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Global biomass fuel resources

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Abstract

An overview of biomass for production of densified biofuels on a global scale is given. Bioenergy production as heat, electricity, and liquid fuels represents about 14% of the World's primary energy supply. About 25% of the usage is in industrialised countries and the other 75% is used in developing countries. There is an estimated 3870 (10^6) ha of forest worldwide. The average area of forest and wooded land per inhabitant varies between 6.6 ha in Oceania, 0.2 ha in Asia, and 1.4 ha in Europe. The world's total above-ground biomass in forests amounts to 420 (10^9) tonnes, of which more than 40% is located in South America. Estimates by FAO (2000) show that global production and use of woodfuel and roundwood reached about 3300 (10^6) m^3 in 1999. About 55% is used directly as fuel, e.g. as split firewood, and about 90% of this is produced and consumed in the developing countries. The remaining 45% is used as industrial raw material, but about 40% of this is used as primary or secondary process residues, suitable only for energy production. The total sustainable worldwide biomass energy potential is about 100 EJ/a (the share of woody biomass is 41.6 EJ/a), which is about 30% of total global energy consumption today. About 40 EJ/a of available biomass is used for energy. Nearly 60% of this biomass is used only in Asia. A comparison between the available potential with current use shows that on a worldwide level about two-fifths of the existing biomass potential is used, and in most areas of the world the current biomass use is clearly below the available potential. Only in Asia does the current use exceed the available potential. Therefore, an increased biomass use is possible, e.g. for production of densified biofuels, in most countries.

Keywords: Forest biomass; Woody biomass; Biofuel; Renewable energy; Resources

1. Introduction

It is estimated that there are 3870 (10^6) ha of forest worldwide (Table 1) or 30% of the earth's land area, of which about 95% are natural forests and 5% are plantations [2]. Tropical and subtropical forests comprise 56% of the world's forests, while temperate and boreal forests account for 44% [2].

The average area of forest and wooded land per inhabitant varies regionally (Table 2). The area varies between 6.6 ha in Oceania, 0.2 ha in Asia, and 1.4 ha in Europe (3.4 ha in the Nordic

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Table 1
Forest resources, area (ha), year (2000)

	Land area (ha) (10^6)	Forest area (ha) (10^6)	%	Plantations (ha) (10^6)	Forest area per capita (ha)
Africa	2978	649	21.8	8	0.8
Asia	3084	547	17.8	115	0.2
Europe	2259	1039	46.0	32	1.4
North and Central America	2136	549	25.7	2	1.1
Oceania	849	197	23.3	3	6.6
South America	1754	885	50.5	10	2.6
World	13063	3869	29.6	171	0.6

Source: [1,2].

Table 2
Forest resources, above-ground biomass volume and biomass (m^3 and tonne)

	Forest area (ha) (10^9)	Volume (m^3/ha)	Volume (m^3) (10^9)	Woody biomass (tonne/ha)	Woody biomass (tonne) (10^9)
Africa	649	72	46	109	70
Asia	547	63	34	82	44
Europe	1039	112	116	59	61
North and Central America	549	123	67	95	52
Oceania	197	55	10	64	12
South America	885	125	110	203	179
World	3869	100	386	109	421

Source: [1,2].

countries) [2]. This fact indicates that the potential contribution of wood to the energy supply also varies from country to country. There are also large regional differences in accessibility to forests [2]. Therefore, the possibilities for production of densified biofuels vary widely between regions.

The total above-ground wood volume (m^3) and woody biomass (tonnes) in forest has been estimated in 166 countries, representing 99% of the world's forest area [2]. The world's total above-ground biomass in forests is 420 (10^9) tonnes (Table 2), of which more than 40% is located in South America and about 27% is in Brazil alone. The worldwide average above-ground woody biomass is 109 tonnes/ha [2].

Estimates by FAO (2000) show that the global production of woodfuel and roundwood reached 3268 (10^6) m^3 in 1999 (Table 3). Just over half of this was woodfuel, about 90% of that being produced and consumed in the developing countries. On the other hand, industrial roundwood production, totalling 1515 (10^6) m^3 in 1999, is dominated by developed countries, which together accounted for 79% of global production [1,2].

The global use of woodfuel and roundwood is 3271 (10^6) m^3 per year [1,2]. About 55% is used directly as fuel, e.g. as split firewood, mainly in developing countries. The remaining 45% is used as industrial raw material, but about 40% of this is used as primary or secondary process residues, suitable only for energy production, e.g. for production of upgraded biofuels [2].

About 70–75% of the global wood harvest is either used or potentially available as a renewable energy source. This amount does not include the large amount of logging residues and other woody biomass left on-site after logging operations integrated with conventional forestry all over the world [2].

Biomass currently represents approximately 14% of world's final energy consumption [3]. About 25% of the usage is in industrialised

Table 3
Production and use of woodfuel, industrial roundwood, sawn wood and wood-based panels (m^3)

	Woodfuel (m^3) (10^6)		Industrial roundwood (m^3) (10^6)		Sawn wood (m^3) (10^6)		Wood-based panels (m^3) (10^6)	
	Prod.	Use	Prod.	Use	Prod.	Use	Prod.	Use
Africa	463	463	70	66	8	11	2	2
Asia	883	883	244	267	73	87	85	93
Europe	95	92	411	411	116	110	49	49
North and Central America	133	133	618	615	180	174	52	53
Oceania	8	8	40	33	7	7	3	2
South America	168	168	130	127	29	27	5	4
World	1753	1750	1515	1521	415	417	198	205

Source: [1,2].

countries, where a significant level of investment in environmental protection has been made to meet emissions standards, especially air emissions [4]. The other 75% of primary energy use of biomass is in heat production for developing country household energy needs and in process heat production for biomass-based industries through the use of their generated residues [4].

To mitigate climatic change caused by greenhouse gas emissions, the developed world is working to substitute fossil fuels with renewable energy sources. To stabilise the atmospheric concentration of CO_2, global emissions must be reduced by at least 60% from the current levels. Approximately 80% of the total emissions come from use of fossil fuels, mostly from industrialised nations [5]. Much of the remaining 20% is believed to come from deforestation, mostly from tropical nations [5]. Furthermore, there are indications that forestland could contribute more to global CO_2 stabilisation through sustained production chains of fuel for biomass energy systems (e.g. densified biofuels) to replace fossil fuels [2].

2. Material and methods

The aim of this study is to make an overview on woody biomass (other biomass materials are discussed in the study) for production of densified biofuels in a global scale. The FAO database (www.fao.org) concerning forest products, woodfuel, etc. (FAOSTAT) and several FAO and other publications are used for gathering the data. Methods for FAO data collection, etc., are described, e.g. in [6].

3. Raw material sources for densified fuels

The residues generated from the forest products industry could be divided into two categories: (1) logging residues, generated from logging operations, e.g. from final fellings and (2) industrial byproducts, generated by the forest industries during processing of timber, plywood, particleboard, pulpwood, etc. [7,8]. Sources and types of residues are shown in Table 4.

In general, less than 66% of the volume is removed from the forest for further processing, the remaining quantity is left on-site, burnt on-site or utilised as woodfuel, e.g. split firewood or fuel chips. After processing, only 28% of the tree becomes sawn wood, etc. the remainder being residues [9].

3.1. Logging residues

About 60% of the total harvested tree is left in the forest and non-commercial species are often felled and left at site to rot or to make logging easier. Practices such as sawing and squaring logs in the forest, rather than at the sawmill, wastes a further 8–10% and 30–50%, respectively [10].

Table 4
Sources and types of residue

Source of residue	Type of residue
Forest operations	Branches, needles, leaves, stumps, roots, low-grade and decayed wood, slashings and sawdust
Sawmilling and planning	Bark, sawdust, trimmings, split wood, planer shavings
Plywood production	Bark, core, sawdust, veneer clippings and waste, panel trim, sanderdust
Particleboard production	Bark, screening fines, panel trim, sawdust, sanderdust

Source: [7].

Table 5
Proportion of residues generated in selected forest products industries[a]

	Sawmilling[b] (%)	Plywood manu. (%)	Particleboard manu. (%)	Integrated operations (%)
Finished product (range)	45–55	40–50	85–90	65–70
Finished product (average)	50	47	90	68
Residues/fuel	43	45	5	24
Chips and part.	34–15%[c,d]			
Bark	28–21%			
Sawdust	16–23%			
Slabs and edgings	15–32%			
Shavings	5–1%			
Other	3–7%			
Losses	7	8	5	8
Total	100	100	100	100

Source: [7,12–14].
[a]Excluding bark.
[b]Air-dried.
[c]Coniferous.
[d]Non-coniferous.

Logging residues may appear to be an attractive fuel source, but removal and handling costs must be taken into consideration, as well as losses of valuable nutrients included in the green residues. By ensuring that a proper quantity of those green residues are left on-site or by using ash re-cycling, the soil nutrient content would not be decreased [11,8]. Sustainable utilisation of logging residues seems to offer a valuable source of raw material for production of densified biofuels.

3.2. *Mill-site-generated wood waste*

Approximately 45–55% of the log input to a sawmill or plywood plant becomes waste [12–14,7]. The actual quantity of residues differs from plant to plant and depends on several factors, such as wood properties, type of operation and maintenance of the plant [7]. Average figures typical for each type of industry are presented in Table 5.

All wood waste and bark has a value as fuel. The following main categories could be found:

(1) *Bark*: The bark content is 10–22% of the total log volume depending on tree size and species. Bark could be used directly as fuel or it could be used for production of densified fuels.
(2) *Coarse residues*: Such as slabs, edgings, off-cuts, veneer clippings, sawmill and particle-

board trim. These residues may be used for energy purposes and they also have a value as raw material for pulp and particleboard.

(3) *Cores*: Obtained from plywood peeler logs are generally used as roundwood in sawmills or as pulpwood.

(4) *Sawdust*: Is a product of sawmilling. It is the main raw material base for production of densified fuels. The other utilising option is for particleboard production.

(5) *Planer shavings*: are a result of dimensioning and smoothing of sawn wood, plywood and particleboard during the finishing stage. The material is ideal for particleboard production. It is also a good raw material for production of densified fuels.

(6) *Sanderdust*: Produced during the abrasive sanding of sawn wood, plywood and particleboard during the finishing stage. Due to its size and very low moisture content it is well suited for direct firing and densifying.

(7) *Particleboard waste*: the amount is about 5%. This material is often re-cycled in the production process [7].

3.3. Integrated production

The sawmilling and plywood industries produce between 40–55% of waste from their incoming roundwood supply. This amount is sufficient to meet their own energy requirements [7]. However, particleboard production produces little waste, i.e. 5–10%. This quantity is insufficient to cover the needs for heat in these types of industries. This could probably be solved by integration [15]. Sawmilling, veneer, plywood and particleboard production in combination with upgrading for fuel purposes, have good possibilities for integration, with the advantages of shared waste handling processing facilities and services, and the maximum benefit derived from the use of the residues as industrial raw material and fuel (e.g. production of densified fuels). The surplus energy could be fully and economically used to best advantage, but the scale of such a complex may be beyond the means of developing countries [7].

3.4. Alternative use of residues

Residues derived from the forest industries normally have alternative uses as chips for pulp production, raw materials for particleboard and fibreboard production, or as fuel. The level of utilisation is dependent on demand. Table 6 shows the alternative uses of by-products.

Alternative markets and the sale value of wood residues must be taken into consideration when doing feasibility studies for specific plants. The use of residues to cover the internal need of energy is often the main utilising channel for these raw materials. However, direct sales of these products for energy purposes, such as for production of densified fuels (e.g. production of pellets or briquettes), is becoming attractive in several developed countries [6].

Table 6
Alternative use of by-products

Industry	By-product	Use
Sawmilling	Edgings and slabs	Low-cost building materials, woodfuel and raw material for pulp
	Barked edging chips	Raw material for pulp and woodfuel
Plywood	Peeler log cores	Sawn wood, poles
	Core chips	Raw material for pulp
	Veneer chipping and chips	Woodfuel
Particleboard	Uses all the above-mentioned residues as raw material, and the majority of residues are re-cycled in the process	

Source: [7].

Table 7
Biomass energy potentials and current use in different regions (EJ/a) (EJ = 10^{18})

Biomass potential	North Amer.	Latin Amer.	Asia	Africa	Europe	Middle East	Former USSR	World
Woody biomass	12.8	5.9	7.7	5.4	4.0	0.4	5.4	41.6
Energy crops	4.1	12.1	1.1	13.9	2.6	0.0	3.6	37.4
Straw	2.2	1.7	9.9	0.9	1.6	0.2	0.7	17.2
Other	0.8	1.8	2.9	1.2	0.7	0.1	0.3	7.6
= Potential, Sum (EJ/a)	19.9	21.5	21.4	21.4	8.9	0.7	10.0	103.8
Use (EJ/a)	3.1	2.6	23.2	8.3	2.0	0.0	0.5	39.7
Use/potential (%)	16	12	108	39	22	7	5	38

Source: [16–18].

4. Potential of biomass for production of densified fuels

Table 7 shows that the total sustainable worldwide biomass energy potential is about 100 EJ/a (the share of woody biomass is 41.6 EJ/a), which is about 30% (the share of woody biomass is 12.5%) of total global energy consumption today. Large potentials are available in North America, Latin America, Africa, Europe and even the Former USSR [16–18].

According to the European Commission's White Paper [19], the overall aim is to double the share of renewable energy from 6 to 12% of the total energy consumption in the European Union by 2010. According to this White Paper, the major part of this renewable energy could come from woody biomass. This means that, additionally, over 160 million m^3 of woody biomass per year (1 EJ/a) would be used for energy in Europe.

The wood residues potential is especially important in countries where forests cover a considerable part of the whole land area, e.g. North America and the Nordic countries. It is obvious that the potential from wood residues is in the range of about one-fourth of the overall potential of all investigated biomass streams [16].

This is similar to the biomass potential from agriculture. Here, the potentials are high in those regions with large agricultural areas, e.g. Europe (EU) and North America [16]. The regional distribution of the potentials from energy crops that have a share of about 60% of the overall biomass resources investigated here correlates with the available agricultural area. Therefore, the potentials are high in countries with vast agricultural areas and low in countries with small land resources [16,20].

The use of biomass differs significantly throughout the world. Residues produced at industrial processing sites, like bark and sawdust in sawmills, are currently the largest commercially used biomass source [16]. About 40 EJ/a of available biomass is used for energy (Table 7). Nearly 60% of this biomass is used only in Asia. Compared with this, the biomass use in industrialised areas like North America of Europe is fairly low [16].

5. Biofuel trade

Traditionally, all biomass fuels are used more or less in the same geographical region in which they are produced [21]. In recent years, this pattern has been changed, especially in Northern Europe, by large-scale use of re-cycled wood, forest and wood residues and densified biofuels for district heating [22].

Solid biofuels like wood residues (e.g. industrial by-products: bark and sawdust, re-cycled wood), upgraded biofuels (e.g. wood pellets, briquettes) and wood chips are today traded, e.g. in Europe and North America. In several countries there is growing interest in international biomass trade because this can provide biomass fuels at lower prices [22].

6. Discussion and conclusions

Biomass, especially woody biomass and energy crops, is already an important energy carrier contributing substantially to cover energy demands in many parts of the world. This energy carrier has the potential to contribute even more to provide energy to substitute the use of fossil fuel energy, especially in industrialised countries as well as in developing countries. But the exploitation of this potential is only advisable if there are promising economic and/or environmental effects. An important aspect is the assessment of the potentials and appraisal of resources in the setting of targets and limits for their practical utilisation. There is also an on-going discussion on the acceptability and availability of renewable energy. International biofuel trade is going to be an important factor in the future. These facts are beneficial when considering production of densified biofuels based on biomass.

Biomass has a large energy potential. A comparison between the available potential with the current use shows that, on a worldwide level, about two-fifths of the existing biomass energy potential is used. In most areas of the world the current biomass use is clearly below the available potential. Only for Asia does the current use exceed the available potential, i.e. non-sustainable biomass use. Therefore, increased biomass use, e.g. for upgrading is possible in most countries. A possible alternative is to cover the future demand for renewable energy, by increased utilisation of forest residues and residues from the wood-processing industry, e.g. for production of densified biofuels.

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