potential as 25 – 31 EJ.

Manure from animals is a feedstock for biogas or can be used in dried form for combustion. The potential of manure for energy globally is estimated as 5 - 7 EJ.

In countries and regions without bioenergy programs, most of these by-products and residues are burned, dumped into landfills or just left to rot. A systematic use of these by-products offers a potential of 30 – 38 EJ.

Biomass from forests

In 2012, 85% of all the biomass used for energy originated from forests or trees. Wood is by far the most important source for bioenergy. In Sub Saharan African countries (excluding South Africa), wood covers more than 70% of the total final energy use. Just one third of the global forest area of 4 billion ha is used for wood production or other commercial purposes. And those that are managed have space to grow more feedstock. Examples like Sweden and Finland prove that a growing use of forest biomass can go along with a growing wood production. In fact, harvesting trees in forests will increase the net production of biomass, as young trees have a larger net growth than old trees.

The global consumption of wood is likely to increase further in the future because of the continuously growing population as well as the expected increasing demand for biomass for fulfilment of climate policy goals.

Wood for energy comprises different categories such as: wood fuel, charcoal, wood chips, pellets, bark, saw dust, recycled wood, black liquor and other residues of the forest harvest and the wood industry. Some of these materials go direct from the forest to the energy consumer like fire wood, tops, branches and wood of small size; other wood goes first to the industry (stem wood to saw mills, to the pulp industry) and residues in the form of chips, saw dust, bark etc. go the energy sector. In regions without a bioenergy policy, a big share of these by-products is not used but dumped in landfills or let to rot.

The forest area as basis for woody bioenergy is changing. From 1990 to 2010,the global forest area declined by 138 million ha to 4 033 million ha in 2010. On an average, a net loss of 6.9 million ha per year occured. The main losses of forest area occurred in Africa, Latin America and South East Asia whereas the forest area in Europa and China was growing.

In 2012, biomass from forests and other areas with trees contributed 49EJ to the global energy supply. The lion share of this biomass is used in Asia and Africa.

The future potential of wood for energy depends on three aspects:

- A better use and management of existing forests
- The better use of the by-products or residues of trees in non forest areas for bioenergy instead of dumping a huge share of this material as it is done in many parts of the world today.

TABLE 4: GLOBAL POTENTIAL OF BIOMASS IN 2012 AND 2035 (IN EJ)

Main sector	Sub sector	2012 - Current	2035 - Range	2035 - Average
Agriculture	Dedicated crops - Main product	3.5	26 - 34	30
	By products and residues including manure	2.1	30 - 38	34
	Total agriculture	5.6	56 - 72	**64**
Forestry		48.9	72 - 84	78
Organic waste		1.7	6 - 10	8
Total		56.2	134 - 166	**150**

Photo: ppcnet.org

Photo: Per Petersson, Sveaskog

Figure 5: In a sustainable managed forest, trees of different age grow side by side, to left or in some cases even trees of even ages as shown to the right.

• The planting of new forests in order to compensate for the losses of forest in some regions, to increase the global forest area again and use part of this additional production for energy.

Additionally, 23 – 35 EJ of woody biomass can be supplied if these three conditions are fulfilled adding up to 72 – 84 EJ from woody biomass. A big share of this potential exists in North America, Europe including Russia; Asian countries like Japan. Tropical energy plantations including eucayptus and tropical pine with high growth rate and quick maturity are other viable options. In Africa, firewood and charcoal will still remain as major energy sources. The important thing is that the supply chain should be more efficient, from the sourcing to the end use (better charcoal kilns, better stoves etc.), and that the forest management should be improved, by regrowth of trees, better land management and clear land ownership/control. Slash and burn of forests has led to vast deforestation and should be banned.

The big potential of woody biomass in some parts of the world (North America, especially Canada, Eastern Europe, Russia) and the lack of biomass in urban areas will require increased trade to ship the mostly refined biomass as pellets from regions with an oversupply to areas with a lack of biomass. The refining of biomass to pellets, pyrolysis oil or torrefied biomass facilitates trade.

Biomass from waste streams

The organic fraction of waste streams can be used for energy purposes. The technology to convert this feedstock to energy is either waste combustion or anaerobic digestion using the biogas technology. Typical feedstock for energy generation from waste can be seen as:

• Organic fraction of landfills
• Sewage sludge
• Municipal Solid Waste (MSW)
• Organic fraction of agroindustry waste
• Un used food

In many parts of the world, the waste of cities is still dumped in landfills where huge amounts of methane (a highly dangerous greenhouse gas) are being produced. This gas should be collected and used for energy until the use of material for landfills is stopped completely and the waste is either used directly for energy or recycled.

Sewage sludge contains a lot of organic material than can also be used to produce biogas.

The same is the case with MSW. It can be burned in a cogeneration plant to deliver heat and electricity or also be used for biogas. Agro – industries like breweries, sugar plants, slaughterhouses, etc. deliver a lot of organic by products to be used for energy in biogas plants or combustion units. Several studies in Europe show that the potential for biogas including manure without using energy crops is of the order of 3.6PJ per one million inhabitants.

The potential of the global waste streams for energy without residues and manure from agriculture is estimated with 6 - 10 EJ.

Biogas is an important technology for the use of waste, but biogas installations do not only use waste but also manure and biomass from dedicated energy crops such as corn or sorghum. This potential was calculated under agriculture.

GOVERNANCE FOR BIOENERGY TO MOBILIZE THE POTENTIAL

WBA estimates the techno-economic potential of biomass for energy by 2035 in the size of 150 EJ with a range as shown in Table 4. Bioenergy could contribute about 25% of the global energy supply. IRENA, in its study Remap comes to similar results: " Biomass has an auspicious future in the world's supply of renewable energy. Sustainable bioenergy has the potential to be a game-changer in the global energy mix." (7).

The biggest currently non-used potential can be found in by-products, residues and manure from agriculture and landscape maintenance including parks. This quantity is estimated in the size of more than 34 EJ as compared to an additional potential of dedicated energy crops of 30 EJ and from forests from 15 EJ and 8 EJ from organic waste.

This potential can only be used if a wide range of government support policies promote the use of biomass for energy. These support policies comprise policies in favour of agriculture like training, education, financial donations within integrated rural development programs for agriculture and sustainable forestry, protection of agricultural land, reforestation and sustainable management of forests. Bioenergy has to become more economically attractive in many regions of the world. This requires to stop the subsidies for fossil fuels, to introduce CO_2 taxes on the use of fossil fuels, to co-finance the implementation of equipment to convert biomass to energy as for instance biogas installations, wood gasifiers and modern cookstoves and biomass combustion units as combined heat and power units for district heating for the industry and residential sectors. The support programs have to be stable, reliable and specific for each region and country adapted to the regional needs and biomass resources. ■

POSITION OF WBA

A rapid transition of the energy system from fossil fuels to renewables is crucial to mitigate climate change and avoid huge damages for our societies and economies. This transition can only be successful with a strong contribution of biomass to the energy system. The contribution of biomass to primary energy can be increased from 56 EJ in 2012 to about 150 EJ by 2035. In combination with a fast deployment of the other renewable technologies, renewables could cover more than 50% of the energy needs by 2035 and 100% a few decades later.

The deployment of biomass requires reliable government policies to support agriculture, sustainable forestry and create stable markets for bioenergy as transport fuel, as source of the future heat supply and for electricity generation. A strong taxation of fossil fuels is a key instrument to accelerate the transition to a sustainable renewable dominated energy system. WBA calls on governments and international institutions to create favourable frame work conditions for a sustainable growth of biomass for energy in the heat, transport and electricity sector. ■

SOURCES

1. Ralph Sims, Bioenergy options for a cleaner environment: In developed and developing countries. UK. 2014

2. IPCC, Fourth Assessment Report: Climate Change. 2007

3. WBA, Global Bioenergy Statistics. Stockholm. 2015

4. FAO, Extent of land use categories in the year 2000. 2006

5. FAO, Global forest resource assessment report. Rome. 2010

6. GCP, Global Carbon Project. 2016

7. IRENA, Global Bioenergy Supply and Demand Projections for the year 2030. Abu Dhabi. 2013

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On the way to 100% RES the potential of biomass has to be used. A positive example is the province of *Niederösterreich* in Austria. In 2015, this province with 1,4 million inhabitants reached a 100% renewable based electricity supply based on hydro, wind, bioenergy and photovoltaics!"