MSc Program
Renewable Energy in Central and Eastern Europe

Is there a serious potential for bio-energy based resources for biofuels (especially 2nd generation) taking into consideration that Is there a serious potential for bio-energy based resources for biofuels (especially 2nd generation) taking into consideration that there is no competition with resources for food production or other existing production streams?

A Master's Thesis submitted for the degree of
"Master of Science"

supervised by
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Gänserndorf, August 2010

Affidavit

I, **Tobias Legerer**, hereby declare

1. that I am the sole author of the present Master Thesis, " Is there a serious potential for bio-energy based resources for biofuels (especially 2nd generation) taking into consideration that there is no competition with resources for food production or other existing production streams?", 134 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master Thesis as an examination paper in any form in Austria or abroad.

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Abstract

The world used an unbelievable 2.079 trillion[1] liters of liquid fuels in 2007 for transportation. Biofuels contribute only a very small amount yet.
Biomass is by far the biggest contributor to bioenergy and offers a big potential for biofuels. A big potential is seen in 2nd generation biofuels – especially for those from lignocellulosic sources – because they do not compete for food resources.

Biofuels had a pretty good start and looked like the one big alternative in substituting fossil fuels. Technical modifications for vehicles were quite low, energy density high, but then the discussion about food or fuel rose and biofuels were made responsible for rising commodity prices.
At the moment everybody is talking about electric mobility and electric vehicles. And for the public it looks as if electric vehicles are the only valid alternative in individual transportation.
From the author's point of view biofuels can make a strong contribution to the reduction of greenhouse gases if resources are used properly and any source that is already used by the food industry is not considered.

The special focus of this work is on agricultural and wood-based residues and wastes that form the vast majority of currently used biomass. Their long term potential is mainly dependent on the future developments in agricultural and forestry production.
These residues and wastes have one very big advantage: they are not used by the food industry, or they are not used at all. But how big is the volume of these "free" or not yet used resources?
This paper finds an answer to the question if there is a serious potential for bio-energy based resources for 2nd generation biofuels taking into consideration that there is no competition with resources for food production or other existing production streams?

The 10 countries with the biggest wood resources (Russian Federation, Brazil, Canada, United States, China, Australia, Democratic Republic of Congo, Indonesia, Peru and India) and the EU27 are examined in detail focusing on residues from agriculture and forestry to figure out existing unused biomass potential for the

[1] International Energy Agency: Oil in the World. http://www.iea.org/stats/, 16.8.2010

production of biofuels from lignocellulosic material (2nd generation biofuels). Based on literature and online research information is condensed and calculations on unused biomass potentials in terms of volume and energy content are carried out.

The residue potential of 2,300 million tons of unused agricultural residues and 365 million tons of forestry residues together with 66 million tons of woody waste from municipal solid waste streams would theoretically lead to 589 billion liters of lignocellulosic Bioethanol. This amount would substitute more than 28% of the worldwide liquid fuel demand in 2007.
The available potential from municipal solid waste and landfill gas is hard to predict, as no qualified data was available, but it also has to be kept in mind, as it will be considerable.

Residues and waste material can provide a significant amount of resources for the production of 2nd generation biofuels without any competition with food industries and without any competition with industries that already use some of these residues and wastes. But 2nd generation biofuels still have some challenges to solve before becoming a success story.

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List of Abbreviations

BTL	Biomass to liquid
BDt	Bone dry ton
BIMAT	Biomass Inventory and Assessment Tool, Canada
CNG	Compressed natural gas
DED	Deutscher Entwicklungsdienst/German Development Service
EEA	European Environment Agency
EJ	Exajoule
EU	European Union
EU27	European Union (27 member states)
FAO	Food and Agriculture Organization of the United Nations
FAOStat	Website - statistical data collected and maintained by FAO
FASW	Forests available for woody supply
FOWL	Forest and other wooded land
FT	Fisher Tropsch
G-20	Group of Twenty Finance Ministers and Central Bank Governors
GDP	Gross Domestic Product
GW	Gigawatt
Ha	hectare
IBGE	Instituto Brasileiro de Geografia e Estatística/ Brazilian Institute of Geography and Statistics
IEA	International Energy Agency
IPCC	International Panel on Climate Change
kg	Kilogram
kWh	Kilowatt-hour
LNG	Liquefied natural gas
MDF	Medium Density Fiberboard
MSW	Municipal solid waste
MTce	Million tons of coal equivalent
Mtoe	Million tons of oil equivalent
MW	Megawatt
ODt	Oven dry ton
OECD	Organization for Economic Co-operation and Development
PJ	Petajoule
PPP	Purchasing Power Parity
PWh	Petawatt-hours
R&D	Research and Development
SNG	Synthetic natural gas
TWh	Terawatt-hours
UBF	Unused biomass factor
UNDP	United Nations Development Program
USDA FAS	United States Department of Agriculture Foreign Agricultural Service
W20	Water content 20%
W60	Water content 60%
WEO	World Energy Outlook

1 Introduction

In 2007 the worldwide liquid fuel consumption (final consumption) in the transportation sector was an unbelievable 2.079 trillion liters in 2007.[2]
Although 1st generation biofuels, especially Biodiesel and Bioethanol, are already produced in industrial scale and their production capacity increased several times over the last years they only deliver a small portion of the overall fuel demand. But Brazil is an example where politics recognized the possibilities for local production some decades ago and Bioethanol contributes a significant portion of the domestic fuel demand.
The biggest challenge faced by 1st generation biofuels is a social-economical one, as they were made responsible for raising food prices and the ethical discussion about the use of food resources for fuel production occurred.
Transportation accounts for about one third of the worldwide greenhouse gas emissions and biofuels have a significant better CO_2 balance than fossil fuels.
2nd generation biofuels especially when coming from lignocellulosic sources overcome the discussion about food or fuel. Fuel from wood and other lignocellulosic sources seems to be the big hope for the biofuel industry.
About 30% of the world (land area) is covered with wood. This seems like a big lignocellulosic potential. And there also seems to be some potential in the agricultural and the waste sector. But how big is it in reality?

1.1 Motivation

I work for the automotive industry for more than 17 years now and have always been fascinated by cars their technology especially by fast and powerful ones. A few years ago when 1st generation biofuels (especially Ethanol) came into the market I was certain that this would provide a real alternative to fossil fuel. I was part of the Austrian launch team that introduced and promoted Ford Flexifuel technology to the Austrian market and pretty sure that I have seen a possible future of transportation. Certain enough to buy a private Flexifuel car that offered me the possibility to either fill up with gasoline or Ethanol. Something I discovered in the early 90ies during a longer trip across Brazil driving an alcohol car. But I did not buy any Ethanol in Austria yet.

[2] International Energy Agency: Oil in the World. http://www.iea.org/stats/, 16.8.2010

Soon after I bought my car commodity prizes rose to a level that made Ethanol production in Austria no longer economical. And the discussion about the use of vegetables for food or fuel begun and is still ongoing.
But I'm still certain that biofuels can make a strong contribution to the reduction of greenhouse gases if resources are used properly and any source that is already used by the food industry is not considered.
Today everybody is talking about electric mobility and electric vehicles. And you get the impression, that electric vehicles are the only valid alternative in individual transportation. But very few models can be bought and even fewer can be seen on the streets. Many problems on the way to mass production are still to be solved. But public interest for the topic is so big that it puts biofuels into a niche.
I think we have to go for every suitable alternative in the transportation sector. And biofuels are there alongside the necessary technology for their use in transportation. One of the biggest advantages of biofuels compared to batteries is their high energy density. So let's have a look if there is a theoretical potential.

1.2 What is the core objective / the core question?

The objective of this master thesis is to figure out a realistic biomass potential for biofuels. This potential should come from sources that do not compete with food or fodder production. And it should not compete with other existing production businesses that use these sources to avoid price competition.
Is there still any potential for biofuels if we leave out everything that directly competes for resources that are already used for agriculture or might be for future agricultural production? There will always be a discussion on which parts of land could be used for food production or not.
So the core question is the following:

Is there a serious potential for bio-energy based resources for biofuels (especially 2nd generation) taking into consideration that there is no competition with resources for food production or other existing production streams?

By trying to answer this question for selected countries another question helped: What could be the special "power" of 2nd generation biofuels and the possibilities that go along with the usage of lignocellulosic material? Something we cannot eat.

Therefore this work concentrates on existing use of resources and is looking for residue streams from agriculture, forestry and municipal waste that are not yet used. No attention is given to theoretical biomass potentials that could be made available under certain circumstances.

1.3 Citation of main literature

In the search for an answer to the question raised above different country reports from the IEA Task 40: [Walter, A. et. al., 2009] for Brazil, [Bradley, 2009] for Canada, gave valuable information about the possible bio-energy based resources for biofuels in these countries and made it easier to gather relevant information.
In [Jölli, D. et. al., 2005] the basic figures for the calculation of unused biomass in the current agricultural and forestry production and possible sustainable extraction could be found and made the calculation of residues potential possible.
A lot of general information about bioenergy was found in [Bauen, A. et. al., 2009], as well as valuable information about 1st and 2nd generation biofuels especially on their challenges that was found in [Sims, R. et. al., 2008].

1.4 Structure of work

Chapter 2 gives an overview about the pathways from bioenergy to biofuels delivering a description of different kind of feedstocks that are used in biofuel production, an overview about biofuels and their production routes and ends with various challenges that are still on the way of biofuels harming their success.
Chapter 3 deals with biomass potential in general as to give an idea of the size of the theoretical energy potential in general and looks at different sources for biofuels.
Chapter 4 researches the specific biomass potential for 10 selected countries plus the EU 27 and shows their unused available potential for biofuels.
Chapter 5 answers the main question and concludes the paper.

1.5 Method of approach

This work is based on literature and internet research. Starting with the assumption that forests that cover 30% of the total land area of the world are the biggest source for lignocellulosic material. 10 countries were selected with regard to their wood area and together with the EU27 investigated in detail.

2 From Bioenergy to Biofuels

2.1 Overview

Bioenergy[3] is expected to become one of the key energy resources for global sustainable development. However, bioenergy cannot be infinite, because the land area available for biomass production is limited and a certain amount of biomass should be reserved for food (and fodder) and materials.

At present forestry, agricultural and municipal residues and wastes are the main feedstock for the generation of electricity and heat from biomass and therefore the main source for bioenergy. In addition a very small share of sugar, grain and vegetable oil crops are used as bioenergy feedstock for the production of liquid biofuels.

Following the IEA World Energy Outlook 2007[4] renewable energy (hydro, solar, wind, geothermal and bioenergy) supplies some 64 EJ (1,528 Mtoe) globally, which represents 12,7% of the global annual primary energy consumption, of which bioenergy supplies 77% (49.36 EJ or 1,178.84 Mtoe) and therefore delivers by far the biggest share of renewable energy.

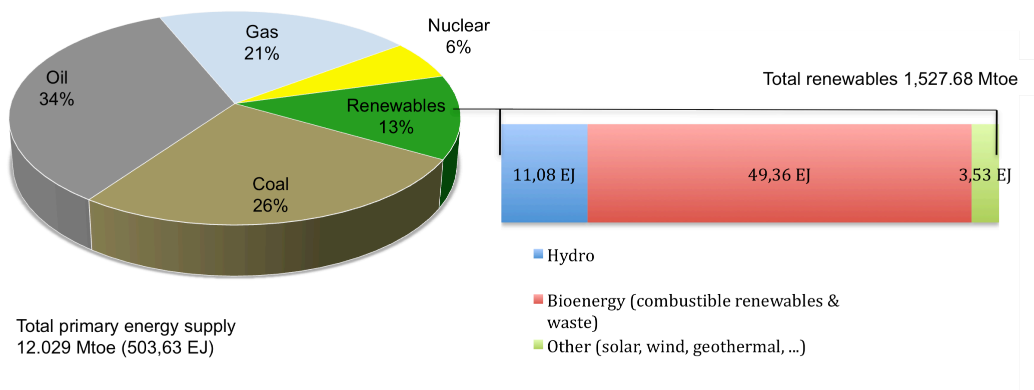

Figure 1: Share of bioenergy in the world energy supply mix; Source: [International Energy Agency 2007]

Biomass is all matter with organic origin that is carbonaceous material (plants, animals, residues, dead matter which is not yet fossil, all material derived from organic matter – e.g. paper, alcohol or organic waste).

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[3] Bauen, A. et al.: Bioenergy – a Sustainable and Reliable Energy Source. In: IEA Bioenergy ExCo 2009:06, IEA Bioenergy, 2009

[4] International Energy Agency: World Energy Outlook 2007 – China and India Insights. International Energy Agency, 2007

Plant biomass is used for a large number of purposes: energy and fuel, food, feed, clothing, paper, building materials and others. This causes direct competition between different applications using the same biomass sources but also competition for land on which to grow biomass and other uses of the same land (e.g. nature protection).[5]

Biomass includes a wide range of products and by-products from forestry and agriculture as well as municipal and industrial waste streams. It thus includes: trees, arable crops, algae and other plants, agricultural and forest residues, effluents, sewage sludge, manure, industrial by-products and the organic fraction of municipal solid waste. After a conversion process, the biomass can be used as a fuel to provide heat, electricity or transport fuel, depending on the conversion technology and the type of primary biomass.[6]

Bioenergy (biomass energy) is solar energy stored in the chemical bonds of carbon and hydrogen chains as a result of photosynthesis or the metabolic activity of organisms. Biomass can be referred to as the nature's solar battery reflecting its ability to store energy until required which makes it more predictable and responsive than the sun or wind.[7]

Biofuel[8,9] is any fuel that is derived from biomass like oil plants, cattle and pig manure, residual waste, wood and other lignocellulosic material.

Due to their "compatibility" with current engine technologies and their ability to subsidize fossil fuels biofuels play an important role in alternative transportation scenarios.

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[5] European Environment Agency: Maximizing the Environmental Benefits of Europe's bioenergy potential. In: EEA Technical report No. 10/2008, European Environment Agency, 2008

[6] European Environment Agency: How much Bioenergy can Europe produce without harming the Environment? In: EEA Report No. 7/2006, European Environment Agency, 2006

[7] Bauen, A. et al.: Bioenergy – a Sustainable and Reliable Energy Source. In: IEA Bioenergy ExCo 2009:06, IEA Bioenergy, 2009

[8] Gruss, P. et al.: Die Zukunft der Energie. Verlag C.H.Beck, 2008

[9] Nemenyi, N. et al.: Liquid Biofuels. In: Renewable Energy Textbook. 2009

A general classification of generations of biofuels has been made according to the technological stage meaning that first generation biofuel technology is already existing, whereas second generation biofuel technology is in pilot scale or under implementation. Third generation biofuel technology is still in research stage.

First generation biofuels are made from sugar, starch, vegetable oil, or animal fats using conventional technology. Most of these feedstocks are in the food chain and therefore the production of biofuels competes with food production and might cause higher prices due to the competition for limited resources.
Products: ethanol from traditional sources, vegetable oil and biodiesel and biogas from digestion.

Second generation biofuels are made from non-food crops, agricultural and forestry residues, chiefly lignocellulosic materials. Therefore they do not directly compete with food production for feedstocks. But specially grown energy crops will compete for land and water with food crops.
Products: lignocellulosic ethanol, Fisher-Tropsch Liquids (FT) or Biomass to Liquid (BTL), NexBTL, Biobuthanole, Bio-methane.

Biofuel from algae and BioHydrogen are seen as **third generation biofuels**.
Algae are low-input, high-yield feedstocks and can be used as a resource for biofuel production. Yields for Algae are expected to deliver up to 20 times and above more energy per hectare compared to conventional land crops such as rapeseed.[10]
Products: Bio-methane, BTL, lignocellulosic ethanol, Bio-diesel, BioHydrogen.

2.2 Biomass as Feedstock

Biomass is the most important renewable energy source today. In 2007 total bioenergy (combustible renewables and waste) supply was 1,178 Mtoe (13,7 PWh or 49,4 EJ) with around 90% of this being of woody origin (lignocellulosic material)[11]. Agriculture contributes 10% to the bioenergy mix. Municipal solid wastes and landfill gas contribute 3% but have a large untapped potential.

[10] Oilgae: Algae Biodiesel Reference. http://www.oilgae.com/algae/oil/biod/ref/ref.html, 13.5.2010
[11] Bauen, A. et al.: Bioenergy – a Sustainable and Reliable Energy Source. In: IEA Bioenergy ExCo 2009:06, IEA Bioenergy, 2009

Based on data from the IPCC 2007 found in [Bauen, A. et al., 2009], the different sources for biomass and their portion in the primary bioenergy mix can be seen in the figure below.

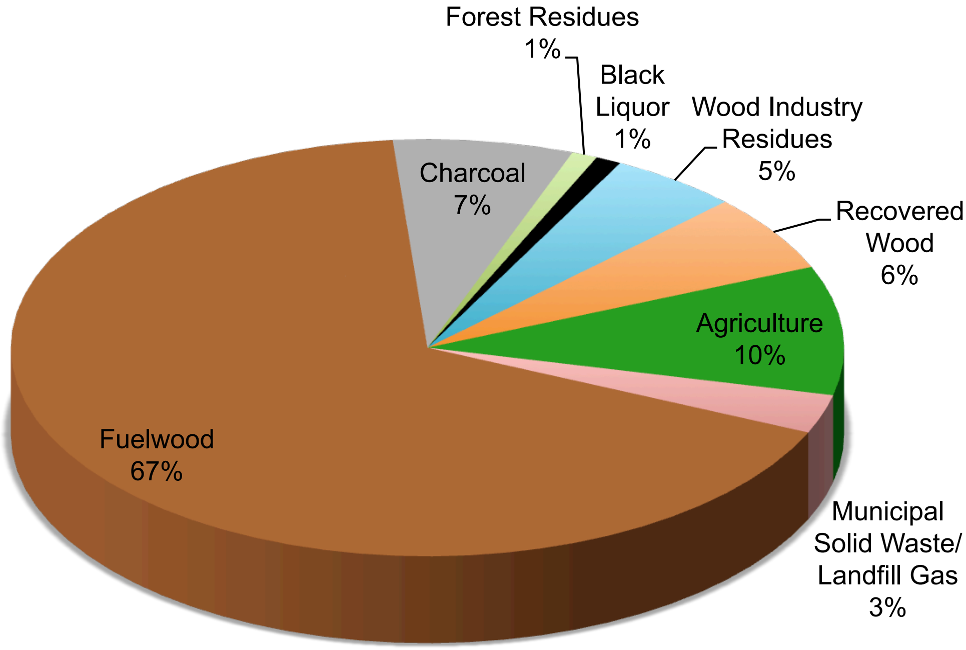

Figure 2: Share of biomass sources in the primary bioenergy mix; Source: [Bauen, A. et al., 2009]

Fuelwood accounts for 2/3 of bioenergy which displays the fact that the main application for bioenergy is still cooking and heating. Only small contributions come from forest residues or other residue streams.

2.2.1 Feedstock classification

Besides other classification biomass resources can be structured by their origin (where do the come from) and by feedstock usage (which generation of biofuels can be produced).

First generation feedstocks considering *oil plants* like suflower or rapeseed*, cereals like* wheat, rye, tricicale or maize and *sugar plants* like sugar beet or sweet sorghum*.* These plants can be used as input fuel for 1st generation biofuels.

Second generation feedstocks or lignocellulosic plants considering *woody plants* (from short rotation forestry) and *herbaceous lignocellulosic plants* (grass or crop residues) summing up all feedstock that can be used as input fuel for 2nd generation biofuels.

Lignocellulose is the botanical term used for biomass from woody or fibrous plant materials being a combination of lignin, cellulose and hemicellulose polymers interlinked with a heterogeneous matrix. The relative importance of each of the polymers can vary significantly with the feedstock type.
The combined mass of cellulose and hemicellulose in the plant material varies with species but is typically 50-75% of the total dry mass with the remainder consisting of lignin (In the biochemical conversion process lignin represents a potential valuable source of chemical feedstock. In ethanol plants it may be combusted to provide process heat and power. In the thermo-chemical route all polymers including lignin are converted to synthesis gas.).

Feedstocks from lignocellulosic materials include cereal straw, wheat chaff, rice husks, corn cobs, corn stover, sugarcane bagasse, nut shells, forest residues, wood processing residues and purpose grown energy crops such as vegetative grasses and short rotation forests.

Looking at the origin of biomass resources we see biomass coming from agriculture, forestry or production (residues - additional secondary sources derived from agro- and wood industries, waste sources from construction and demolition, and municipal solid waste.[12]).

Agricultural feedstocks include all traditional plants from the food industry mentioned above for the production of 1st generation biofuels (plants that contain oil, sugar or starch), specially grown energy plants (short rotation trees and grass) and residues from agricultural production (wastes associated with harvest, such as straw or stubble or stover - parts of the plant that are not used for food production).

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[12] Biofuels Research Advisory Council: Biofuels in the European Union. Biofuels Research Advisory Council, March 2006

New energy crops, particularly perennial grasses (e.g. Miscanthus, switchgrass, prairie grass) and short-rotation forest species (e.g. Eucalypthus, poplars, Robinia) can be high yielding when grown under good conditions and harvested over long seasons to provide a steady supply stream at the processing plant, thus avoiding costly storage of large biomass volumes for several months between harvests.

Agricultural residues can provide an additional contribution of biomass for biofuel production. These residues include straw, stubble, stalk, cob, husks and peelings. Residues from fruit trees and nuts include fibers, husks and shells. The availability of these residues for energy purposes is restricted by technical, environmental and economic factors. Crop residues fulfill also an important ecosystem service essential to maintenance of soil fertility and erosion protection.[13]

Unused biomass from agriculture can be divided into two categories: parts of the plant which are retained on the field and losses of parts of the plant due to the harvest methods.[14] This paper will not deal with the later ones.

Forest feedstocks

The forest industry has recently expressed strong interest in becoming providers of biomass for bioenergy (for heat and power generation) and biofuel production using both softwood and hardwood residues from existing wood processing plants. Residues from the wood processing industry can provide low-cost feedstocks already collected on site. Bark, off-cuts, sawdust etc. are particularly attractive for thermo-chemical processing due to their low moisture content (<20%) and uniform properties.

Unused biomass in forestry can be divided into woody forest residues and primary timber processing mill residues.[12] This paper will concentrate on woody forests residues that remain in the forest and are not used for production of energy.

Urban feedstocks (waste & production residues)

The annual per capita production of municipal solid waste (MSW) mainly household waste varies from less than 100 kg in developing countries to more than 700 kg in

[13] Fischer, G. et al.: Assessment of Biomass Potentials for Biofuel Feedstock in Europe: Methodology and Results. IIASA Land Use Change and Agriculture Program, July 2007
[14] Jölli, D. et al: Unused Biomass Extraction in Agriculture, Forestry and Fishery. In: Seri Studies, Sustainable Europe Research Institute (SERI), March 2005

industrialized countries and is closely correlated with the gross domestic product of a country. MSW consists of biodegradable waste (food and kitchen waste, green waste and paper) recyclable material (glass, cans, metal, plastic, etc.) inert waste (construction and demolition waste) and composite waste (clothing, waste plastic like toys, etc.). Biodegradable waste could be used for biogas production. When disposed in landfills it occurs as landfill gas.

Another potential secondary source of biomass is from urban wood residues (such as demolition timber, pallets, containers, packaging). However this maybe less suitable feedstock for biofuels given its potential variability and it could better suit for direct combustion for heat.

Potential feedstock also comes from animal production were manure can be used for biogas production although the availability is varying due to different forms of animal husbandry.

Following the classifications from above the reminder of this work will concentrate on different feedstocks for the generation of 2nd generation biofuels as described in the table below because these feedstocks do not compete with food production.

Table 1: Feedstock for 1st & 2nd generation biofuels

Feedstock	Source
1st generation	
Oil plants	Agriculture
Starch plants	Agriculture
Sugar plants	Agriculture
Manure	Urban
2nd generation	
Lignocellulosic plants	
Timber	Forestry
Wood residues	Forestry
Grass	Agriculture
Energy crops	Agriculture
Crop residues	Agriculture
Municipal solid waste	Urban

2.3 From Biomass to Bioenergy

To utilize energy from biomass a conversion process is necessary. This process can be a *thermo-chemical* conversion (combustion, gasification and pyrolysis), a *bio-chemical* conversion (digestion and fermentation) or *extraction* (e.g. for biodiesel production).

The production of heat by the direct combustion of biomass is the leading bioenergy application throughout the world and is often cost-competitive with fossil fuel alternatives.[15]

There are many bioenergy conversion routes that can be used to convert raw biomass feedstock into a final energy product. Several conversion technologies have been developed that are adapted to the different physical nature and chemical composition of the feedstock and to the energy service required. Upgrading technologies for biomass feedstocks (pelletisation, pyrolysis, etc.) are being developed to convert raw bulky biomass into denser and more practical energy carriers for more efficient transport, storage and convenient use in subsequent conversion processes.

The figure below gives an overview of different biomass sources, conversion processes and final energy products, here biofuels.

[15] Bauen, A. et al.: Bioenergy – a Sustainable and Reliable Energy Source. In: IEA Bioenergy ExCo 2009:06, IEA Bioenergy, 2009

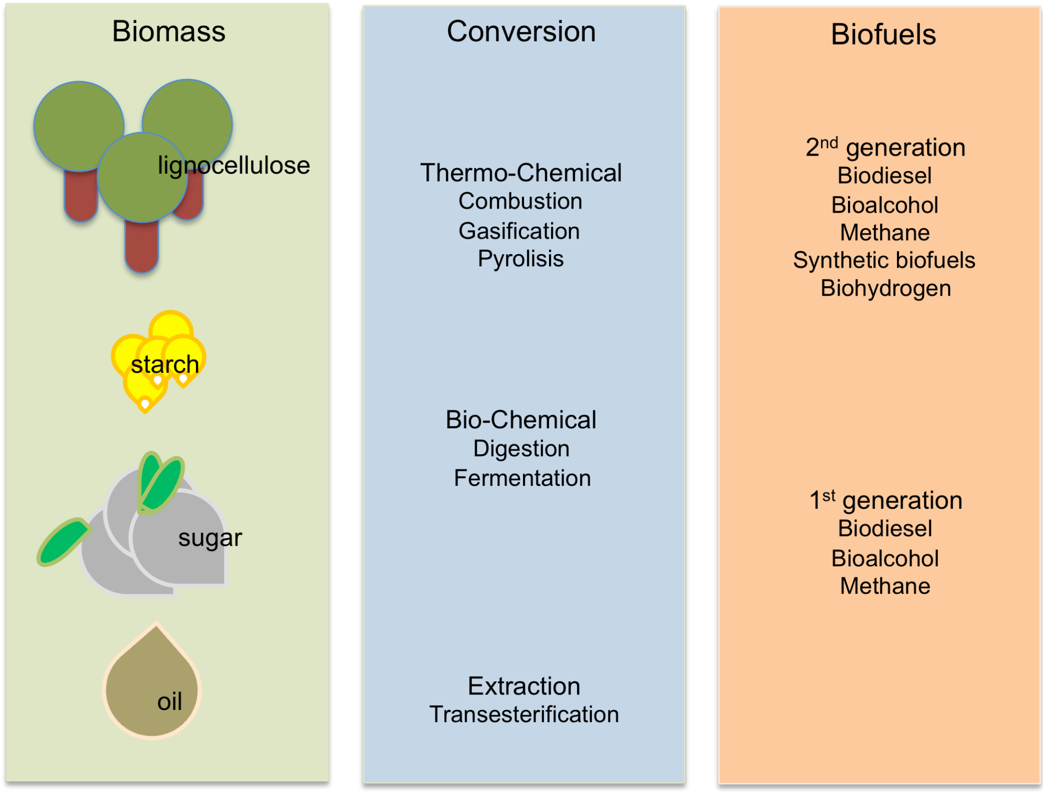

Figure 3: From biomass to biofuels

2.4 Biofuels

The following chapter gives an overview on various biofuels, their actual development stage and possible gaps for their future deployment. Focus is given on 1st and 2nd generation biofuels as 3rd generation biofuels (biofuels from algae, Biohydrogen) are still in a very early research stage (although they seem very promising).

2.4.1 1st generation biofuels

In the transport sector 1st generation biofuels are widely deployed in several countries. Bioethanol from starch and sugar crops and biodiesel from oil corps and residual oils and fats are the main products. Production costs of current biofuels vary significantly depending on the feedstock used (due to price volatility on the world market) and on the scale of the plant.

The production of 1st generation biofuels is characterized by mature commercial markets and proven technologies but they face both social and environmental challenges.

2.4.1.1 Bioethanol

Bioethanol (ethyl alcohol) is a liquid biofuel that is currently mainly produced from organic feedstocks containing sugars - such as sugarcane, corn, wheat, sugar beet, molasses, and other crops/feedstocks containing sugar or starch - through a fermentation process.

The traditional biological conversion routes for Bioethanol are well established. The main raw materials needing to be extracted are sucrose or starch. For sucrose from sugarcane or sugar beet crops, the juices are first mechanically pressed from the cooked biomass followed by fractionation.

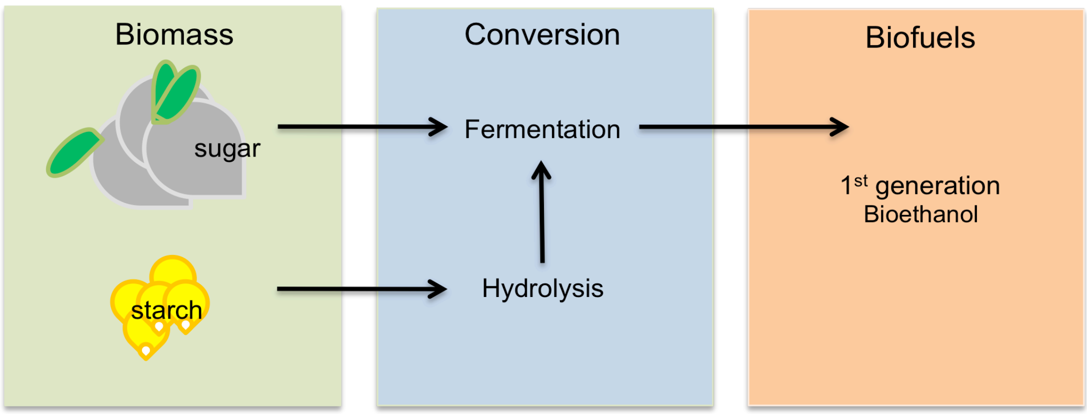

Figure 4: Schematic conversion process for 1st generation Bioethanol

The sucrose is metabolised by yeast cells fermenting the hexoses and the ethanol is then recovered by destillation.
Starch crops must first be hydrolysed into glucose before the yeast cells can convert the carbohydrates into ethanol. Pre-treatment consists of milling the grains of corn, wheat or barley followed by liquefaction and fractionation. Acidic or enzymatic hydrolysis then occurs prior to fermentation of the resulting hexoses. Although highly efficient, the starch grain based route consumes more energy than the sucrose based route. From the fermentation process onwards both routes are almost identical. Overall using either sugar or starch is a mature technology to which few significant improvements have been made in recent years.

By far the largest volume of biofuel production comes from ethanol, produced from a wide range of feedstocks but with 80% coming from corn (maize) and sugar cane. Corn ethanol is mainly in the US (24.4 billion liters in 2007) and sugarcane ethanol in Brazil (18 billion liters in 2007). The world production has tripled between 2000 and 2007 to reach over 25.5 Mtoe.[16]

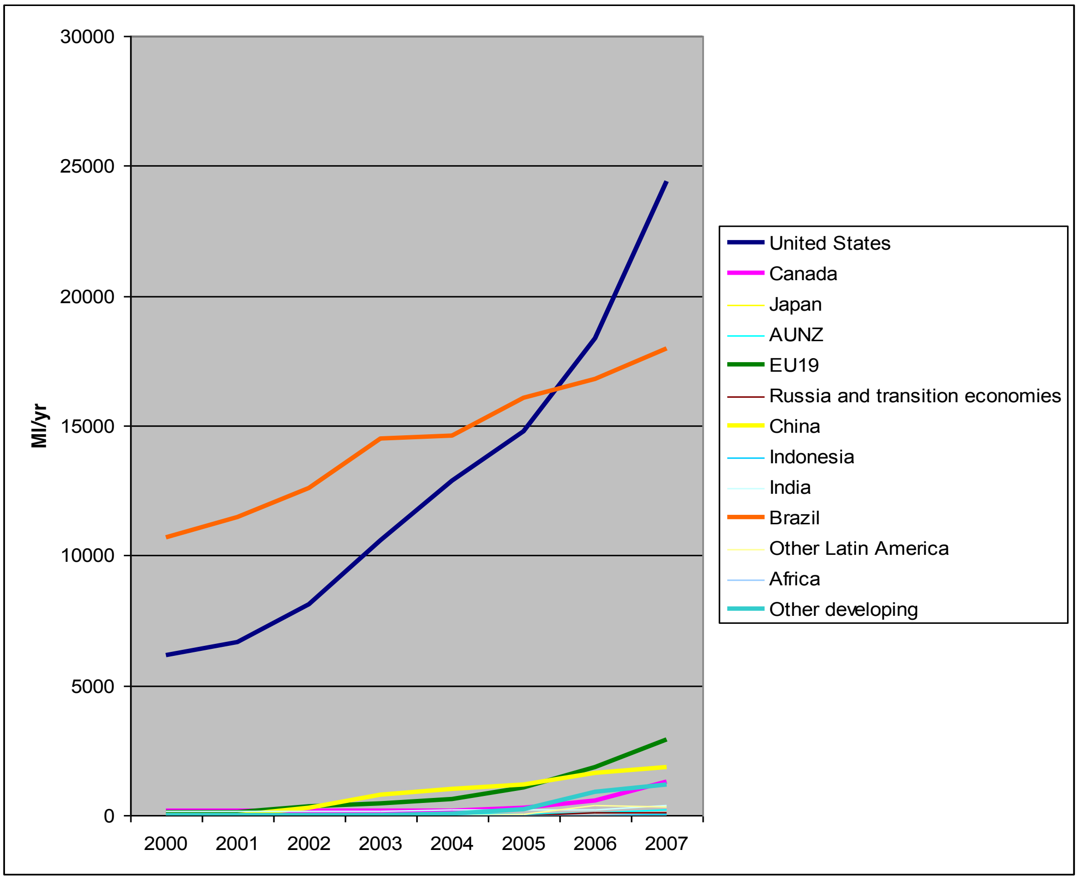

Figure 5: Global ethanol production trends in major producing countries and regions; Source: [Sims, R. et al, 2008]

[16] Sims, R. et al.: From 1st to 2nd Generation Biofuel Technologies – An Overview of Current Industry and RD&D Activities. IEA Bioenergy, November 2008

2.4.1.2 Biodiesel

Biodiesel – also called FAME for fatty acid methyl esters - is a general name for alkyl-esters from organic feedstock in forms of vegetable oil, animal fat and aquatic biomass (algae).

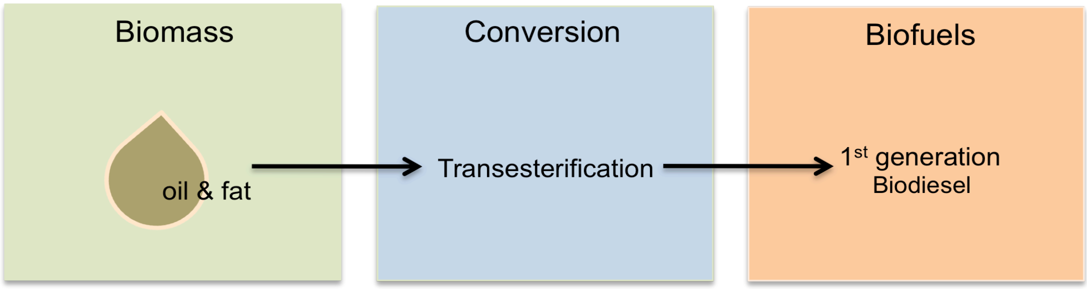

Figure 6: Schematic conversion process for 1st generation biodiesel

The production of biodiesel from converting raw vegetable oil and fats to esters is relatively simple at either small or large scale and is well understood. It is based on trans-esterification of vegetable oil or fats through addition of methanol (or other alcohols) and a catalyst, giving glycerol as a co-product.
The basic inter-ersterification process for biodiesel production at normal pressure and ambient temperature can easily be reproduced although the quality of the resulting fuel can vary. During oil-pretreatment the water content and free fatty acids in the incoming lipids (oil or fat) are monitored. Then alcohol and catalyst are mixed. The mixture is then charged into a closed reaction vessel and oil or fat is added. After complete reaction two major products - glycerin and Biodiesel – exist. The two components are then separated and the excess alcohol is removed. Biodiesel is then purified.
During the process of converting vegetable oil or animal fat into biodiesel many unwanted reactions and chemical substances can develop and contaminate the fuel.

The potential for Biodiesel is more limited than for ethanol. Production increased by a factor of 10 from 2000 to 2007 to reach around 8.6 Mtoe or 0.2% of total diesel fuel demand. [17]

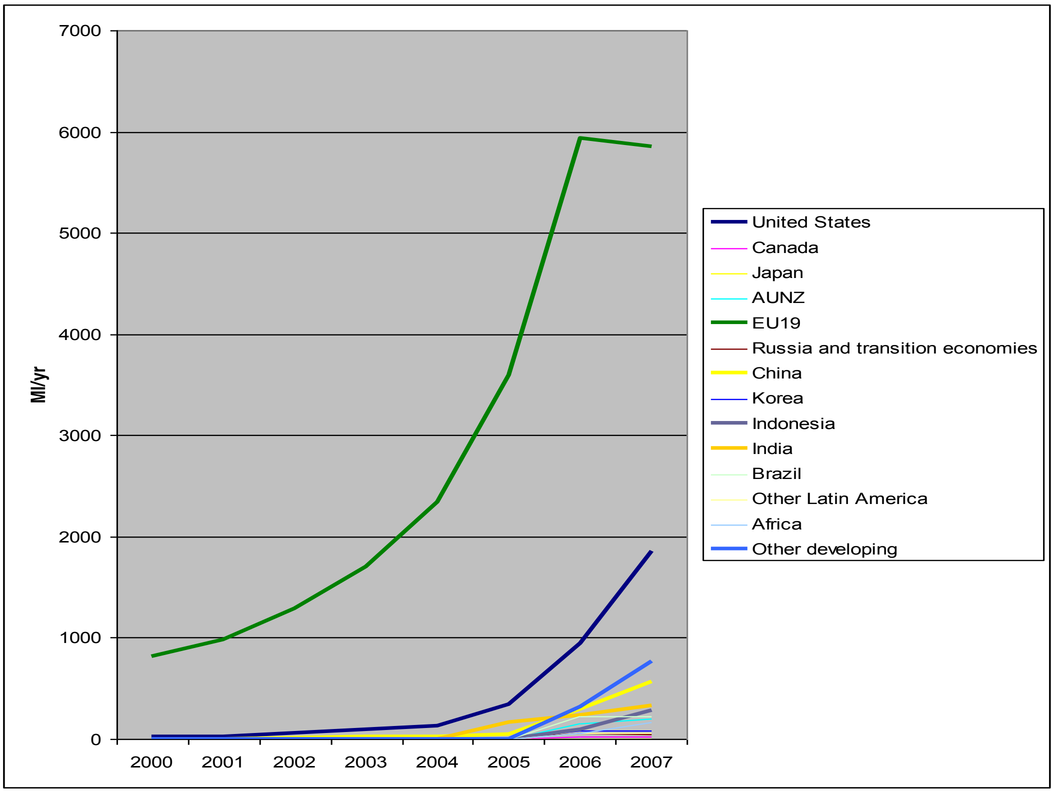

Figure 7: Global biodiesel production trends in major producing countries and regions; Source: [Sims, R. et al., 2008]

Concerns at deforestation have also resulted from the various initiatives to produce more vegetable oil feedstocks for biodiesel in several countries, particularly palm oil in Indonesia and Malaysia and soybean in Brazil. Consequently there has been considerable interest in other oil-bearing crops that can grow on marginal or semi-marginal lands. Jatropha is one example but like most crops without adequate water and nutrient replenishment it cannot produce high oil yields over the long term. Nevertheless investments in several large plantations have been made.

2.4.1.3 Biogas – Synthetic Natural Gas (SNG) – Bio-methane

Biogas is a mixture of methane and carbon dioxide produced by an anaerobic digestion process. [18] Almost any organic material can be processed with anaerobic

[17] Sims, R. et al.: From 1st to 2nd Generation Biofuel Technologies – An Overview of Current Industry and RD&D Activities. IEA Bioenergy, November 2008
[18] Wellinger, A.: Biogas. In: Script Renewable Energy in CEE, Module 2. Continuing Education Center, TU Wien, 2009

digestion. This includes biodegradable waste materials such as waste paper, grass clippings, leftover food, sewage and animal waste. The exception to this is woody wastes that are largely unaffected by digestion as most anaerobes are unable to degrade lignin. Anaerobic digesters can also be fed with specially grown energy crops such as silage as the substrate for dedicated biogas production (biogas plant).

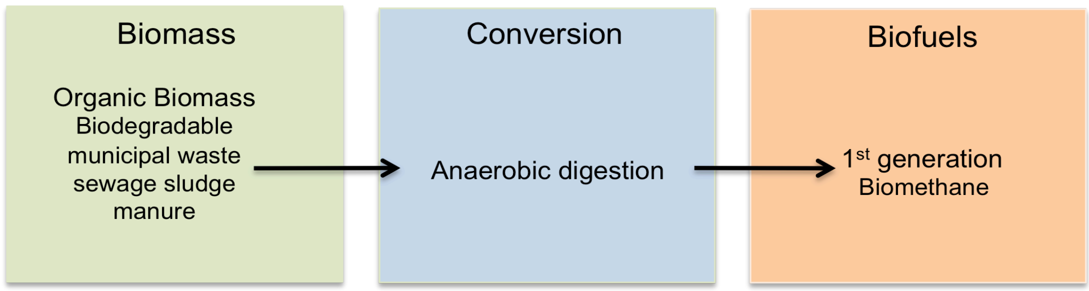

Figure 8: Schematic conversion process for 1st generation biogas

The full process can be considered to occur in four stages:

- Hydrolysis: in which complex molecules are broken down to constituent monomers
- Acidogenesis: in which acids are formed
- Acetogenesis: or the production of acetate
- Methanogenesis: in which methane is produced from either acetate or hydrogen

The utilization of biogas in internal combustion engines is a long established and extremely reliable technology. For many applications the quality of biogas has to be improved. The main components that may require removal in an upgrading system are H_2S, water, CO_2 and halogenated compounds.
Gas used as vehicle fuel and gas for grid integration have the highest quality and upgrading requirements. [19]
Of the 230 PJ of biogas produced in the EU in 2007 only a very small part was used as a vehicle fuel.[20]

[19] Wellinger, A.: Biogas. In: Script Renewable Energy in CEE, Module 2. Continuing Education Center, TU Wien, 2009
[20] Sims, R. et al.: From 1st to 2nd Generation Biofuel Technologies – An Overview of Current Industry and RD&D Activities. IEA Bioenergy, November 2008

2.4.2 2nd generation biofuels

Several technological conversion routes exist for the production 2nd generation liquid or gaseous biofuels from solid biomass (lignocellulosic biomass).
The use of lignocellulosic material as feedstock is the main advantage for 2nd generation biofuels, as they do not compete with food production.

2.4.2.1 Bioethanol

In principle the key steps involved are similar to those for production on 1st generation Bioethanol that converts starch into ethanol.

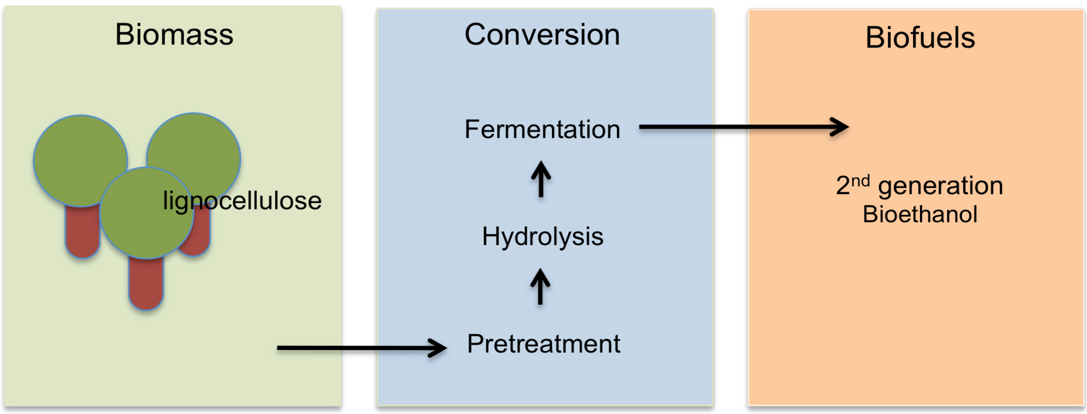

Figure 9: Conversion route for bioethanol 2nd generation

Biological agents specifically enzymes or micro organisms carry out a structured deconstruction of the lingocellulose into its base polymers and to further break down cellulose and hemicellulose into monomeric sugars including glucose and xylose. The sugars can then be fermented into ethanol.

Estimations in [Sims, R. et al., 2008] on the ethanol yields for different feedstocks range between 110 and 300 liters per ton dry matter and are summarized in the table below.

Table 2: Ethanol yield from different feedstocks; Source: [Sims, R. et al., 2008]

	Ethanol yield (liters/t)		**Energy yield (GJ/t)**	
			lower heating value 21.1 MJ/l	higher heating value 23.6 MJ/l
Feedstock				
agricultural residues	110	270	2.3	5.7
forest residues	125	300	2.6	6.3

A survey on biomass resources in Canada [Milbrandt, A. et al., 2008] found out that 1 metric ton of lignocellulosic biomass yields approximately 300 liters of ethanol. In comparison 1 ton of grains yield approximately 360 liters of ethanol.[21]

2.4.2.2 Fischer-Tropsch (FT) fuels

The aim of Fischer-Tropsch-synthesis is the production of liquid biofuels. Synthesis gas from biomass gasification is cleaned from higher hydrocarbons and sulfur and fed into the Fischer-Tropsch reactor. Gasoline and diesel of very high quality can be produced with this process.

In the thermo-chemical route, dry lingo-cellulosic biomass feedstocks are initially subjected to a severe heat treatment in the presence of a controlled amount of air or oxygen so that gasification takes place to produce syngas. This synthesis gas consists of a mixture of mainly CO and H_2 with some CO_2, methane and higher carbon compounds.
One of the main reasons for gasification of biomass is the wide range of application of the producer gas.

2.4.2.3 Bio-SNG (synthetic natural gas)

Bio-SNG can be produced either from wet biomass streams through anaerobic digestion or supercritical water gasification or from relatively dry biomass through gasification then requiring a methanation process to form SNG from CO and H_2. Different components can be converted into methane by changing the catalyst of the process. The process is strongly exothermic and therefore part of the energy of the gaseous components is lost in the form of heat that has to be removed from the reactor and the SNG cooled before storage. Efficient recovery of the reaction heat that amounts 20% of the heating value of the synthesis gas is essential for any industrial methanation technology. Bio-SNG has similar qualities to natural gas, so a benefit is the possibility to distribute it via natural gas pipelines.[22]

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[21] Milbrandt, A. et al.: Survey of Biomass Resource Assessments and Assessment Capabilities in APEC Economies. Asia-Pacific Economic Cooperation, Energy Working Group, November 2008

[22] Sims, R. et Al.: From 1st to 2nd Generation Biofuel Technologies – An Overview of Current Industry and RD&D Activities. IEA Bioenergy, November 2008

As a vehicle fuel SNG is similar to compressed natural gas (CNG) or liquefied natural gas (LNG).

2.4.3 Overview 1st and 2nd generation biofuels

An overview of 1st and 2nd generation biofuels following the energy pathway from feedstock over the conversion process to biofuel is shown in the table below.

Table 3: Overview 1st and 2nd generation biofuels - feedstock & conversion

Raw Material	Conversion	Biofuel group	Specific biofuel
1st generation		**1st generation**	
Sugar, starch	Fermentation	Bioalcohol	Bioethanol Biobutanol
Oil, fat	Trans-esterification	Biodiesel	FAME
Organic	Digestion	Methane	Biogas/SNG
2nd generation		**2nd generation**	
Lignocellulose	Biochemical Enzymatic hydrolisis & fermentation	Bioalcohol	Bioethanol Biobutanol
Lignocellulose	Thermo-chemical pyrolisis, hydrogenation	Biodiesel	green pyrolisis diesel H-Bio hybrid of 1st and 2nd generation
Lignocellulose	Thermo-chemical Gasification & synthesis	Methane	Bio-SNG
Lignocellulose	Thermo-chemical Gasification & synthesis	Synthetic biofuels	BTL biomass to liquid Fischer Tropsch diesel Synthetic diesel Biomethanol
			DME Di-methyl ether Havier alcohols P-series (ethanol + MTHF)
Lignocellulose	Thermo-chemical Gasification & synthesis Biochemical Biological process	Biohydrogen	Hydrogen

It can be noted that there are 3 parallel paths in the biofuel industry development:[23]

- The use of food-type feedstock (1st generation biofuels)
- The use of residues or waste of agriculture and forestry and industry
- The use of energy crops

[23] Biofuels Research Advisory Council: Biofuels in the European Union. Biofuels Research Advisory Council, March 2006

From these 3 pathways the second one (going for residues and waste) seems the most promising one as there are is little to no interference with food production. If existing production processes using these resources are also considered there is no competition for resources.

Another overview from biomass resource to biofuel is given in the figure below. It clearly shows that there are multiple ways to produce the desired fuels.

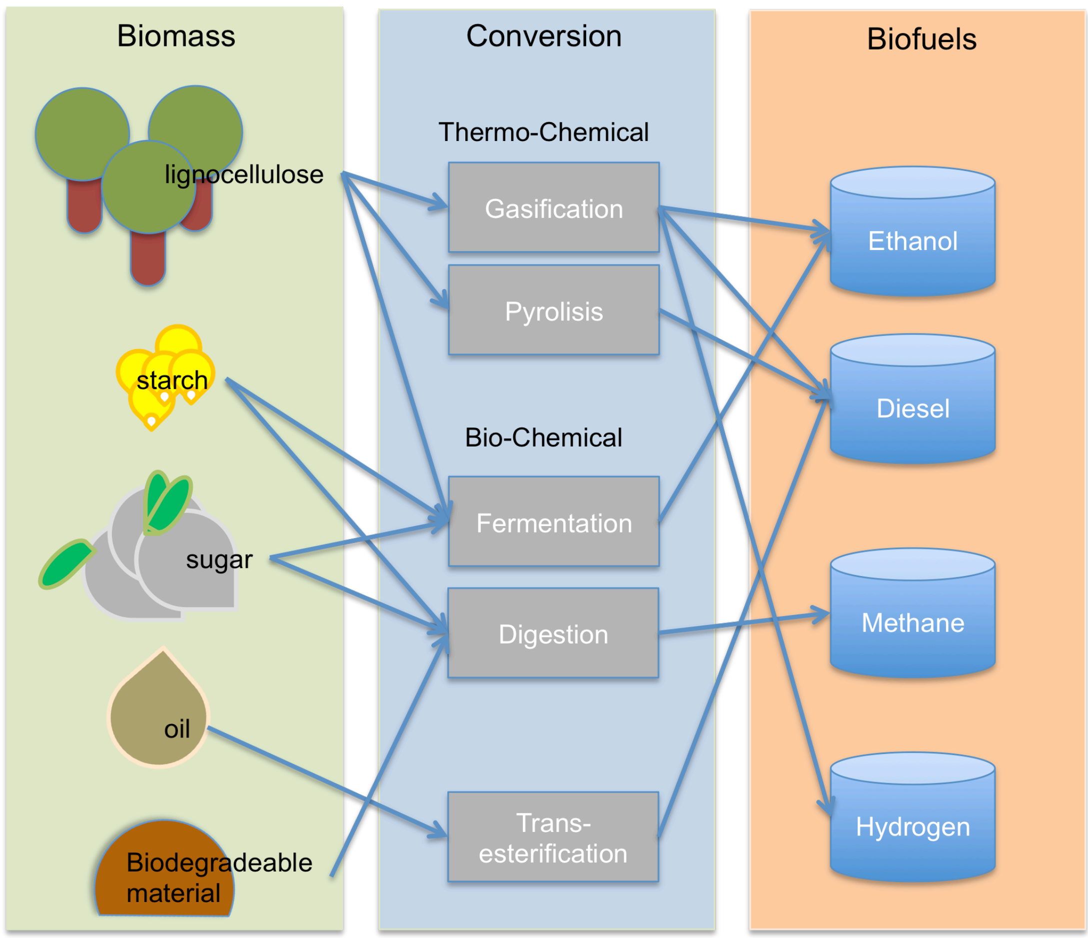

Figure 10: Conversion routes to ethanol, diesel, methane and hydrogen

2nd generation technologies mainly using lignocellulosic feedstocks for the production of ethanol, synthetic diesel and aviation fuels are still immature and need further development and investment to demonstrate reliable operation at commercial scale and to achieve cost reductions through scale-up and replication. The current level of activity in the area indicates that these routes are likely to become commercial over the next decade. Future generations of biofuels such as oils produced from algae are at the applied R&D stage and require considerable development before they can become competitive contributors to the energy market.[24]

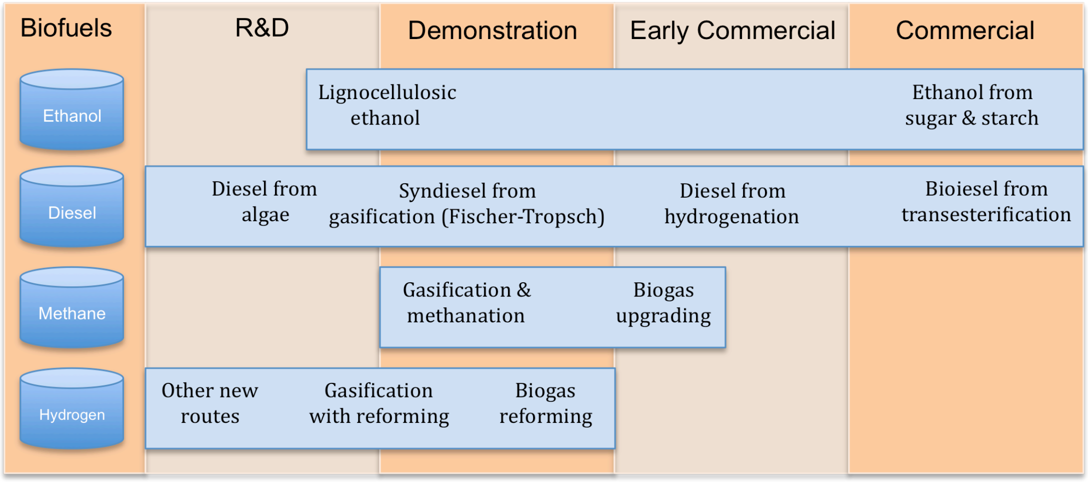

Figure 11: Development status of the main technologies to produce biofuels for transport from biomass

2.4.3.1 Challenges

All biofuels in all stages face various challenges regarding their deployment, their economic feasibility or their social and political acceptance.

1st generation biofuels face several challenges. First: economic ones. Their profitability is heavily dependent on the prices of both fossil fuel and the commodity feedstocks used. Both tend to fluctuate heavily. Second: social ones. Feedstocks used are generally also used as food or fodder leading to increased competition. Third: environmental ones, as greenhouse gas benefits vary widely on the feedstock and process used (they can be negative). Fourth: market issues like the deployment of bio-methane vehicles that suffers from limited infrastructure and therefore limited uptake of gas vehicles.

2nd generation biofuels overall face the big challenge of significant cost reductions in the production process. Otherwise they will not be able to successfully compete fossil fuels and 1st generation biofuels. But the greenhouse gas reduction potential is high and generally better than for 1st generation biofuels.[22]

[24] Bauen, A. et al.: Bioenergy – a Sustainable and Reliable Energy Source. In: IEA Bioenergy ExCo 2009:06, IEA Bioenergy, 2009

3 Biomass potential

3.1 Worldwide biomass potential

In the past several studies have assessed the longer-term biomass potential for different regions using different approaches considering different determining and limiting factors. Therefore their conclusions regarding biomass supply range from about 50 EJ up to 500 EJ (above the current level of primary energy consumption worldwide).[25]

When assessing the biomass potential we have to keep in mind the difference between technical potential which is only limited by technology used and natural circumstances (unconstrained production potential) and the sustainable potential which takes environmental and social issues into consideration.

Agricultural and wood-based residues and wastes form the vast majority of currently used biomass. Their long term potential is mainly dependent on the future developments in agricultural and forestry production.

Energy crops are potentially the largest supply source but their future role is heavily dependent on land availability and biomass yields. Their competition for land depends on the development of the food sector but also on the environmental development such as nature protection.

Several lignocellulosic crops can be grown in less favorable soils and climate conditions, so that large land areas could become available for their production. The production of biofuels from lignocellulosic sources (2nd generation) cannot yet profit from the favorable performance of these crops because technologies have not yet become commercially available.

Following [Bauen, A. et al., 2009] the technical bioenergy potential in 2050 for energy crop production on surplus agricultural land meaning biomass that can be produced on surplus agricultural land not required for food, fodder or other agricultural or forestry commodities production ranges from 0 to 700 EJ per year. Up to 110 EJ per year could be grown on marginal land. Residues from agriculture (up to 70 EJ/year), forest residues (up to 150 EJ/year) and wastes (manure, organic

[25] Bauen, A. et al.: Bioenergy – a Sustainable and Reliable Energy Source. In: IEA Bioenergy ExCo 2009:06, IEA Bioenergy, 2009

wastes up to 105 EJ/year) could provide up to 325 EJ per year. This gives a technical potential for bioenergy of up to 1100 EJ/year in 2050.

The figure below summarizes the worldwide bioenergy potential for 2050. The sustainable biomass potential shown includes mainly agricultural productivity improvement, the increased use and production of energy crops, additional and surplus forest production, agricultural and forest residues.

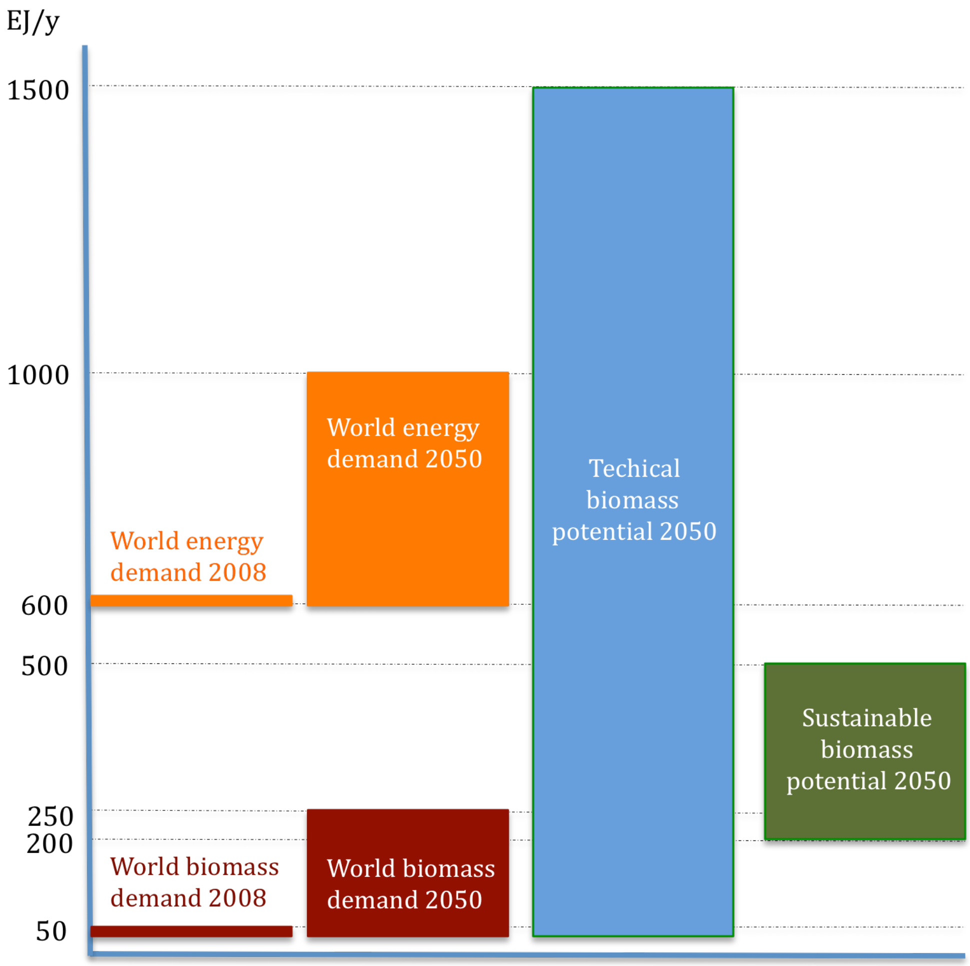

Figure 12: Technical and sustainable biomass supply potentials in 2050; Source: [Bauen, A. et al., 2009]

There is significant potential to expand biomass by tapping the large volumes of unused residues and wastes. The use of conventional crops for energy use can be expanded with careful consideration of land availability and food demand. In the medium term, lignocellulosic crops could be produced on marginal, degraded and surplus agricultural land and provide the bulk of the biomass resource. In the longer term, aquatic biomass (algae) could also make a significant contribution.

3.2 Biomass potential for biofuels

Today about 13% of the worldwide energy supply comes from renewable sources. Bioenergy has a share of about 77% of which woody biomass has the largest portion (about 87%).
Even though food crops for biofuel production often have high yields the bioenergy output per hectare is commonly lower than expected with lignocellulosic crops and they compete with the food industry for resources and might cause higher prices.

Therefore the later chapters will concentrate on lignocellulosic resources (or woody biomass) and especially residues (also crop residues from agriculture) as the they do not compete with the food industry on one hand and with existing production chains on the other hand. So they can be seen as a sustainable feedstock for biofuel production.

3.2.1 Lignocellulosic resources

Low-cost crops and forest residues, wood process wastes, and organic fraction of municipal solid wastes can all be used as lignocellulosic feedstocks.
Focus will be on unused resources especially residues. Where no explicit data is available we will follow the suggested average found in [Jölli, D. et al., 2005] to calculate unused biomass and usable residues from forestry. Calculation factors are summarized in the table below.

Table 4: From roundwood production to usable residues – calculation factor

Total roundwood production	100%
Total used roundwood	70%
Woody residues	30%
of which unusable	35%
Usable woody residues	19.50%

(For more information please refer to Annex A – unused biomass factors.)

Where residues from saw mills are not already used for other production purposes these will also be taken into account that sawnwood is about 60% of roundwood input. The other 40% are residues (bark, saw dust, wood shred) [26] often used for energy production or used as a resource for pellets.

Energy content

Residues from different sources have different energy content mainly caused by the differing water content here mentioned with the figures in brackets that mention the related water content of the residues. [27]

Wood residues: 1.7 kWh/kg (@water content 60%) or 4.285 GJ/m^3.
Saw mill residues: 4 kWh/kg (@water content 20%) or 10.71 GJ/m^3

3.2.2 Agricultural residues

Residues from agricultural production can deliver feedstock for the generation of 1st and 2nd generation biofuels. Unused biomass from agriculture in this paper considers parts of the plant that are retained on the field. Where no explicit data is available we will follow the suggested unused biomass factor form [Jölli, D. et al., 2005] to calculate unused biomass from agriculture. The factors take into account the ratio between product and total biomass and the portion of the unused part of the residues. So they describe the percentage of unused biomass in the total non-product biomass (e.g. straw in the case of cereals). The factors are summarized in the table below.

Table 5: From agricultural production to usable residues - calculation factors; Source: [Jölli, D. et al., 2005]

Crop	Unused biomass factor
Cereals (not maize)	0,5
Maize	1.4
Oil crops	
Soybeans, sunflower, seed	1.89
Other oil crops	1.26

(For more information please refer to Annex – unused biomass factors.)

Energy content

The energy content of different agricultural residues is mainly influenced by water content and very little by their type.

[26] Schilliger Holz, et al: Holzcluster Lauterbach. Folder, www.schillinger.ch
[27] Wikipedia: Brennholz. http://de.wikipedia.org/wiki/Brennholz; 20.5.2010

Straw: 15.8 – 17 GJ/t or 4.78 kWh/kg (@ water content 0%)[28], 13 – 14.4 GJ/t (@water content 15%).[29] Following [Rode, M. et al., 2005] an energy content of 14.4 GJ/t will be used for calculation purposes.

For "green" crop residues other than straw where no figures could be found the same energy content as grass is taken - 1.39 kWh/kg (@water content 20%) or 5 GJ/t.[30]

3.2.3 Municipal solid waste

According to [Zihao Shi, A. et al., 2009] the global potential of municipal solid waste (MSW) as an energy source is not yet quantified. This paper shows that globally up to 82.9 billion liters of waste paper-derived cellulosic ethanol can be produced. The study concentrated on waste paper generation because it was the municipal waste stream with the most complete data. The assumption is made that about 236 kg (or 300 liters) of ethanol can be produced from each ton of wet wood waste (@water content 30%).[31]

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[28] TFZ Straubing: Heizwerttabelle für verschiedene Halmgutbrennstoffe, http://www.tfz.bayern.de/festbrennstoffe/31889/, 16.8.2010
[29] AgrarPlus: Heizwerte. http://www.agrarplus.at/kennzahlen.heizwerte.php, 16.8.2010
[30] Elsäßer, M.: Möglichkeiten der Verwendung alternativer Verfahren zur Verwertung von Grünlandmähgut: Verbrennen, Vergären, Kompostieren. In: Berichte über Landwirtschaft. Staatliche Lehr- und Versuchsanstalt für Viehhaltung und Grünlandwirtschaft Aulendorf, 2003
[31] Zihao Shi, A. et al.: The Biofuel Potential of Municipal Solid Waste. In: GCB Bioenergy (2009), doi: 10.1111. Blackwell Publishing Ltd, August 2009

4 Country analysis

4.1 Justification - method of selection

The potential for lignocellulosic feedstock, especially as a source for 2nd generation biofuels, is vital for the further deployment of bioenergy. The biggest resources for lignocellulosic feedstock come from woods and specially grown energy crops. Therefore a closer look at the situation of the world's forests is taken.

Due to the Global Forest Assessment 2005, forests cover about 30% of the total land area. Forests and wooded land are shown in green color in the figure below.

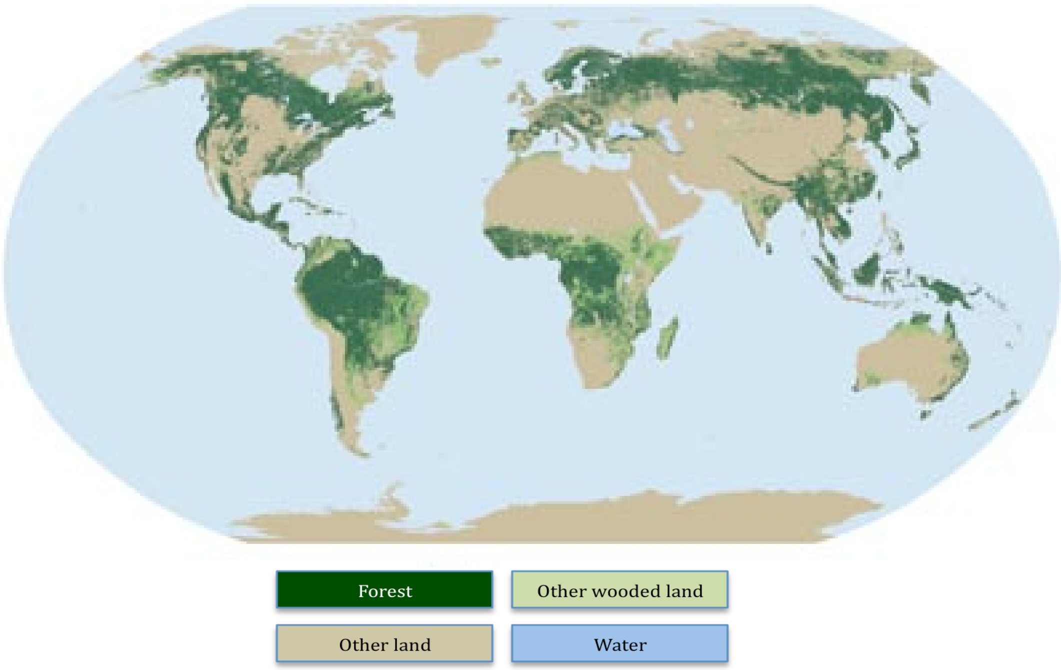

Figure 13: The world's forests[32]

The figure below shows the available forest potential in different regions. Global distribution and availability differ significantly by region.

[32] Food and Agriculture Organization of the United Nations: Global Forest Resources Assessment 2005 – Progress towards Sustainable Forest Management. In: FAO Forestry paper 147, 2006

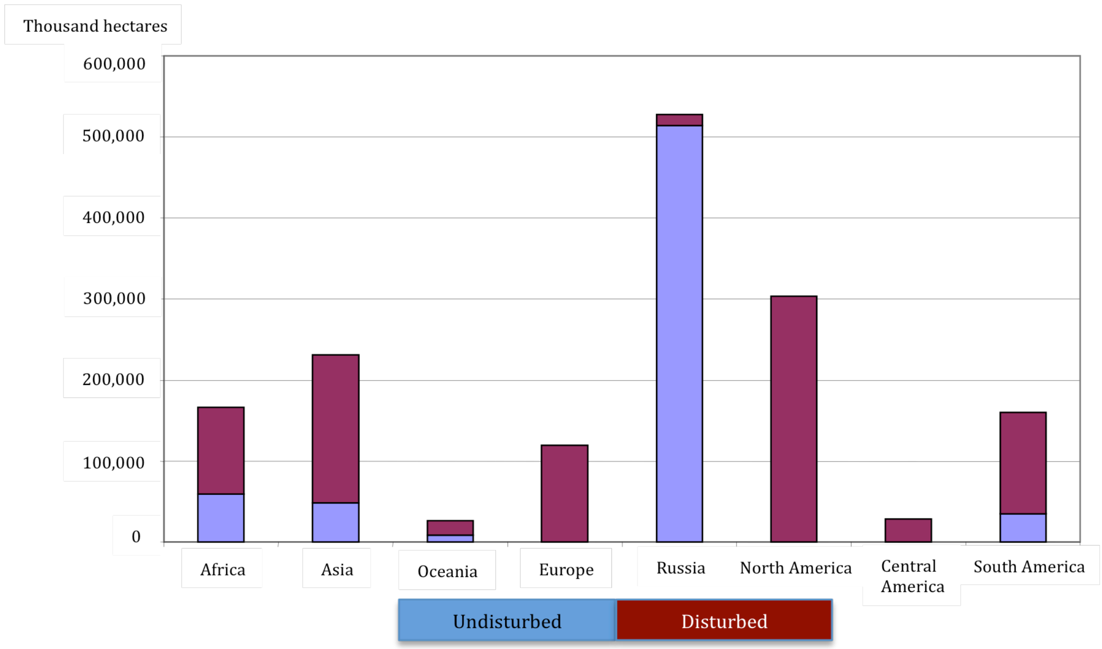

Figure 14: Distribution of natural forests available for harvesting by condition and region; Source: [Waggener, T. et al., 2001]

The largest aggregate area of natural forests is in South America and Russia. The availability of natural forest for harvest is greatest (in terms of actual area) for Russia and North America, while the share of natural forests deemed available for harvesting within a region is the greatest for Europe (85.1%), Russia (76.0%), Asia (56.6%) and North America (56.0%).[33]

Total forest area in 2005 was just less than 4 billion hectares (ha), corresponding to 0.62 hectares per capita. The ten most forest rich countries account for two thirds of total forest area. The 5 most forest rich countries (the Russian Federation, Brazil, Canada, the US and China) account for more than half of the total forest area (2,097 million hectares). The figure below gives an overview of the countries with the largest forest area in 2005.

[33] Waggener, T. et al.: Role of Plantations as Substitutes for Natural Forests in Wood Supply – Lessons Learned from the Asian-Pacific Region. In: Forest Plantations Thematic Papers – Working Paper FP/7. Food and Agriculture Organization of the United Nations, March 2001

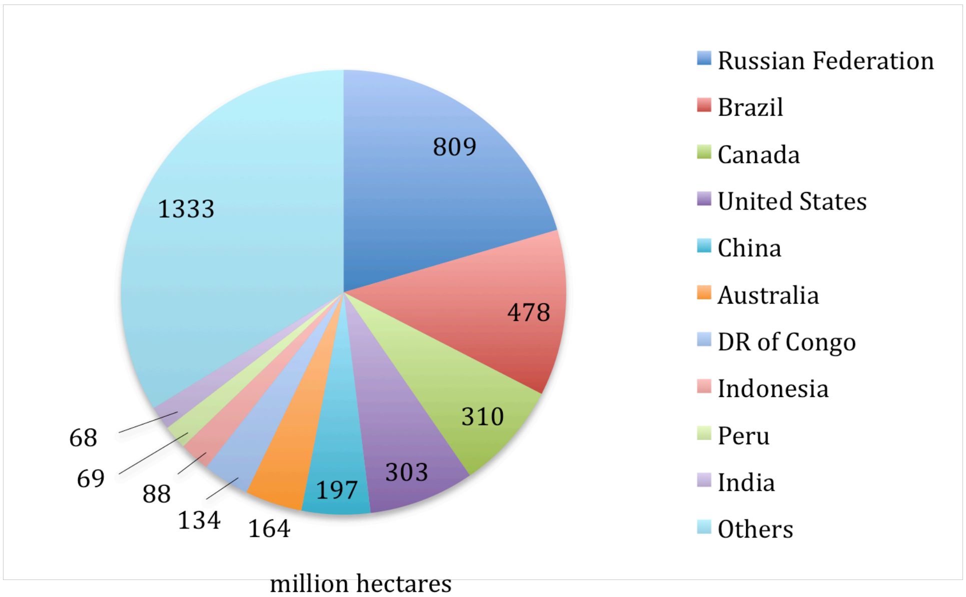

Figure 15: Ten countries with the largest forest area 2005; Source [Food and Agriculture Organization of the United Nations, 2006]

Therefore these countries were selected due to their primary large lignocellulosic potential coming from forest area. As the EU27 countries together would be in the top 10 countries with the largest forest area and are also of special interest for the author living in the EU they have been added.

In the figure below the 10 countries with the largest forest area in 2005 and the EU27 are taken and wooded land is added to forest area.

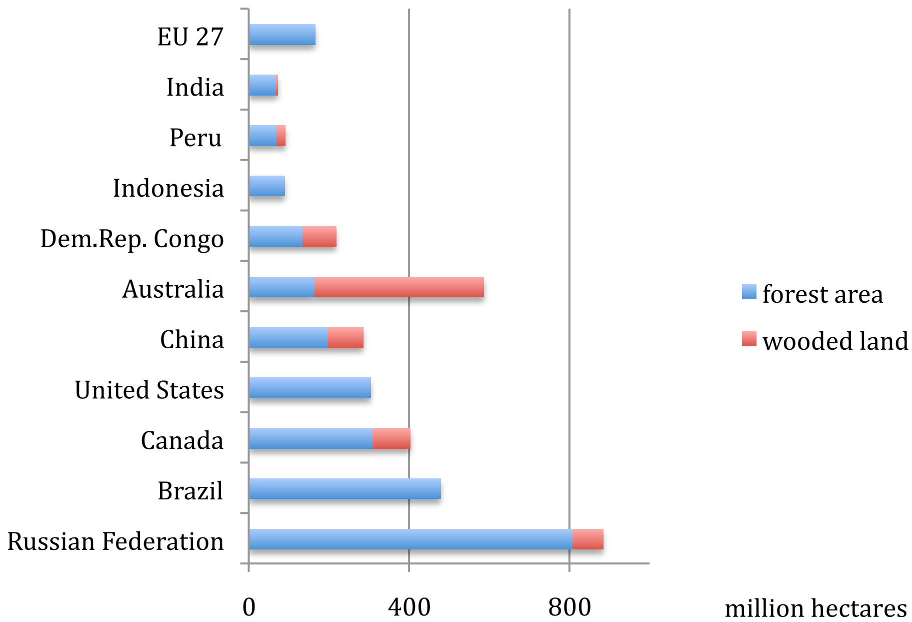

Figure 16: Countries with the largest wood areas (including wooded land); Source: [Food and Agriculture Organization of the United Nations, 2006]

Forest plantations, a subset of planted forests consisting primarily of introduced species, make up an estimated 3.8% of total forest area, or 140 million hectares. Productive forest plantations, primarily established for wood and fiber production, account for 78% of forest plantations, and protective forest plantations, primarily established for conservation of soil and water, for 22%.[34]

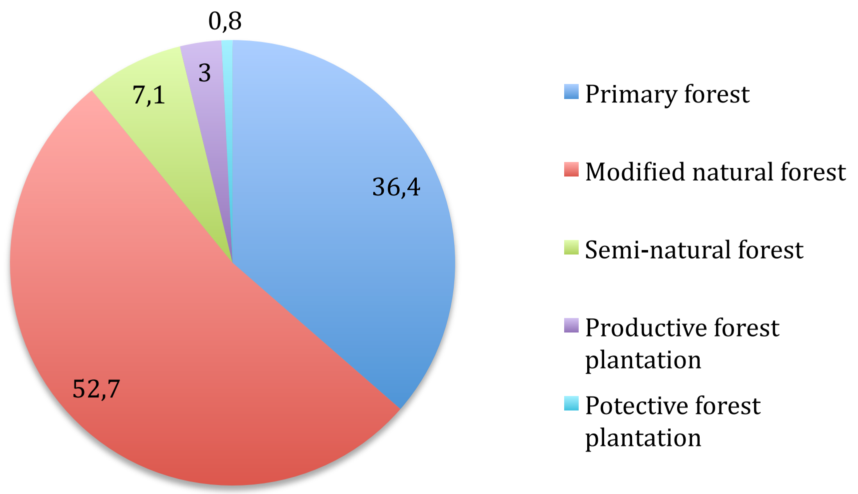

Figure 17: Forest characteristics 2005; Source: [Food and Agriculture Organization of the United Nations, 2006]

China is the country with the largest plantation area. But compared with the total forest area of 197 million hectares less than 15% are plantations. The share is even smaller in all other countries listed in the table below showing the countries with the biggest plantation area.

[34] Food and Agriculture Organization of the United Nations: Global Forest Resources Assessment 2005 – Progress towards Sustainable Forest Management. In: FAO Forestry paper 147, 2006

Table 6: Ten countries with the largest area of productiove forest plantations 2005: Source: [Food and Agriculture Organization of the United Nations, 2006]

Country/area	Area of productive plantations (1,000 ha)
China	28530
US	17061
Russia	11888
Brazil	5384
Sudan	4728
Indonesia	3399
Chile	2661
Thailand	1997
France	1968
Turkey	1961

Another important factor for biofuels comes from the regional demand for transportation energy as biofuels are planned to give a substantial contribution to the replacement of fossil fuels in that sector.

The demand for transportation energy correlates with the vehicle fleet. Vehicle fleets (for passenger light duty vehicle fleet) taken from World Energy Outlook 2009 show regions and countries with the biggest fleets and therefore the biggest energy demand.

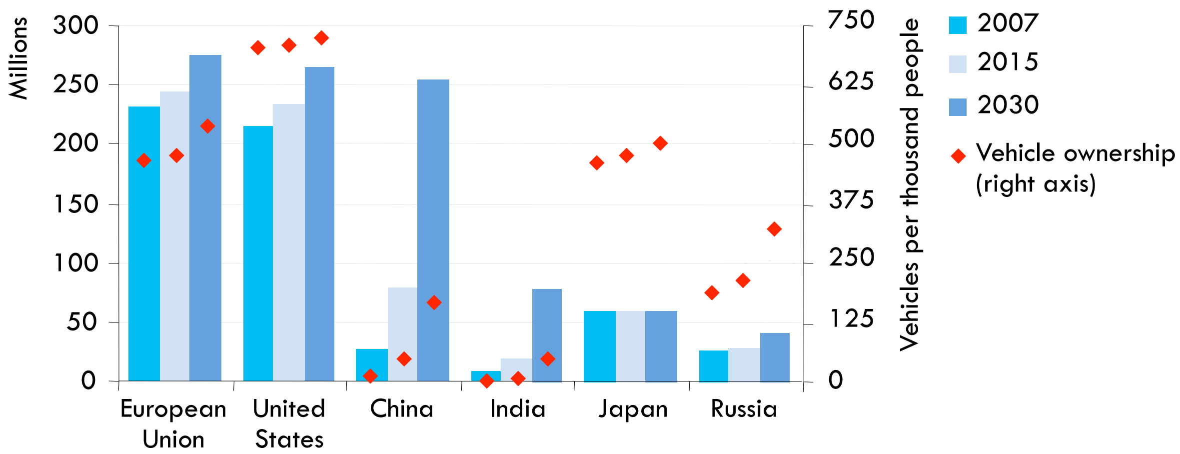

Figure 18: Passenger light-duty vehicle fleet in different regions and countries[35]

[35] International Energy Agency: World Energy Outlook 2009. International Energy Agency, 2009

4.2 Country selection

The country selection was made according to the size of forest area. EU27 was taken as one representative of "Others", due to the origin of the study in Austria and the size of the total wood area in the EU27, which would set them on 6th place. Therefore in the following chapters the 10 countries with the biggest wood resources and the EU27 are examined in more detail focusing on residues from agriculture and forestry to figure out existing unused biomass potential for the generation of biofuels from lignocellulosic material (2nd generation biofuels).

Selected countries are *Russian Federation, Brazil, Canada, United States, China, Australia, Democratic Republic of Congo, Indonesia, Peru, India and the EU27*.

In the following chapters each of the mentioned countries and the EU27 is investigated according its bioenergy potential derived from various residue streams (agricultural biomass, forestry and wood industry, municipal waste). Most recent data in terms of actuality was taken from FAOStat[36] (Top 20 commodities – see tables in Annex D) or from literature where more accurate data was available. The actual source to each figure can be found in the tables in the summary of each chapter.

4.2.1 Calculations

Several calculations were made in each country section. These are described in the following part.

4.2.1.1 Biomass residues

For the calculation of usable biomass residues unused biomass factors were taken from [Jölli, D. et al., 2005] and production figures were multiplied with the according factors.

The table below gives some samples for unused biomass factors for different agricultural plants.

[36] FAO: Top 20 Commodities. Food and Agriculture Organization of the United Nations, FAOStat, http://faostat.fao.org, Production

Table 7: From agricultural production to usable residues - calculation factors; Source: [Jölli, D. et al., 2005]

Crop	Unused biomass factor
Cereals (not maize)	0.5
Maize	1.4
Oil crops	
Soybeans, sunflower, seed	1.89
Other oil crops	1.26

For more details on unused biomass factors please refer to Annex A – unused biomass factors.

Example: Russia's wheat production was 61.7 million tons. Multiplied with the unused biomass factor for wheat 0.5 a residue potential of 30.9 million tons is calculated.

Table 8: Calculation example: residue potential

Cereal	Source	Production in million tons	Unused biomass factor	Residue potential (calculated)	Energy content per ton GJ	Total energy content PJ
Wheat	2009	61.7	0.5	30.9	14.4	444.2

4.2.1.2 Energy content

For the calculation of the energy content in the biomass potential found the following figures from literature were taken:

Table 9: Energy content of different biomass residues

Residue	Energy content		Source
Wood residues	4.285	GJ/m^3	36
Saw mill residues	10.71	GJ/m^3	36
Straw	14.4	GJ/t	19
Other crop residues	5	GJ/t	21

Following the Example in Table 8: the energy content of straw is 14.4 GJ per ton multiplied by the residue potential found, here 30.9 million tons shows a total energy potential of 444.2 PJ.

4.2.1.3 Energy potential vs. energy used in transport sector

In the summary of each country chapter a comparison is made showing the ratio between energy used in the transport sector and the energy potential found in unused biomass.

4.2.1.4 Bioethanol potential

To give an idea of how much biofuel could be produced out of the biomass residue potential found a calculation for Bioethanol (2nd generation) yield was made with the assumptions that 200 liters could be derived from each ton of agricultural residues and 300 from each ton of wood residues.

The calculated figure was than compared with the worldwide liquid fuel consumption (final consumption) in the transportation sector of 2.079 trillion liters in 2007.[37]

Example: The residue potential found in Russia is 76.8 million tons of agricultural residues and 34.4 million tons of forestry residues as seen in the table below.

Table 10: Summary residue potential in Russia

Russia	million tons
agricultural residues	76.8
forestry residues	34.4

Bioethanol yield: 76,819,000 x 200 + 34,432,500 x 300 = 29,932,200,000 liters or 1.44% of worldwide fuel consumption in 2007.

[37] International Energy Agency: Oil in the World. http://www.iea.org/stats/, 16.8.2010

4.3 Russian Federation

4.3.1 General Information

With about 17 million km^2 Russia is by far the the largest country in the world covering more than a ninth of the Earth's land area. Russia is also the ninth most populous nation in the world with 142 million people[38]. It extends across the whole of northern Asia and 40% of Europe, spanning nine time zones and incorporating a wide range of environments and landforms. Russia has the world's largest reserves of mineral and energy resources, the world's largest forest reserves and its lakes contain approximately one-quarter of the world's fresh water.

Most of Russia consists of vast stretches of plains that are predominantly steppe to the south and heavily forested to the north, with tundra along the northern coast. Russia possesses 10% of the world's arable land. [39]
Throughout much of the territory there are only two distinct seasons: winter and summer. Spring and autumn are usually brief periods of change between extremely low and extremely high temperatures. The enormous size of the country and the remoteness of many areas from the sea result in the dominance of the humid-continental and subarctic climate.
Russia is also considered well ahead of most other resource-rich countries in its economic development, with a long tradition of education, science, and industry. Although energy prices are high, oil and gas only contribute to 5.7% of Russia's GDP and the government predicts this will drop to 3.7% by 2011. The average salary in Russia was $ 640 per month in early 2008, up from $ 80 in 2000. The country has more higher education graduates than any other country in Europe.
Russia is very rich in energy resources. Russia has the largest known natural gas reserves of any state on earth, along with the second largest coal reserves, and the eighth largest oil reserves. This is 32% of world proven natural gas reserves (23% of the

[38] Energy Information Administration: Country Report – Russia. Energy Information Administration. In: International Energy Annual 2006. Energy Information Administration, http://www.eia.doe.gov/emeu/cabs/Russia/Full.html, 2.6.2010
[39] Wikipedia: Russia, http://en.wikipedia.org/wiki/Russia, 2.6.2010

probable reserves), 12% of the proven oil reserves (42% of the probable reserves), 10% of the explored coal reserves (14% of the estimated reserves) and 8% of the proven uranium reserves.[40]

Renewable energy is largely undeveloped although Russia has many potential renewable energy resources. It has for example the 5th largest hydroelectric potential in the world (with a economically feasible potential of 852 TWh – of which about 19% are already used).[41]

Country statistics[42]

Total area: 1,688 million hectares

Population: 142 million people

Wood: over 808 million hectares (47.9% of total area)

GDP/capita in US$[43]: 1,604 billion /11,832 (nominal), 2,260 billion/15,923 (PPP)

Total energy consumption in the transport sector was 82 Mtoe or 343 PJ in 1999 (20% of total energy demand)[44]

4.3.2 Biomass Resources[45]

Russian experts estimate that the amount of renewable energy that is economically recoverable is more than 270 Mtce (791.3 PJ) per year. Out of this biomass has a potential of 35 Mtce (102.5 PJ).

Russia’s biomass resources include vast forests, open woodlands and agricultural and wood waste. In 2001 Russia had 406 million hectares of agricultural land (23.8% of total land area) and 1,097 million hectares of forested land (64.1% of total land area).

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[40] Energy Information Administration: Country Report – Russia. Energy Information Administration. In: International Energy Annual 2006. Energy Information Administration, http://www.eia.doe.gov/emeu/cabs/Russia/Full.html, 2.6.2010

[41] World Energy Council: 2007 Survey of Energy Resources. World Energy Council, 2007

[42] Food and Agriculture Organization of the United Nations: Global Forest Resources Assessment 2005 – Progress towards Sustainable Forest Management. In: FAO Forestry paper 147, 2006

[43] World Bank: Gross Domestic Product 2008 & Gross Domestic Product 2008, PPP. In: World Development Indicators Database. Word Bank, April 2010

[44] International Energy Agency: Russia Energy Survey 2002. International Energy Agency, 2002

[45] International Energy Agency: Renewables in Russia – From Opportunity to Reality. International Energy Agency, 2003

According to the IEA statistics (2002), Russia used 7.5 Mtoe (31.4 PJ) of combustible renewable and wastes in 1999 (and 6.9 Mtoe in 2000).

Russia is the world's top producer of rye, barley, buckwheat, oats and sunflower seed, and one of the largest producers and exporters of wheat, linseed, hempseed and soybeans.[46] For details on the potentials found from agricultural residues please refer to the table in the summary of this chapter.

4.3.2.1 Forestry residues (from roundwood production)

Forests are a major land use-land cover type in Russia. Forest land (territories identified for forests and forestry) comprises 51.6% of the country's land. Closed forests (forested areas) cover 776 million hectares or 45.4% of the total land area. Of the total forested area, in 2003, 18% of forests were classified as protective forests, 7.6% were destined mostly for ecological services with prohibited or restricted industrial logging, and 69.4% were basically destined for timber extraction. Due to large areas of protective and low productive forests, only 45% of Russian forests are classified as forests available for industrial logging (about 349 million hectares).[47]

Russia's annual net growth in forested area is nearly 1 billion m^3. The allowable cut is only about 540 million m^3. This amount would theoretically generate 105.3 million m^3 of residues, delivering 451 GJ of bioenergy and 31.6 billion liters of 2nd generation ethanol.
Russia's forest potential is not yet fully exploited because of environmental constraints, low standing volumes, the remoteness of forests from domestic and international markets, the absence of a transportation network and technological limitations. [48]

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[46] FAO: Country Rank in the World by Commodity. Food and Agriculture Organization of the United Nations, FAOStat, http://faostat.fao.org/site/339/default.aspx, 2.6.2010
[47] Shvidenko, A. et al.: Russian Forests and Forestry. CD-Rom. International Institute for Applied Systems Analysis and the Russian Academy of Science, 2007
[48] International Energy Agency: Renewables in Russia – From Opportunity to Reality. International Energy Agency, 2003

In 2005 Russia produced about 134 million m^3 of industrial roundwood.[49] According to FAOStat industrial roundwood production in 2008 was 136.7 million m^3.

4.3.2.2 Saw mill residues

In 2005 Russia produced about 21.5 million m^3 of sawnwood. According to FAOStat sawnwood production in 2008 was 21.6 million m^3.

Little could be found about the current use of sawmill residues. As the pellets industry is one potential user of sawmill residues a look was taken into the Russian pellet industry. Russian pellet companies are concentrated mostly in the North-West of Russia and in the central part of it in regions where there are forests or woodworking industry developed. Production capacities were around 550.000t per year. Several big plants will have started operation in 2009 as well as working plants are going to increase production volumes. The expectation for 2009 production was more than 850,000t of pellets.[50] Due to these figures the assumption was made that 90% of the sawmill residues could still be used as a resource for biofuel production.

4.3.2.3 Municipal waste

The Russian waste paper market volume is estimated to be 9 million tons per year, of which only 3 to 4% are reused and the rest is disposed.[51] This potential could yield to an additional 2.6 billion liters of Ethanol per year.

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[49] Killmann, W. et al.: The Russian Forestry Sector in the Global Forest Products Market: Trends, Outlook and Opportunities for Development. In: Presentation to the VII International Forestry Forum. International Forestry Forum, October 2006

[50] Sikkema, R. et al.: Wood Pellets Production and Trade in Russia, Belarus & Ukraine. In: Market Research Report, WP 6.1 Assessment of international pellet trade developments in non-EU countries. Pellets@las, Utrecht University, May 2009

[51] Tolli, a. et al.: Reducing Empty Container Flow by Promoting Baltic and Russian's Wastepaper Export to China through Port of Tallinn. In: The 8th International Conference "Reliability and Statistics in Transportation and Communication – 2008". Tallinn University of Technology, 2008

4.3.3 Summary - Residues potential

The table below gives a summary of the potentials for bioenergy in unused residues in Russia taking actual production figures into account. The calculation gives an overall potential of 111.3 million tons of unused biomass resources with an energy content of 1,019.5 PJ. This potential would theoretically overfill the local demand in the transport sector almost 3 times.

The total Bioethanol potential derived from different waste sources is about 33.5 billion liters (29.9 billion liters from residues and 2.6 billion liters from waste paper).

Table 11: Russia's unused residues potential

Russia	**Source**	production	unused biomass factor	unused biomass	energy content	bioenergy
		mio. t		mio. t	GJ/t	PJ
agricultural residues						
Cereals						
Wheat	2009	61.7	0.5	30.9	14.4	444.2
Barley	2009	17.9	0.5	9.0	14.4	128.9
Rye	2009	4.3	0.5	2.2	14.4	31.0
Buckwheat	2007	1	0.5	0.5	14.4	7.2
Oats	2009	5.4	0.5	2.7	14.4	38.9
Maize	2009	4	1.4	5.6	5	28
Sugar beet	2007	28.8	0.05	1.44	14.4	20.7
Oil crops						
Soybeans	2009	0.9	1.89	1.70	5	8.5
Sunflower	2009	6.4	0.5	3.2	5	16
Vegetables						
Other	2007	9.8	0.45	4.41	5	22.05
Tomatoes	2007	2.3	0.9	2.07	5	10.35
Potatoes	2007	36.8	0.36	13.248	5	66.24
forestry residues						
		Mio. m^3			GJ/m^3	
roundwood	2008	136.7	0.195	26.7	4.285	114.2
saw mill	2008	19.4	0.4	7.8	10.71	83.3
Total				111.3		1,019.5
	29,932,200,000	l lignocellulosic Ethanol				
	1.44%	of worldwide fuel consumption 2007				

Source:
2009: Source USDA FAS
2007: FAOStat, commodities by country
2008: FAOStat, forestry
5 = energy content of grass

Other vegetables include:
Carrots, Onions, Cucumber, Pumpkins, Watermelons and Vegetable fresh nec.

4.4 Brazil

4.4.1 General Information[52, 53]

Brazil is worldwide the fifth largest country by geographical area, and the fifth most populous country. By 2005, according to UNDP (2009), 57.5% of the country area was still covered by forests.

The climate of Brazil comprises a wide range of weather conditions across a large area and varied topography, but most of the country is tropical. Brazil hosts five major climatic subtypes: equatorial, tropical, semiarid, highland tropical, temperate, and subtropical. The different climatic conditions produce environments ranging from equatorial rainforests in the north and semiarid deserts in the northeast, to temperate coniferous forests in the south and tropical savannas in central Brazil.

The natural heritage of Brazil is severely threatened by cattle ranching and agriculture, logging, mining, resettlement, oil and gas extraction, over-fishing, wildlife trade, dams and infrastructure, water contamination, climate change, fire, and invasive species.

Brazil is the largest national economy in Latin America. Major export products include aircraft, electrical equipment, automobiles, ethanol, textiles, footwear, iron ore, steel, coffee, orange juice, soybeans and corned beef.

In 2007 almost 46% of its primary energy supply was covered by renewable sources. Brazil is the 10th largest energy consumer in the world and the largest in South America. At the same time, it is an important oil (the world's 15th largest oil producer) and gas producer (with proven reserves in 2005 of 306 billion m^3, with possible reserves expected to be 15 times higher) in the region and the world's second largest ethanol fuel producer (after the U.S.). Ethanol production reached 27.7 billion liters in the harvest season 2008-2009. Domestic consumption was close

[52] Walter, A. et al.: Country Report – Brazil. In: IEA Bioenergy Task 40. International Energy Agency, University of Campinas, 2009
[53] Wikipedia: Brazil. http://en.wikipedia.org/wiki/Brazil, 5.6.2010

to 20 billion liters. Biodiesel production in 2008 was close to 1.2 billion liters, but production in the first half in 2009 increased by 42% over the same period in 2008.

Country statistics

Total area: 851.5 million hectares

Population: almost 184 million people (IBGE, 2008 – considering historic growth rates 191.4 million are estimated for mid 2009)

Wood: 477 million hectares (57.5% of total area)

GDP/capita in US$[54]: 1,575 billion/8,220 (nominal), 1,978 billion/10,513 (PPP)

Total energy consumption in the transport sector was 2.4 EJ in 2007 (29% of total energy consumption)

4.4.2 Biomass Resources

Brazilian agriculture is well diversified, and the country is largely self-sufficient in food. Agriculture accounts for 8% of the country's GDP, and employs about one-quarter of the labor force in more than 6 million agricultural enterprises.
Currently the main biomass resources in Brazil are wood, sugarcane and oil seeds. In 2007 the contribution of wood and sugarcane to the total energy supply was 2,783 PJ or 30.9% of the total energy supply.

The main agricultural commodities in 2007 were sugar cane, soybeans and maize. Brazil has a long tradition with soybeans production and is currently the second largest producer (after the U.S.) with 57.8 million tons (FAOStat) in 2007 and about 65 million tons in 2009[55]. Soybeans occupy about 25 million hectares (30% of agricultural area).
Field residues have been rarely used for energy production, remaining as an important alternative.

4.4.2.1 Special residues from sugarcane bagasse

More than 549 million tons of sugarcane where produced in 2007. Sugarcane *bagasse* is derived from the fibers of the sugarcane plant. On average, sugarcane has 13-14% of fibers (260-280 kg) per ton of sugarcane crushed with 50% moisture

[54] World Bank: Gross Domestic Product 2008 & Gross Domestic Product 2008, PPP. In: World Development Indicators Database. Word Bank, April 2010
[55] United States Department of Agriculture: Production, Supply and Demand Online. Foreign Agricultural Service, http://www.fas.usda.gov/psdonline, 20.05.2010

(absolute). Currently most of the sugarcane bagasse is burned for steam production at mill site. Bagasse is inefficiently used at fuel; at least 50% of the bagasse could be saved in an efficient industrial unit.

The availability of sugarcane trash (leaves etc. that are traditionally burned on the field) at the field is almost equal than bagasse, but so far almost not being used. In Brazil, the average availability is $140kg_{dry}$ of trash per ton of sugarcane. It is estimated that up to 50% of the trash (70kg/t) could be sustainably recovered (protecting soil and plants). Taking these figures this would lead to a potential of 38.4 million tons sugarcane trash. If the energy content of grass is taken this residues have an energy potential of 192 PJ.

4.4.2.2 Forestry residues

In the North region the production is mainly based on extrativism while in the South planted forests are dominant, based on short-rotation coppices. Dedicated forests are mainly of pines (1.8 million hectares) and eucalyptus (4.5 million hectares)[56]. The forestry sector tends to expand occupying land currently used for several other activities, mainly pastureland.

In 2009, the production of sustainable forest roundwood in Brazil (from eucalypt and pine planted forests) reached an estimated 250.3 million m^3 per year. Therefore a yearly sustainable yield of about 37.6 m^3 (pine) to 40 m^3 (eucalypt) per hectare and year is produced.

Usable residues have a calculated potential of 48.8 million m^3 with an energy potential of 209 PJ for 2009.

Due to the IEA country report[57] forestry/wood residues have a potential of 1.000 PJ in 2010.

4.4.2.3 Saw mill residues

Saw mill residues have been used more frequently than field residues (wood slashes), although their uses are still low and mostly inefficient. In the Brazilian

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[56] Brazilian Association of Forest Plantation Producers: ABRAF Statistical Yearbook 2010 – base year 2009, Brazilian Association of Forest Plantation Producers, 2010

[57] Walter, A. et al.: Country Report – Brazil. In: IEA Bioenergy Task 40. International Energy Agency, University of Campinas, 2009

south there is already a market for biomass residues from wood industries, reducing the feasibility of pellets production for exporting or the production of biofuels.
Pine sawn wood production in 2009 was 8.47 million m^3. Therefore the potential for saw mill residue is about 3.388 million m^3 with an energy potential of 36.29 PJ in 2009.

4.4.2.4 Municipal waste

Due to Brazil's first National Solid Waste Survey [Oliviera, L. et al., 2003] using 20 million tons of municipal solid waste that accumulate every year, of which less than 10% were properly disposed, could boost electricity supplies by 50TWh or 17% of the nation's consumption.[58]

4.4.3 Summary - Residues potential

The table below gives a summary of the potentials for bioenergy in unused residues in Brazil taking actual production figures into account. The calculation gives an overall potential of 275.2 million tons of unused biomass resources with an energy content of 1,679.8 PJ. This potential would theoretically supply about 70% of the local demand in the transport sector.

The total Bioethanol potential derived from different waste sources is about 60.2 billion liters.

[58] Oliviera, L. et al.: Brazilian Waste Potential: Energy, Environmental, Social and Economic Benefits. In: Energy Policy 31 (2003), Elsevier, 2003

Table 12: Brazil's unused residues potential

Brazil	**Source**	production	unused biomass factor	unused biomass	energy content	bioenergy
		mio. t		mio. t	GJ/t	PJ
agricultural residues						
Cereals						
Wheat	2009	4.9	0.5	2.45	14.4	35.28
Maize	2007	52.1	0.5	26.05	14.4	375.12
Rice, paddy	2007	11	0.5	5.5	14.4	79.2
Oil crops						
Soybeans	2009	68	1.89	128.5	5	642.6
Cotton	2009	5.9	1.89	11.2	5	55.8
Bagasse	2007a	549	0.07	38.43	5	192.2
Vegetables						
Other	2007	4.5	0.45	2.025	5	10.125
Tomatoes	2007	3.4	0.9	3.06	5	15.3
Potatoes	2007	3.6	0.36	1.296	5	6.48
Beans	2007	3.2	1.4	4.48	5	22.4
forestry residues						
		Mio. m^3			GJ/m^3	
roundwood	2009a	250.3	0.195	48.8	4.285	209.1
saw mill	2009a	8.47	0.4	3.4	10.71	36.3
Total				275.2		1,679.8
	60,251,350,000	l lignocellulosic Ethanol				
	2.90%	of worldwide fuel consumption 2007				
Source:						
2007: FAOStat, commodities by country						
2007a						
2009: Source USDA FAS						
2009a: ABRAF statistical yearbook 2010				5 = energy content of grass		
Other vegetables include:						
Watermelons and Vegetable fresh nec.						

4.5 Canada

4.5.1 General Information[59, 60]

Canada is occupying most of northern North America, extending from the Atlantic Ocean in the east to the Pacific Ocean in the west and northward into the Arctic Ocean. It is the second largest country in the world after Russia and because of its vast size, Canada has more lakes than any other country, containing much of the world's fresh water. But population density with 3.3 inhabitants per km^2 is among the lowest in the world.

Average winter and summer high temperatures across Canada vary according to the location. Winters can be harsh in many regions of the country, particularly in the interior and Prairie Provinces, which experience a continental climate with severe wind chills. In non-coastal regions, snow can cover the ground almost six months of the year (more in the north). Coastal British Columbia enjoys a temperate climate, with a mild and rainy winter.

Canada is one of the world's wealthiest nations, with a high per-capita income and it is blessed with considerable natural resources including oil, gas, coal, hydro, minerals, and forests. Growth of the manufacturing, mining, and service sectors has transformed the nation from a largely rural economy into an industrial, urban economy.

Canada has a large, well-developed forest sector and has historically been one of the world's largest exporters of wood products. It is one of the world's largest suppliers of agricultural products with the Canadian Prairies being one of the most important producers of wheat, canola, and other grains.

Canada total primary energy supply in 2008 was 4,136.5 Mtoe or (17,322 PJ) of which 34.7% were from natural gas, 39.5% from petroleum, 8.5% from coal, 7.8% from

[59] Bradley, D.: Canada Report on Bioenergy 2009. In: IEA Task 40 – Biotrade. International Energy Agency, Climate Change Solutions, July 2009

[60] Wikipedia: Canada. http://en.wikipedia.org/wiki/Canada, 10.6.2010

hydropower, 5.9% from nuclear and the rest from waste wood and other renewables. Primary energy consumption in 2008 was 2,857 Mtoe (11,300 PJ).[61]

Country statistics

Total area: 998.5 million hectares km^2

Population: over 33 million people (estimation for 2010: over 34 million)

Wood: 402 million hectares or 41% of Canada's land area (thereof 26.5 million hectares or 6.6% National parks)

GDP/capita in US$[62]: 1,501 billion/ 39,668 (nominal), 1,301 billion/ 38,025 (PPP)

Total energy consumption in the transport sector was 2.43 EJ in 2008 (29.3% of total energy consumption) – about 20 million registered cars (up to 4.5t, driving about 300.000 million km/year)[63]

4.5.2 Biomass resources[64]

Farmland occupies 67.5 million hectares or 6.7% of the total land area. Crops are grown on 36.6 million hectares. Total crop production in 2001 was estimated at 78.3 million ODt (oven dry ton or bone dry ton) - 70% wheat or barley or tame hay. 56.1 million ODt of straw or stover were produced of which 29.3 million ODt could be removed without harming the soil. 17.3 million ODt (309TJ) of agricultural biomass is available per year.

4.5.2.1 Forestry residues

Forest biomass can be broadly separated into three categories; mill residues (bark, sawdust and shavings from pulp mill and sawmill operations), forest residue (tops, branches and leaves from harvest and thinning operations that are left forest or at the roadside after delimbing), and standing timber (Mountain Pine Beetle Wood and unmerchantable wood for example).

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[61] Natural Resources Canada: Important Facts on Canada´s Natural Resources, Energy, Natural Resources Canada. www.nrcan.gc.ca, 12.6.2010

[62] World Bank: Gross Domestic Product 2008 & Gross Domestic Product 2008, PPP. In: World Development Indicators Database. Word Bank, April 2010

[63] Minister of Industry: Canadian Vehicle Survey: Quarterly July to September 2009. In: Statistics Canada – Catalogue no. 53F0004X. Statistics Canada, Transportation Division, March 2010

[64] Bradley, D.: Canada Report on Bioenergy 2009. In: IEA Task 40 – Biotrade. International Energy Agency, Climate Change Solutions, July 2009

In 2005, 191 million m^3 of industrial roundwood was harvested on 1,108,000 ha (0.3% of total forest land). Due to falling demand for wood products in the US, only 182 million m^3 wood was harvested in 2007 and an estimated 160 million m^3 in 2008, resulting in a decline in available mill residues.

4.5.2.2 Saw mill residues

A 2005 mill residue survey[65] of Canadian pulp mills and sawmills indicated that 2004 production of bark, sawdust and shavings was 21.1 million ODt (Oven Dry tons = Bone Dry tons, 365 PJ). Of this 17.7 million ODt were used (e.g. onsite energy production, sold). But 2.7 million ODt (46PJ) were left unused. This unused surplus dropped to 14 million ODt in 2009.

In some provinces (BC, Alberta and Manitoba) sawmills were required to incinerate bark and sawdust that was not used, while in the other provinces incineration was forbidden and mills piled excess residues on site. An estimated 20.9 million ODt (359 PJ) of bark was available in 2005.

With mill residue surpluses' especially gone until the sawmill industry recovers, forestry and energy companies are looking to harvest residues at roadside. In Ontario for example 90% of harvest residues are left at roadside, due to full tree harvesting methods. While in Quebec only 60% of harvest residues are left at roadside, due to cut-to-length methods.
Harvest residues include low-value materials resulting from harvesting and commercial thinning operations, primarily tops and branches, bark and log exterior residue.
The estimated maximum of residues available on a sustainable level according to BIMAT[66] is 31.1 million BDt (due to lower annual harvest estimates assume only 22 million BDt) per year.

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[65] Canadian Forest Service: Estimated Production, Consumption and Surplus Mill Wood Residues in Canada – 2004. In: National Report. Natural Resource Canada – Canadian Forest Service – Policy, Economics and Industry Branch, Forest Products Association of Canada, November 2005
[66] Canadian Forest Service: Biomass Inventory and Assessment Tool. Canadian Biomass Innovation Network, Canadian Forest Service, Agriculture and Agri-Food Canad, National Land and Water Information Service

4.5.2.3 Municipal waste

Urban wood residues (discarded wood products, whole trees) are estimated at 9.75 million BDt per year. 33.2 million tons of municipal solid waste has been produced in 2004.

4.5.3 Summary

The table below gives a summary of the potentials for bioenergy in unused residues in Canada taking actual production figures into account. The calculation gives an overall potential of 104.6 million tons of unused biomass resources with an energy content of 923,2 PJ. This potential would theoretically supply about 38% of the local demand in the transport sector.

The total Bioethanol potential derived from different waste sources is about 25 billion liters.

Table 13: Canada's unused residues potential

Canada	**Source**	production	unused biomass factor	unused biomass	energy content	bioenergy
		mio. t		mio. t	GJ/t	PJ
agricultural residues						
Cereals						
Wheat	2009	28.6	0.5	14.3	14.4	205.92
Barley	2007	11	0.5	5.5	14.4	79.2
Rye	2007	0.25	0.5	0.125	14.4	1.8
Buckwheat	2007		0.5	0	14.4	0
Oats	2007	4.69	0.5	2.345	14.4	33.768
Maize	2007	11.6	1.4	16.2	14.4	233.9
Sugar beet	2007	0.7	0.05	0.035	14.4	0.504
Oil crops						
Soybeans	2007	2.69	1.89	5.0841	5	25.4
Rapeseed	2007	9.6	1.26	12.096	5	60.5
Linseed	2007	0.6	1.26	0.756	5	3.8
Vegetables						
Peas	2007	4.5	0.9	4.05	5	20.25
Tomatoes	2007	0.8	0.9	0.72	5	3.6
Potatoes	2007	5	0.36	1.8	5	9
Beans	2007	0.3	1.4	0.42	5	2.1
forestry residues						
		Mio. m^3			GJ/m^3	
roundwood	2008	152.6	0.195	29.757	4.285	127.5
saw mill	2005	2.7	0.4	1.08	10.71	11.6
municipal waste						
woody waste	2005	9.75	1	9.75	10.71	104.4
Total				104.06		923.2
	24,870,320,000	l lignocellulosic Ethanol				
	1.20%	of worldwide fuel consumption 2007				

Source:
2009: Source USDA FAS
2007: FAOStat, commodities by country
2008: FAOStat, forestry
2005: IEA Country Report Canada

5 = energy content of grass

4.6 United States of America (U.S.)

4.6.1 General Information[67, 68]

At 3.79 million 9.83 million km^2 and with over 309 million people, the United States is the third or fourth largest country by total area, and the third largest both by land area and population. The land area of the contiguous United States is approximately 770 million hectares. Alaska, separated from the contiguous United States by Canada, is the largest state at 150 million hectares and Hawaii, occupying an archipelago in the central Pacific, southwest of North America, has just over 1.6 million hectares.

The United States, with its large size and geographic variety, includes most climate types. To the east of the 100th meridian, the climate ranges from humid continental in the north to humid subtropical in the south. The southern tip of Florida is tropical, as is Hawaii. The Great Plains west of the 100th meridian are semi-arid. Much of the Western mountains are alpine. The climate is arid in the Great Basin, desert in the Southwest, Mediterranean in coastal California, and oceanic in coastal Oregon and Washington and southern Alaska. Most of Alaska is subarctic or polar. Extreme weather is not uncommon as the states bordering the Gulf of Mexico are prone to hurricanes, and most of the world's tornadoes occur within the country, mainly in the Midwest's Tornado Alley.
According to the International Monetary Fund, the U.S. GDP of $14.3 trillion constitutes 24% of the gross world product at market exchange rates and almost 21% of the gross world product at purchasing power parity.
The United States is the third largest producer of oil in the world, as well as its largest importer. It is the world's number one producer of electrical and nuclear energy, as well as liquid natural gas, sulfur, phosphates, and salt. While agriculture

[67] Hess, R. et al.: Country Report – United States. In: IEA Task 40 – Sustainable International Bioenergy Trade: Securing Supply and Demand. International Energy Agency, Idaho National Laboratory, June 2009
[68] Wikipedia: United States, http://en.wikipedia.org/wiki/United_States, 10.6.2010

accounts for just less than 1% of GDP, the United States is the world's top producer of corn and soybeans.
In 2004 there were over 136 million automobiles registered and another 100 million trucks. As of 2003 there were 759 automobiles per 1,000 Americans, compared to 472 per 1,000 inhabitants of the European Union the following year.

Country statistics
Total area: nearly 983 million hectares
Population: about 305 million people
Wood: 283 million hectares or 28.8% of land area (forest land - grassland 25.9%, crop land 19.5%)
GDP/capita in US$[69]: 14,093 billion/46,381 (nominal and PPP)
Transportation sector uses 28% of the national energy consumption or 29.3 EJ (primary energy consumption in 2008: 99.3 Quadrillion Btu or 104.7 EJ)

4.6.2 Biomass resources[70]

The land base of the US is about 983 million hectares. About half of this land has some potential for growing biomass. Cropland and forestland have the potential to supply more than 1.3 billion BDt of biomass per year (998 million BDt from agriculture, 368 million BDt from forestry).

The amount of biomass that can be removed sustainably from agricultural land is currently about 194 million BDt per year. Following the IEA Country Report the volume could be increased about five times within the next 35 to 40 years.

Crop residues[71] (corn, wheat, soybeans, cotton, sorghum, barley, oats, rice, rye, canola, beans, peanuts, potatoes, safflower, sunflower, sugarcane, and flaxseed are included) are estimated from total grain production (crop to residue ratio, moisture content, sustainability issues e.g. harming the soil) in 2002 with 157.2 million BDt.

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[69] World Bank: Gross Domestic Product 2008 & Gross Domestic Product 2008, PPP. In: World Development Indicators Database. Word Bank, April 2010
[70] Hess, R. et al.: Country Report – United States. In: IEA Task 40 – Sustainable International Bioenergy Trade: Securing Supply and Demand. International Energy Agency, Idaho National Laboratory, June 2009
[71] Milbrandt, A.: A Geographic Perspective on the Current Biomass Resource Availability in the United States. In: Technical Report NREL/TP-560-39181. National Renewable Energy Laboratory, December 2005

4.6.2.1 Forestry residues

Biomass derived from forestland currently accounts for about 142 million BDt. Forest residues derived from the USAF Forest Service's Timber Product Output database for 2002 are 56.6 million BDt.

Unused primary mill residues (wood materials and bark generated at manufacturing plants) were 1.6 million BDt in 2002. Secondary mill residues (wood scraps and sawdust) were estimated at 2.6 million BDt.

4.6.2.2 Municipal waste

Estimates for urban wood residues coming from wood chips, pallets, yard waste, utility tree trimming and construction and demolition wood were 30.9 million BDt.

4.6.3 Summary

The table below gives a summary of the potentials for bioenergy in unused residues in the United States taking actual production figures into account. The calculation gives an overall potential of 779 million tons of unused biomass resources with an energy content of 8,793 PJ. This potential would theoretically supply about 30% of the local demand in the transport sector.

The total Bioethanol potential derived from different waste sources is about 165 billion liters.

Table 14: United States unused biomass potential

US	**Source**	production	unused biomass factor	unused biomass	energy content	bioenergy
		mio. t		mio. t	GJ/t	PJ
agricultural residues						
Cereals						
Wheat	2007	55.8	0.5	27.9	14.4	401.76
Barley	2007	4.6	0.5	2.3	14.4	33.12
Rice, paddy	2007	9	0.5	4.5	14.4	64.8
Sorghum	2007	12.6	0.5	6.3	14.4	90.72
Oats			0.5	0	14.4	0
Maize	2007	331.2	1.4	463.7	14.4	6,677
Sugar beet	2007	31.9	0.05	1.595	14.4	22.968
Bagasse	2007	27.7	0.07	1.939	5	9.695
Oil crops						
Soybeans	2007	72.8	1.89	137.592	5	688
Rapeseed			1.26	0	5	
Cotton	2007	6.1	1.89	11.529	5	57.6
Vegetables						
Other	2007	7.9	0.45	3.555	5	17.775
Tomatoes	2007	14.1	0.9	12.69	5	63.45
Potatoes	2007	20.3	0.36	7.308	5	36.54
forestry residues						
		Mio. m^3			GJ/m^3	
roundwood	2008	336	0.195	65.52	4.285	280.8
saw mill	2002	4.2	0.4	1.68	10.71	18.0
municipal waste						
woody waste	2002	30.9	1	30.9	10.71	330.9
Total				778.988		8,793.11
	165,607,600,000	l lignocellulosic Ethanol				
	7.97%	of worldwide fuel consumption 2007				

Source:
2009: Source USDA FAS
2007: FAOStat, commodities by country
2008: FAOStat, forestry
2002: IEA Country Report US — 5 = energy content of grass

Other vegetables include:
Lettuce and Onions

4.7 China

4.7.1 General Information[72, 73]

The People's Republic of China is situated in the eastern part of the Asian Continent on the western coast of the Pacific. With a total land area of 9.6 million km^2, China is the largest country in Asia and the third largest in the world, next to Russia and Canada. With over 1.3 billion people it is the most populous state in the world.

With a vast territory, China has diverse types of land resources. There are more mountains than plains, with cultivated land and forests constituting small proportions. Various types of land resources are unevenly distributed. The cultivated land is mainly in plains and basins in the monsoon regions of east China, while forests are mostly found in the remote mountainous areas in the northeast and the southwest. Grasslands are chiefly distributed on inland plateaus and in mountains.

China has a climate mainly dominated by dry seasons and wet monsoons, which leads to temperature differences in winter and summer. In winter, northern winds coming from high latitude areas are cold and dry; in summer, southern winds from sea areas at lower latitude are warm and moist. The climate in China differs from region to region because of the country's extensive and complex topography.

China contains also a variety of forest types. Both northeast and northwest reaches contain mountains and cold coniferous forests, supporting animal species, which include moose and Asiatic black bear, along with some 120 types of birds.

Moist conifer forests can have thickets of bamboo as an understorey, replaced by rhododendrons in higher montane stands of juniper and yew. Subtropical forests, which dominate central and southern China, support an astounding 146,000 species of flora. Tropical rainforest and seasonal rainforests, though confined

[72] China.ord.cn: Natural Conditions – Location and Territory. http://www.china.org.cn/english/en-shuzi2004/information1.htm; 7.5.2010
[73] Wikipedia: People´s Republic of China. http://en.wikipedia.org/wiki/People's_Republic_of_China, 8.5.2010

to Yunnan and Hainan Island, actually contain a quarter of all the plant and animal species found in China.

Since the introduction of market-based economic reforms in 1978, China has become the world's fastest growing major economy, the world's largest exporter and second largest importer of goods. Rapid industrialization has reduced its poverty rate from 53% in 1981 to 8% in 2001.

Private car ownership is increasing at an annual rate more than 15%. The sale of automobiles had been increasing rapidly after the financial crisis in 2009, and China surpassed the United States to become the largest automobile market in the world with total sales of more than 13.6 million cars per year.

Although China's agricultural output is the largest in the world, only about 15% of its total land area can be cultivated. China's arable land, which represents 10% of the total arable land in the world, supports over 20% of the world's population. Of this land only about 1.2% (116,580 km^2) permanently supports crops. The land is divided into approximately 200 million households, with an average land allocation of just 0.65 hectares.

Total energy production in 2002 was 1,390 Mtce or 4.07 EJ of which 70.7% were from coal, 17.2% from oil, 3.2 from natural gas and 8.9% from hydropower.

Total installations of hydropower reached 145 GW through 2007. China has set the target of 190 GW for 2010. It also has the largest wind resources in the world and three-quarters of them are offshore.

About 50 MW of installed solar capacity was added in 2008, more than double the 20 MW in 2007, but still a relatively small amount. According to some studies, the demand in China for new solar modules could be as high as 232 MW each year from now on until 2012.

China emerged as the world’s third largest producer of ethanol (after the U.S. and Brazil) as of the end of the 10th Five Year Plan Period in 2005 and at present ethanol accounts for 20% of total automotive fuel consumption in China.

Country statistics[74]

Total land area: 960 million hectares

Population: 1.33 billion people (2010 estimate)

Cultivated land: 130.04 million hectares (cultivated area 4.67 million hectares)

Wood: forest area 233.97 million hectares

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[74] National Bureau of Statistics of China: China Statistical Yearbook 2003. National Bureau of Statistics of China, 2003

Grassland: 400 million hectares

GDP/capita in US$[75]: 4,326 billion/16,391 (nominal), 7,909 billion/31,834 (PPP)

Transportation (and Storage, Post and Telecom Services) sector used 1,025 Mtce (3 EJ) or 76% of the national energy consumption (primary energy consumption in 2002: 1,349 Mtce or 3.95 EJ)

4.7.2 Biomass Resources

According to the 2003 China Land and Resources Communiqué, released by the Ministry of Land and Resources, China's cultivated land stood at 123.39 million hectares in 2003. The cultivated land is mainly distributed in Northeast China Plain, North China Plain, and the Middle-Lower Yangtze Plain, and in the Pearl River Delta and Sichuan Basin.

About 75% of China's cultivated area is used for food crops. Rice is China's most important crop, raised on about 25% of the cultivated area. Wheat is the second most-prevalent grain crop, grown in most parts of the country. Corn and millet are grown in north and northeast China and oat in Inner Mongolia and Tibet. Other crops include sweet potatoes, white potatoes and various other fruits and vegetables. Oil seeds are important in Chinese agriculture, supplying edible and industrial oils and forming a large share of agricultural exports. Other oilseed crops are sesame seeds, sunflower seeds and rapeseed. Other important food crops for China include tea, sugarcane, and sugar beets.

Total grain production based on the Statistical Yearbook 2003[76] was 457 million tons, including 174.5 million tons of rice, 90 million tons of wheat and 121.3 million tons of corn. 29 million tons of oil-crops were produced, 0.96 million of fiber crops (jute and hemp) and 90 million tons of sugarcane.

4.7.2.1 Forestry resources

China now has a total of 233.97 million hectares of forests, which cover 16.55 percent of the national total land area, far less than the world's average level of 30.8 percent. Natural forests are concentrated in the northeast and the southwest, but scarce in the densely inhabited and economically developed eastern plains and the vast northwestern region.

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[75] World Bank: Gross Domestic Product 2008 & Gross Domestic Product 2008, PPP. In: World Development Indicators Database. Word Bank, April 2010

[76] National Bureau of Statistics of China: China Statistical Yearbook 2003. National Bureau of Statistics of China, 2003

However, the forests in China are rich in tree species, with the number of arbor species alone exceeding 2,800. In order to conserve environment and meet the needs of economic construction, China has launched large-scale afforestation campaigns. The area of planted forests has reached 33.79 million hectares, accounting for 31.86 percent of the nation's total forest area, making China a country with the largest area of planted forests in the world.
With the start of the 11th Five-Year Plan for 2006 to 2010, the annual harvest quota of forest plantations increased to 157 million m^3, surpassing that of natural forests with 91 million m^3. The State Forest Administration forecasts the supply of industrial roundwood from domestic sources for 2010 with 241.5 million m^3.[77]

4.7.2.2 Sawmill residues

According to Chinese official statistics sawnwood production in 2005 was 18 million m^3, but these figures do not entirely capture the production from small-scale producers that account for large parts of the country total. Different studies estimate sawnwood production to be up to 64.6 million m^3 in 2004.

4.7.2.3 Municipal waste

The total amount of industrial solid waste in China was about 580 million tons in 1990. Until 1990, about 6.5 billion tons industrial waste was stockpiled in China, occupying an area of 58,692 hectares, of which 4,060 hectares is potential farming land.[78]
Incineration together with composting, landfill and dumping site has become the major solution to municipal solid waste in China. Recycling seems to be in a very early stage.[79]
Therefore it is assumed that there is no realistic potential from municipal solid waste in China at the moment.

[77] Kun, Z. et al.: Demand and Supply of Wood Products in China. In: Forest Products Working Paper 1. Food and Agriculture Organization of the United Nations, 2007
[78] Wei, J. et al.: Solid Waste Disposal in China – Situation, Problems and Suggestions. In: Waste Management and Research Vol. 15. No. 6. International Solid Waste Association, 1997
[79] Lin, J. et al.: Municipal Solid Waste Management in China. January 2007

4.7.3 Summary

The table below gives a summary of the potentials for bioenergy in unused residues in China taking actual production figures into account. The calculation gives an overall potential of 769.82 million tons of unused biomass resources with an energy content of 7.9 EJ. This potential would theoretically supply more than double the amount of the local demand in the transport sector in 2003.

The total Bioethanol potential derived from different waste sources is about 160 billion liters.

Table 15: China's unused biomass potential

China	Source	production	unused biomass factor	unused biomass	energy content	bioenergy
		mio. t		mio. t	GJ/t	PJ
agricultural residues						
Cereals						
Wheat	2009	112.5	0.5	56.25	14.4	810
Coarse Grains	2009	172.7	0.5	86.35	14.4	1,243.4
Barley			0.5	0	14.4	0
Rice, paddy	2009	134.3	0.5	67.15	14.4	966.96
Buckwheat			0.5	0	14.4	0
Oats	2007		0.5	0	14.4	0
Maize	2007	152.4	1.4	213.4	14.4	3,072.4
Sugar beet			0.05	0	14.4	0
Bagasse	2007	113.7	0.07	7.959	5	39.795
Oil crops						
Soybeans	2009	15.54	1.89	29.3706	5	146.9
Rapeseed	2009	12.64	1.26	15.93	5	79.6
Cotton	2009	14.4	1.89	27.216	5	136.1
Vegetables						
Other	2007	341.9	0.45	153.855	5	769.275
Tomatoes	2007	33.6	0.9	30.24	5	151.2
Potatoes	2007	64.8	0.36	23.328	5	116.64
forestry residues						
		Mio. m^3			GJ/m^3	
roundwood	2010	241.5	0.195	47.0925	4.285	201.8
saw mill	2008	29.3	0.4	11.72	10.71	125.5
Total				769.82		7,859.6
	159,844,750,000	l lignocellulosic Ethanol				
	7.69%	of worldwide fuel consumption 2007				

Source:
2009: Source USDA FAS
2007: FAOStat, commodities by country
2008: FAOStat, forestry
2010: State Forest Administration (forecast)
2005: Official Chinese Statistic — 5 = energy content of grass

Other vegetables include:
sweet potatoes, watermelons, cabbages, cucumbers, onions and Vegetable fresh nec.

4.8 Australia

4.8.1 General Information[80, 81]

Australia is the flattest continent with the oldest and least fertile soils and about 7.6 million km^2, which makes it the 6th biggest country in the world. The population density with 2.8 inhabitants per square kilometer is among the lowest in the world but a large proportion of the population lives along the temperate southeastern coastline. Just under three quarters of Australia lies within a desert or semi-arid zone.
The climate of Australia is significantly influenced by Ocean currents, including the Indian Ocean Dipole and the El Niño-Southern Oscillation, which is correlated with periodic drought, and the seasonal tropical low-pressure system that produces cyclones in northern Australia. Although most of Australia is semi-arid or desert, it includes a diverse range of habitats from alpine heaths to tropical rainforests, and is recognized as a mega diverse country.
Rich in natural resources, Australia is a major exporter of agricultural products, particularly wheat and wool, minerals such as iron-ore and gold, and energy in the forms of liquefied natural gas and coal.
In 2007/08 Australia's energy production was 17.36 EJ. The main fuels produced in Australia are coal (9% of total world resources), uranium (38% of total world resources) and natural gas. Australia is a net energy exporter with net exports of more than 2/3 of domestic energy production. Australia's energy consumption in 2007/08 was about 5.7 EJ.
Renewable energy accounts for 5% of Australia's total energy consumption. The production is dominated by bagasse, wood and wood waste and hydropower

80 Wikipedia: Australia. http://en.wikipedia.org/wiki/Australia, 10.6.2010
81 Cuevas-Cubria, C. et al.: Energy in Australia 2010. Australian Government Department of Resources, Energy and Tourism, 2010

(accounting for 87% of renewable energy production). The rest came from wind, solar and biofuels.

Country statistics

Total area: 769.2 million hectares

Population: 19.8 million people (2006 census; actual estimation from the Australian Bureau of statistics is 22.38 million people)

Wood: 149 million hectares or 19% of the continent's land area (forest land) of which 1.97 million hectares are plantations and 9.4 million hectares are in public forests where timber production is permitted[82]

Crop land: about 12 million hectares

GDP/capita in US$[83]: 1,015 billion/53,862 (nominal), 831 billion/38,910 (PPP)

Transportation sector used 1.388 EJ or 24% of the total 5.772 EJ energy consumed in 2007/08[84] - 14.35 million vehicles (including motorcycles) were registered in 2006[85]

4.8.2 Biomass Resources[86, 87]

Australia is a major agricultural producer and exporter, despite agriculture's 3.5% share of GDP. There is a mix of irrigation and dry-land farming. Cereals, oilseeds and grain legumes are produced on a large scale in Australia's food and fodder production. Wheat is the cereal with the greatest production in terms of area and value to the Australian economy. Wheat production in 2007 was 13 million tons, barley production 5.9 million tons and more than 1 million tons of rapeseed were produced.[88]

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[82] Minister for Agriculture, Fisheries and Forestry: Australia's Forests at a Glance 2010. Australian Government Department of Agriculture, Fisheries and Forestry, Bureau of Rural Services, 2010

[83] World Bank: Gross Domestic Product 2008 & Gross Domestic Product 2008, PPP. In: World Development Indicators Database. Word Bank, April 2010

[84] Cuevas-Cubria, C. et al.: Energy in Australia 2010. Australian Government Department of Resources, Energy and Tourism, 2010

[85] Australian Bureau of Statistics: Australia at a Glance, 2008, Industry. Australian Bureau of Statistics, http://www.abs.gov.au, 11.6.2010

[86] Department of Agriculture, Fishery and Forestry: Australia's Forests. Australian Government Department of Agriculture, Fishery and Forestry, http://www.daff.gov.au/forestry/national/australias-forests, 6.5.2010

[87] Minister for Agriculture, Fisheries and Forestry: Australia's Forests at a Glance 2010. Australian Government Department of Agriculture, Fisheries and Forestry, Bureau of Rural Services, 2010

[88] FAOStat: Commodities by Country, Top Production, Australia. http://faostat.fao.org/site/339/default.aspx, 11.6.2010

Sugarcane, grown in tropical Australia, is also an important crop although the unsubsidized industry (while lower-cost than heavily subsidized European and American sugar producers) is struggling to compete with the huge and much more efficient Brazilian sugarcane industry. According to FAOStat sugarcane production in 2007 with 36.3 million tons (compared to 549.7 million tons in Brazil) was the number 1 commodity in terms of volume.

Most of Australia is too dry to support forests as arid lands occupy about 70 per cent of the interior of Australia. Native forests are generally located in areas with an average of more than 500 millimeters of rain annually. Commercial plantations have been established mainly in areas with more than 700 millimeters of annual rainfall. Australia's forests are extremely diverse and unique.
Native forest types in Australia are dominated by eucalypts (78%) followed by acacias (7%) and melaleucas (5%). In contrast, about half (52% or just over 1 million hectares) of Australia's plantations are exotic conifers (predominantly Pinus radiata), often referred to as softwood plantations, while the other half (48% or 0.95 million hectares) are hardwood (predominantly eucalypt) plantations.

Climate and soil properties broadly determine the distribution of forest types and classes across Australia, although other factors, especially fire frequency and intensity, are important.

4.8.2.1 Forestry residues

In 2006/07, 27 million m^3 of logs were harvested from Australia's production forests. Around two-thirds of this log harvest was from plantations with the reminder from native forests. Australia's total log harvest has increased by 35 per cent over the past ten years consisting of a 75 per cent increase in logs harvested from plantations and a 10 per cent decrease in logs from native forests over this period. In this year 5.1 million m^3 of sawnwood, 1.7 million m^3 of wood based panels and 3.2 million tons of paper and paperboard were produced.[89]

[89] Department of Agriculture, Fishery and Forestry: Australia's Forests Industries. Australian Government, Department of Agriculture, Fisheries and Forestry, Australia´s Forest Industries, http://www.daff.gov.au/forestry/national/industries, 11.6.2010

In 2008 total log harvest was 28.4 million m^3.[90]

4.8.2.2 Saw mill residues

More than 3 million m^3 of broadleaved saw logs and more than 8.5 million m^3 of coniferous saw logs were processed in Australian sawmills in 2006/07.[91]
The waste streams from sawmills are increasingly put to a wider variety of uses. Some of Australia's softwood mills are able to sell or use practically all of their waste streams, meaning almost not products get dumped but there are still sawmills where some or all residues are either dumped or burnt for no useful purpose, particularly hardwood mills which are generally smaller in size than softwood mills. In 1999 timber residues from sawmills and material that was not chipped for export or used for board products was estimated to have an energy equivalency of about 120 PJ per year.[92]

4.8.2.3 Municipal waste[93]

Urban waste management practices vary considerably across Australia. In 2002/03 17.4 million tons of waste was sent to landfill, of which approximately 9.5 million tons per year consisted of various organic materials, such as food wastes, garden wastes, paper, cardboard, wood and timber.
From 2.1 million tons of wood and timber wastes about 0.44 million tons are recycled.

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[90] Minister for Agriculture, Fisheries and Forestry: Australia's Forests at a Glance 2010. Australian Government Department of Agriculture, Fisheries and Forestry, Bureau of Rural Services, 2010
[91] Australian Bureau of Agricultural and Rural Economics: Australian Forest and Wood Products Statistic, September and December quarters 2007. In: Australian Forest and Wood Products Statistic – ABARE project 3117. Australian Bureau of Agricultural and Rural Economics (ABARE), 2008
[92] Goble, D. et al.: Opportunities for Using Sawmill Residues in Australia. In: Manufacturing & Products, Project Number: PR08.2046. Forest and Wood Products Australia, November 2007
[93] Clean Energy Council: Biomass – Resource Appraisal. Clean Energy Council, 2008

4.8.3 Summary

The table below gives a summary of the potentials for bioenergy in unused residues in Australia taking actual production figures into account. The calculation gives an overall potential of 48.43 million tons of unused biomass resources with an energy content of 468 PJ. This potential would theoretically supply 34% of the local demand in the transport sector.
The total Bioethanol potential derived from different waste sources is about 11 billion liters.

Table 16: Australia's unused biomass potential

Australia	**Source**	production	unused biomass factor	unused biomass	energy content	bioenergy
		mio. t		mio. t	GJ/t	PJ
agricultural residues						
Cereals						
Wheat	2009	21.42	0.5	10.71	14.4	154.2
Coarse Grains	2009	12.27	0.5	6.135	14.4	88.3
Barley	2007	5.9	0.5	2.95	14.4	42.5
Rice, paddy			0.5	0	14.4	0
Buckwheat			0.5	0	14.4	0
Oats	2009	1.16	0.5	0.58	14.4	8.352
Maize	2007		1.4	0	14.4	0
Sugar beet			0.05	0	14.4	0
Bagasse	2007	36.3	0.07	2.541	5	12.71
Oil crops						
Soybeans			1.89	0	5	0
Rapeseed	2009	1.84	1.26	2.32	5	11.6
Cotton	2009	0.4	1.89	0.756	5	3.8
Tomatoes	2007	0.3	0.9	0.27	5	1.35
Potatoes	2007	1.2	0.36	0.432	5	2.16
forestry residues						
		Mio. m^3			GJ/m^3	
roundwood	2008a	28.4	0.195	5.538	4.285	23.7
saw mill	2008a	11.5	0.4	4.6	10.71	49.3
municipal waste						
woody waste	2008a	2.1	1	2.1	10.71	22.5
msw	2008a	9.5	1	9.5	5	47.5
Total				48.43		468.0
	11,859,880,000	l lignocellulosic Ethanol				
	0.57%	of worldwide fuel consumption 2007				

Source:
2009: Source USDA FAS
2007: FAOStat, commodities by country
2008: FAOStat, forestry
2008a: Australian Government

5 = energy content of grass

4.9 Republic of Congo

4.9.1 General Information[94]

The Democratic Republic of Congo (until 1997 named Zaire) is a country located in Central Africa, with a small length of Atlantic coastline. It is the third largest country in Africa by area. With a population of more than 68 million people it is the 18th most populous nation in the world, and the fourth most populous nation in Africa.
As a result of its equatorial location, the Congo experiences large amounts of precipitation and has the highest frequency of thunderstorms in the world. The annual rainfall can total upwards of 2,000 mm in some places, and the area sustains the Congo Rainforest, the second largest rain forest in the world (only the rainforest of the Amazon is bigger).
The economy relies heavily on mining however, much economic activity occurs in the informal sector and is not reflected in GDP data. The Democratic Republic of Congo is the world's largest producer of cobalt ore, and a major producer of copper and industrial diamonds. It has 70% of the world's coltan (columbite also called niobite) and more than 30% of the world's diamond reserves.

The Democratic Republic of Congo produces crude oil, but is not able to process its oil in refineries. Petroleum products, mainly used in the transportation sector, have to be imported. Over 90% of the energy consumed in Democratic Republic of Congo comes from traditional biomass, mainly used by the rural population, as well as by the industry sector.
The Democratic Republic of the Congo is blessed with the greatest hydropower potential in Africa, and among the largest in the world. This potential is a result of the country's location with the catchment area of the Congo river. The republic's technically feasible potential is 774,000 GWh/year (estimated in 1997). In 1991, the

[94] Wikipedia: Democratic Republic of Kongo. http://en.wikipedia.org/wiki/Democratic_Republic_of_the_Congo, 21.6.2010

economically feasible potential was estimated at 419,210 GWH/year, less than 1% of the technically feasible potential has been developed.[95]

Country statistics

Total area: 234,5 million hectares

Population: 68.7 million (2009 estimate)

Wood: total forest area 155.5 million hectares (67% of total land area)[96]

GDP/capita in US$[97]: 11.7 billion/171 (nominal), 20.1 billion/332 (PPP)

Total energy consumption in the transport sector was 107 Mtoe or 448 PJ in 1999[98] (20% of 527 Mtoe or 2.2 EJ - total energy consumption)

Forest in the Congo Basin

The forest ecosystems of the Congo basin, of which the Democratic Republic of Congo has the greatest extent, span across much of Central Africa, from the Atlantic Ocean's Gulf of Guinea to the mountains of the Albertine Rift in the east. Covering about 1.813 million km^2 in six countries, they constitute the second largest area of contiguous moist tropical forest left in the world and represent approximately one fifth of the world's remaining closed canopy tropical forest. This vast area hosts a wealth of biodiversity, including over 10,000 species of plants, 1,000 species of birds, and 400 species of mammals, and three of the world's four species of great apes. It is also home to more than 24 million people, many of which depend on the forest for their livelihoods. The Congo basin forests not only play a critical role for global biodiversity conservation, they also provide vital regional and global ecological services as a carbon sink and catchment basin. [99]

With large forests, exceedingly high biodiversity, extraordinary hydroelectric potential, and substantial endowments of cobalt (28 percent of the world's supply), copper (6 percent), and industrial diamonds (18 percent), the Democratic Republic of Congo

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[95] Energy Recipies: Developing Renewables, Country energy information Congo. In: Renewable Energy in Emerging and Developing Countries. Final Report RECIPES Project, European Union Sixth RTD Ramework Programme. March 2007

[96] Eba'a Aryi, R. et al.: The Forests of the Democratic Republic of Congo in 2008. In: State of the Forest 2008. Observatoire des Forest d'Afrique Centrale, 2008

[97] World Bank: Gross Domestic Product 2008 & Gross Domestic Product 2008, PPP. In: World Development Indicators Database. Word Bank, April 2010

[98] World Resource Institute: Energy Resources – Country Profile Congo. In: Earth Trends: The Environmental Information Portal, http://earthtrends.wri.org/text/energy-resources/country-profile-41.html, 21.6.2010

[99] USAID: Congo Basin Forest Partnership. Sub-Sahara Africa Iniciatives. http://www.usaid.gov/locations/sub-saharan_africa/initiatives/cbfp.html, 24.6.2010

should be a relatively rich country. Instead, years of widespread crippling corruption and mismanagement have left it one of the world's poorest countries. [100]

4.9.2 Biomass Resources

The agricultural sector supports two-thirds of the population. Agricultural production has stagnated since independence. The principal crops are cassava, yams, plantains, rice, and maize. The country is not drought-prone but is handicapped by a poor internal transportation system, which impedes the development of an effective national urban food-supply system. Land under annual or perennial crops constitutes only 3.5% of the total land area. Agriculture is divided into two basic sectors: subsistence, which employs the vast majority of the work force, and commercial, which is export-oriented and conducted on plantations. Subsistence farming involves four million families on plots averaging 1.6 hectares, usually a little larger in Savanna areas than in the rain forest. Subsistence farmers produce mainly manioc, corn, tubers, and sorghum.

Manioc or cassava is the third largest source of carbohydrates for meals in the world. Cassava roots are very rich in starch. Cassava is used worldwide for animal feed as well. Cassava hay is produced at a young growth stage, 3–4 months, harvested about 30–45 cm above ground, and sun-dried for 1–2 days until it has final dry matter of at least 85%[101]. As almost everything from the plant is used no residues from cassava were accounted.

In 1999, food-crop production included 16.5 million tons manioc, 1.7 million tons of sugarcane, 1.1 million tons of corn. Plantains totaled 1.8 million tons sweet potatoes, 0.37 million tons bananas and others (yams, pineapples). Domestic food production is insufficient to meet the country's needs, and many basic food products have to be imported. By the mid-1990s, the production of the Democratic Republic of Congo's principal cash crops (coffee, rubber, palm oil, cocoa, tea) was mostly produced by private farms. Commercial farmers number some 300,000, with holdings between 12 and 250 hectares. Palm oil production is concentrated in three large operations, two of them foreign-owned. Production in 1999 totaled 157,000 tons. Palm oil production remains profitable in the Democratic Republic of Congo

[100] Mongabay.com: Democratic Republic of Congo. http://rainforests.mongabay.com/20zaire.htm, 24.6.2010
[101] Wikipedia: Cassava, http://en.wikipedia.org/wiki/Cassava, 30.6.2010

due to a 100% tax on competing imported oil. [102]

4.9.2.1 Forestry residues[103]

Available data on forest resources in the Democratic Republic of Congo covers only a portion of the Congolese territory. Until 2004, the only figures available came from National inventories or inventories carried out in areas with forest titles. These inventories covered around 20 million hectares, but often with a low sampling rate. Since 2005, more exhaustive management inventories have been carried out on approximately 2 million hectares.

In addition to the fact that the Democratic Republic of Congo's timber resources are considered of poorer quality, the low level of harvesting can be explained by the high costs of evacuating products due to difficult access and transportation. The road network in the central basin, though dense, is impractical for trucks and timber can only be transported as far as Kinshasa (1,500 km of transport from Kisangani) by river. After Kinshasa, the Congo River is no longer navigable, and products must be transported by road to the port of Matadi, which does not have sufficient storage capacity and is frequently congested. At the moment, only the forests near waterways are developed. Most logging sites achieve very low production, often less than 2,000 m^3 per month, for various reasons including artisanal production, lack of production means, lack of logistics and maintenance.

Official forest production fell between 1998 and 2003, to about 50,000 m^3 a year. Since then, strong growth has been observed and production has reached levels in 2007 of that before the war of about 300.000m^3.
Industrial timber processing in the Democratic Republic of Congo is primarily located in Kinshasa, with the notable exception of a large industrial site in Bandundu. Processing facilities are largely outdated or operating at a very low level of production with many idled or halted timber-processing plants.
The volume of timber produced by the informal sector is inherently difficult to quantify. It is considerable in the Democratic Republic of Congo. While products from the industrial sector are generally intended for export, the informal sector is the main source of domestic timber. It was found that artisanal loggers produced

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102 Encyclopedia of the Nations: Congo, Democratic Republic of (DROC), Agriculture. http://www.nationsencyclopedia.com/Africa/Congo-Democratic-Republic-of-the-DROC-AGRICULTURE.html, 21.6.2010
103 Eba'a Aryi, R. et al.: The Forests of the Democratic Republic of Congo in 2008. In: State of the Forest 2008. Observatoire des Forest d'Afrique Centrale, 2008

between 1.5 and 2.4 million m^3, which is between five and eight times the production of the industrial sector.

Due to the factors mentioned above little to no forest residue potential exists at present. Due to the huge forest area there is a big substantial potential for the future.

4.9.2.2 Saw mill residues[104]

The industry focuses on sawn timber production (33 sawmills listed, but many are not operational), flooring, peeled veneer (6 units listed), plywood and sliced veneer (2 units, only one of which is operational).

No figures could be found about the production of sawn wood and the usage of saw mill residues. Due to the poverty of the country it might be similar to Indonesia where almost all residues are used as fuelwood.

4.9.2.3 Municipal waste

No information could be found about municipal waste management in the Democratic Republic of Congo.

4.9.3 Summary

The table below gives a summary of the potentials for bioenergy in unused residues in the Democratic Republic of Congo taking actual production figures into account. The calculation gives an overall potential of 1.9 million tons of unused biomass resources with an energy content of 26.16 PJ. This potential would theoretically supply 28% of the local demand in the transport sector.

The total Bioethanol potential derived from different waste sources is about 566 million liters.

[104] Eba'a Aryi, R. et al.: The Forests of the Democratic Republic of Congo in 2008. In: State of the Forest 2008. Observatoire des Forest d'Afrique Centrale, 2008

Table 17: DR Congo's unused biomass potential

DR Congo	Source	production	unused biomass factor	unused biomass	energy content	bioenergy
		mio. t		mio. t	GJ/t	PJ
agricultural residues						
Cereals						
Wheat			0.5	0	14.4	0
Coarse Grains			0.5	0	14.4	0
Barley			0.5	0	14.4	0
Rice, paddy	2007	0.31	0.5	0.155	14.4	2.232
Buckwheat			0.5	0	14.4	0
Oats			0.5	0	14.4	0
Maize	2007	1.16	1.4	1.6	14.4	23.4
Sugarbeet			0.05	0	14.4	0
bagasse	2007	1.55	0.07	0.1085	5	0.5425
Oil crops						
Soybeans			1.89	0	5	0
Rapeseed			1.26	0,00	5	0
Cotton			1.89	0	5	0
forestry residues						
		Mio. m^3			GJ/m^3	
roundwood			0.195	0	4,285	0
saw mill			0.4	0	10,71	0
Total				1.89		26.16
	377,500,000	l lignocellulosic Ethanol				
	0.02%	of worldwide fuel consumption 2007				
Source:						
2009: Source USDA FAS						
2007: FAOStat, commodities by country						
2008: FAOStat, forestry			5 = energy content of grass			

4.10 Indonesia

4.10.1 General Information[105]

The republic of Indonesia is a country in Southeast Asia and Oceania. Indonesia comprises 17,508 islands of which about 6,000 are inhabited islands. With a population of around 230 million people, it is the world's fourth most populous country, and has the world's largest population of Muslims.

Indonesia's size, tropical climate, and archipelagic geography, support the world's second highest level of biodiversity (after Brazil), and its flora and fauna is a mixture of Asian and Australasian species.

Forests cover approximately 60% of the country. In Sumatra and Kalimantan, these are predominantly of Asian species. However, the forests of the smaller, and more densely populated Java, have largely been removed for human habitation and agriculture. Indonesia's high population and rapid industrialization present serious environmental issues, which are often given a lower priority due to high poverty levels and weak, under-resourced governance. Issues include large-scale deforestation, much of it illegal, and related wildfires causing heavy smog over parts of western Indonesia, Malaysia and Singapore. Over-exploitation of marine resources and environmental problems associated with rapid urbanization and economic development, including air pollution, traffic congestion, garbage management, and reliable water and wastewater services are the biggest challenges for the future. Deforestation and the destruction of peat lands make Indonesia the world's third largest emitter of greenhouse gases.

Indonesia is the largest economy in Southeast Asia and a member of the G-20 major economies. Indonesia's estimated gross domestic product (nominal) for 2008 was US$ 511.7 billion. The services sector is the economy's largest and accounts for 45.3% of GDP (2005). This is followed by industry (40.7%) and agriculture (14.0%). However, agriculture employs more people than other sectors, accounting

[105] Wikipedia: Indonesia. http://en.wikipedia.org/wiki/Indonesia, 24.6.2010

for 44.3% of the 95 million-strong workforce. Major industries include petroleum and natural gas, textiles, apparel, and mining. Major agricultural products include palm oil, rice, tea, coffee, spices, and rubber.
In 2008[106] Indonesia's energy production was of 304.61 Mtoe coming mainly from fossil sources (coal, oil, gas). About 17% of the energy supplied came from renewable sources.
Following the Ministry of Energy and Mineral Resources[107], Indonesia estimates a renewable energy potential of 450 MW of small hydropower, 50 GW of biomass and 27.6 GW of geothermal energy (about 40% of the world's geothermal resources are located in Indonesia, due to the active volcanic belt[108]). There is also some solar potential (4,80 KWh/m^2/day) as well as some wind energy potential of 9 GW (3-6 M/sec).

Country statistics

Total area: 191,9 million hectares
Population: 228.5 million[109]
Wood: total forest area about 100 million ha (about 52% of total area)
GDP/capita in US$[110]: 510.7 billion/2,329 (nominal), 907.9 billion/4,156 (PPP)
Total energy consumption in the transport sector was 27.95 Mtoe or 117 PJ in 2008 (18.5% of 151.1 Mtoe or 632 PJ - total energy consumption) – In 2008 about 9.9 million passenger cars but also 47.7 million motorcycles were registered (65.3 million motor vehicles in total)[111]

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[106] Minister of Energy and Mineral Resources: Handbook of Energy & Economic Statistics of Indonesia 2009. Ministry of Energy and Mineral Resources of the Republic of Indonesia, 2009

[107] Minister of Energy and Mineral Resources: Indonesia´s Renewable Energy Potential. Ministry of Energy and Mineral Resources of the Republic of Indonesia, http://www.esdm.go.id/news-archives/general/49-general/1963-indonesias-renewable-energy-potential.html, 24.6.2010

[108] Minister of Energy and Mineral Resources: Key Indicator of Indonesia Energy and Mineral Resources. Ministry of Energy and Mineral Resources of the Republic of Indonesia, 2007

[109] Minister of Energy and Mineral Resources: Handbook of Energy & Economic Statistics of Indonesia 2009. Ministry of Energy and Mineral Resources of the Republic of Indonesia, 2009

[110] World Bank: Gross Domestic Product 2008 & Gross Domestic Product 2008, PPP. In: World Development Indicators Database. Word Bank, April 2010

[111] Badan Pusat Statistik. Number of Motor Vehicles by Types 1987-2008. Republik of Indonesia, Statistic Indonesia, http://dds.bps.go.id/eng/tab_sub/view.php?tabel=1&daftar=1&id_subyek=17&notab=12, 24.6.2010

4.10.2 Biomass Resources

Following the Indonesian Agricultural Development Plan 2006[112] agricultural land availability in Indonesia is relatively limited. The average land per capita is only 0.09 hectares (900m^2), and the average landholding of 53% farm households is less than 0.5 hectares per household. Agricultural development is facing increasing demand for agricultural products, particularly food due to increasing population, while agricultural resource capacity, especially land and water is limited or even declining. The arable land area is declining due to a slower rate of new agriculture land expansion while agriculture land conversion keeps on increasing. The competition for water is also increasing due to increasing demand of households and the industry. Due to the rapid growth of agricultural land conversion from agriculture to other purposes, especially in Java and around the cities, it is necessary to utilize less fertile and marginal lands.

Although rice, vegetables, and fruit constitute the bulk of the small farmer's crops, about 20% of their output is crops for export, especially rubber. Of the estate grown crops, rubber, tobacco, sugar, palm oil, hard fiber, coffee, tea, cocoa, and cinchona are the most important.[113]
Rice is by far the most important agricultural commodity in Indonesia. In 2005, rice made up around 23% of total agricultural production. Cassava and maize are the other two principal food crops in Indonesia, accounting for further 13%. Other important agricultural products include sugar cane, palm oil, and rubber with a total share of 19%[114].

4.10.2.1 Forestry residues[115]

About 88% of the forest cover is classified as tropical moist forest. Mixed hill forests account for about 65% of the natural forest and are the main contributor for timber production. There has been a rapid loss of forest over the past 40 years (about 1.3 million hectares per year between 1990 and 2000). About 70% of the natural forest

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[112] Minister of Agriculture: Indonesian Agricultural Development Plan for 2005-2009. Ministry of Agriculture of the Republic of Indonesia, 2006
[113] Encyclopedia of the Nations: Indonesia – Agriculture. http://www.nationsencyclopedia.com/Asia-and-Oceania/Indonesia-AGRICULTURE.html#ixzz0rm6IOHQr, 24.6.2010
[114] Russel, B. et al.: Agriculture in Indonesia. In: ABARE Conference Paper 07.6 ABARE Project 3186. Australian Bureau of Agricultural and Resource Economics, August 2007
[115] International Tropical Timber Organization: Status of the Tropical Forest Management 2005 - Indonesia. In: 2006 Status of Tropical Forest Management ITTO Technical Series No. 24. International Tropical Timber Organization, 2006

are permanent forest estate of which about 48.5 million hectares are classified for production.
Total wood production in 2003 was estimated to be about 120 million m^3, thereof 34 million m^3 of industrial wood and 86 million m^3 of fuelwood.

4.10.2.2 Saw mill residues

In 2000, the wood based industry contained 4,400 sawmills with an installed capacity of 19 million m^3, 120 plywood mills with an installed capacity of 11.1 million m^3, 39 particleboard mills, 102 blockboard mills, 13 chip mills, two MDF units, 81 pulp and paper mills (with a capacity of 5.23 million tons of pulp and 9.12 million tons of paper) and a large number of secondary processing units.
The output of wood-based primary processing industries in 2003 was 388,000 m^3 of wood residues, 6.25 million m^3 of sawnwood and 7.33 million m^3 of wood based panel products.

Unlike the very small volume of logging residues currently being used, it is apparent that much larger percentages of mill residues are already utilized. Especially in wood-deficit areas, residues are unlikely to be dumped. Rather it is likely that these residues are used by local people as fuelwood or claimed for further industrial processing.[116] Therefore no sawmill residues will be taken into account.

4.10.2.3 Municipal waste

Following [Chaerul, M. et al., 2007] every Indonesian generates 0.76 kg of solid waste on average per day summing up to about 187,366 tons per day. Increasing waste generation due to the rising population and waste generation rate becomes a serious challenge for the Indonesian government, as they will have to establish a proper municipal solid waste management system.[117]
According to the fact that no overall waste management system is in place, no realistic potential can be accounted in this area yet.

[116] Enters, T.: Trash or Treasure? Logging and Mill Residues in Asia and the Pacific. In: RAP Publication: 2001/16. Food and Agriculture Organization of the United Nations, 2001
[117] Chaerul, M. et al.: Municipal Solid Waste Management in Indonesia: Status and the Strategic Actions. In: Journal of the Faculty of Environmental Science and Technology, Vol. 12. No.1. Oklahoma University, March 2007

4.10.3 Summary

The table below gives a summary of the potentials for bioenergy in unused residues in Indonesia taking actual production figures into account. The calculation gives an overall potential of 54.19 million tons of unused biomass resources with an energy content of 672,38 PJ. This potential would theoretically supply more than 5 times the amount of the local demand in the transport sector (or almost all energy used).
The total Bioethanol potential derived from different waste sources is about 12 billion liters.

Table 18: Indonesia's unused biomass potential

Indonesia	**Source**	production	unused biomass factor	unused biomass	energy content	bioenergy
		mio. t		mio. t	GJ/t	PJ
agricultural residues						
Cereals						
Wheat			0.5	0	14.4	0
Coarse Grains	2009	8.7	0.5	4.35	14.4	62.6
Barley			0.5	0	14.4	0
Rice, paddy	2009	38.3	0.5	19.15	14.4	275.76
Buckwheat			0.5	0	14.4	0
Oats			0.5	0	14.4	0
Maize	2007	13.28	1.4	18.6	14.4	267.7
Sugarbeet			0.05	0	14.4	0
bagasse	2007	25.3	0.07	1.771	5	8.855
Oil crops						
Soybeans	2009	0.8	1.89	1.512	5	7.6
Rapeseed			1.26	0,00	5	0
Cotton			1.89	0	5	0
Cabbages	2007	1.3	0.45	0.585	5	2.925
Potatoes	2007	2.8	0.36	1.008	5	5.04
forestry residues						
		Mio. m^3			GJ/m^3	
roundwood		35.55	0.195	6.93225	4.285	29.7
saw mill		4.7	0.4	1.88	10.71	20.1
Total				55.78		680.34
	12,037,275,000	l lignocellulosic Ethanol				
	0.58%	of worldwide fuel consumption 2007				

Source:
2009: Source USDA FAS
2007: FAOStat, commodities by country
2008: FAOStat, forestry
5 = energy content of grass

4.11 Peru

4.11.1 General Information

Peru is a country in western South America bordered on the north by Ecuador and Colombia. On the east it is bordered by Brazil, on the southeast by Bolivia, on the south by Chile, and on the west by the Pacific Ocean. Peru is a multiethnic country formed by the combination of different groups over five centuries, which covers 1,285,220 km^2 and unlike other equatorial countries, does not have an exclusively tropical climate because of the influence of the Andes and the Humbold Current. They cause great climatic diversity ranging from moderate temperatures, low precipitations, and high humidity to heavy rainfall and high temperatures and cold winters. Because of its varied geography and climate, Peru has a high biodiversity with 21,462 species of plants and animals (reported as of 2003) of which 5,855 are endemic.

With about 29 million inhabitants, Peru is the fourth most populous country in South America as of 2007 of which 34.8% are classified as being poor, including 11.5% who are extremely poor.[118]

Peru is currently a net importer of energy. Between 2005 and 2006, Peru increased its primary energy imports by 22.6%. Crude oil comprised the largest share of the total energy imported (88%), because domestic crude is not of adequate quality for further refinement. The rest of Peru's energy imports consist of coal. Its proven energy reserves at the end of 2007 were 447.4 million barrels of crude oil, 334.73 billion m^3 of natural gas and 45.9 million tons of coal. Furthermore, in 2006, Peru had proven uranium reserves around 1,800 tons located in the northwest of the country in the Puno region. The largest share of Peru's energy reserves comes from natural gas (around 45% of the total). Peru's primary energy supply also includes a

[118] Wikipedia: Peru, http://en.wikipedia.org/wiki/Peru, 25.6.2010

considerable rate of non-conventional energy including wood, biogas, solar and others.[119]

Of the electric power produced in Peru in 2000, 81.4% was from hydropower, 17.9% was thermal (mostly from diesel fuel, gasoline, and natural gas), and less than 1% was from other sources. The hydroelectric potential has been estimated at 60 GW.[120]

The Peruvian government tries to reduce the dependency on crude oil by promoting the supply of natural gas but also of renewable energy sources. Thanks to the high potential of water energy and the high consumption of wood, especially for cooking in rural areas, the proportion of bioenergy is already significant (28%). In 2006, crude oil covered 47% of the domestic energy supply, while natural gas covered 21 % and mineral coal delivered 4%.[121]

Country statistics

Total area: 128.5 million hectares

Population: 28.22 million (2007 census)

Wood: total forest area about 68.7 million hectares (about 53.7% of total area)[122]

GDP/capita in US$[123]: 129.1 billion/ 4,477 (nominal), 245.35 billion/ 8,509 (PPP)

Total energy consumption in the transport sector was 3 Mtoe or 12.6 PJ in 2002 (28.6% of 10.5 Mtoe or 44 PJ - total energy consumption). Estimations for 2010 are at 4 Mtoe or 16.7 PJ in the transport sector (30.8% of total energy demand) and 13 Mtoe or 54.4 PJ for final energy demand[124]. Actual figures report 41 cars/100 people.[125]

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[119] Asia-Pacific Economic Cooperation: APEC Energy Overview 2008. Asia-Pacific Economic Cooperation, March 2009

[120] Encylopedia of the Nations: Peru – Energy and power. http://www.nationsencyclopedia.com/Americas/Peru-ENERGY-AND-POWER.html, 25.6.2010

[121] Schweizer, T.: Agricultural Potential of Bioenergy Production in Peru, Master Thesis. University of Hohenheim, April 2009

[122] Mongobay.com: Peru. http://rainforests.mongabay.com/20peru.htm, 27.6.2010

[123] World Bank: Gross Domestic Product 2008 & Gross Domestic Product 2008, PPP. In: World Development Indicators Database. Word Bank, April 2010

[124] Asia-Pacific Economic Cooperation: APEC Energy Demand and Supply Outlook 2006. Asia-Pacific Economic Cooperation, March 2006

[125] NationMaster.com: South America – Peru – Transportation. http://www.nationmaster.com/country/pe-peru/tra-transportation, 25.6.2010

4.11.2 Biomass Resources[126]

The arable land in Peru covers only 4.3% of the land surface. The harvested area is even smaller because fallow land according to the national agricultural census is already included. Natural pastures, mainly situated in the Andes, require 13.2% while 47.5% of the national area consists of primary rainforest.
The significant lack of traffic infrastructure is for sure one of the biggest barriers for agricultural development in Peru. Many agricultural zones in the Andes or in the rainforest are not accessible on suitable roads. Tarred streets are extremely seldom, especially in the rainforest. Agriculture in Peru mostly takes place on handcraft level or with the help of draught animals. Low input crops like cereals whose cultivation is mechanized in all developed country are produced under enormous labor input.
The most important crops with regard to the harvested area are rice, coffee, potatoes and maize.
At present, wood is clearly the most important biomass resource in Peru. Oil palms, sweet potatoes and sugar cane are also cultivated, but at the moment, they serve alimentary purpose exclusively. All the other energy crops, namely castor-oil-plants, rapeseed, sweet sorghum and jatropha are still cultivated on the scale of investigation. Sugar cane for ethanol as well as oil palms and Jatropha curcas for biodiesel or vegetable oil are considered the most important energy crops for the future. In contrast to the former two, there is not much practical experience with Jatropha curcas.

4.11.2.1 Special energy crops

Jatropha curcas is currently considered one of the white hopes of bioenergy crops in Peru. Its vegetable oil can be used directly as fuel or be processed to biodiesel. The seeds are highly toxic for human beings and animals as well.
Peru shows optimal climatic conditions for Jatropha curcas. The cultivation is possible on the coast as well as in the rainforest. At the moment, however, there is no cultivation on a big scale. The total area of Jatropha curcas in Peru is estimated to be smaller than 1000 hectares. One of the most important promoters of jatropha cultivation is the DED (German Development Service - Deutscher Entwicklungsdienst) with its three projects with smallholders. The whole area is between 100 and 150 hectares (as of November 2008).

[126] Schweizer, T.: Agricultural Potential of Bioenergy Production in Peru, Master Thesis. University of Hohenheim, April 2009

4.11.2.2 Forestry residues

Peru has the third largest extent of tropical rainforests in the world, after Brazil and the Democratic Republic of Congo. These forests are some of the richest in the world, both in terms of biological diversity and natural resources (timber, energy, mineral resources). About half of Peru is forested. Of this, more than 80 percent is classified as primary forest.

Deforestation and degradation are also increasingly the result of development activities, especially logging, commercial agriculture, mining, gas and oil operations, and road construction. Peru has no experience in industrial timber harvesting, whereby large tracts of forests are clear for cut as can be seen in other parts of the Amazon. Most logging in Peru has been selective, thereby degrading forest rather than completely clearing it. Currently most logging in Peru is illegal. [127] (The Worldbank estimates that 80% of Peru's logging is illegal.)

Following the EIA report on Peru's forest sector much of the official information related to the sector was previously found on the website of INRENA (the forest authority until November 2008), but upon the deactivation of this institution, the information was no longer updated and what was there was removed.[128]

According to the FAO Global Forest Resource Assessment 2005 total logging was 10.8 million m^3 in 2005 of which only 1.9 million m^3 (17.5%) has been industrial roundwood and the rest (8.9 million m^3) has been fuelwood.

Therefore usable residues from roundwood production can be estimated at 0.37 million m^3 (as from total removal an estimated 2.1 million m^3 could be available).

4.11.2.3 Saw mill residues

No figures about the sawmill industry in Peru could be found. The only source found for sawnwood production was FAOStat and the according figures can be found in the table in the summary below.

4.11.3 Summary – Residues potential

The table below gives a summary of the potentials for bioenergy in unused residues in Peru taking actual production figures into account. The calculation gives an

[127] Mongobay.com: Peru. http://rainforests.mongabay.com/20peru.htm, 27.6.2010
[128] Environmental Investigation Agency: Peru's Forest Sector: Ready for the New International Landscape? Environmental Investigation Agency, 2009

overall potential of 6.6 million tons of unused biomass resources with an energy content of 69.22 PJ. This potential would theoretically supply more than 3 times the amount of the local demand in the transport sector (or almost all energy used). The total Bioethanol potential derived from different waste sources is about 1.42 billion liters.

Table 19: Peru's unused biomass potential

Peru	**Source**	production	unused biomass factor	unused biomass	energy content	bioenergy
		mio. t		mio. t	GJ/t	PJ
agricultural residues						
Cereals						
Wheat			0.5	0	14.4	0
Coarse Grains			0.5	0	14.4	0
Barley			0.5	0	14.4	0
Rice, paddy	2007	2.43	0.5	1.215	14.4	17.496
Buckwheat			0.5	0	14.4	0
Oats			0.5	0	14.4	0
Maize	2007	1.69	1.4	2.4	14.4	34.1
Sugar beet			0.05	0	14.4	0
Bagasse	2007	8.22	0.07	0.5754	5	2.877
Oil crops						
Soybeans			1.89	0	5	0
Rapeseed			1.26	0	5	0
Cotton			1.89	0	5	0
Potatoes	2007	3.6	0.36	1.296	5	6.48
Onions	2007	0.6	0.45	0.27	5	1.35
forestry residues						
		Mio. m^3			GJ/m^3	
roundwood	2008	2.33	0.195	0.45435	4.285	1.9
saw mill	2008	1.168	0.4	0.4672	10.71	5.0
Total				6.64		69.22
	1,420,945,000	l lignocellulosic Ethanol				
	0.07%	of worldwide fuel consumption 2007				
Source:						
2009: Source USDA FAS						
2007: FAOStat, commodities by country						
2008: FAOStat, forestry			5 = energy content of grass			

4.12 India

4.12.1 General Information

India is one of the oldest civilizations in the world with a kaleidoscopic variety and rich cultural heritage. It has achieved great socio-economic progress during the last 62 years of its independence. India has become self-sufficient in agricultural production and is now one of the top industrialized countries in the world (and one of the few nations to have gone into outer space). It covers an area of 3.3 million km^2, extending from the snow-covered Himalayan heights to the tropical rain forests of the south. As the 7th largest country in the world, India stands apart from the rest of Asia, marked off as it is by mountains and the sea, which give the country a distinct geographical entity. Bounded by the Great Himalayas in the north, it stretches southwards and at the Tropic of Cancer, tapers off into the Indian Ocean between the Bay of Bengal on the east and the Arabian Sea on the west.[129]

India's climate is strongly influenced by the Himalayas and the Thar Desert, both of which drive the monsoons. The Himalayas prevent cold Central Asian Katabatic wind from blowing in, keeping the bulk of the Indian subcontinent warmer than most locations at similar latitudes. The Thar Desert plays a crucial role in attracting the moisture-laden southwest summer monsoon winds that, between June and October, provide the majority of India's rainfall. Four major climatic groupings predominate in India: tropical wet, tropical dry, subtropical humid, and montane.[130]

India has the world's second largest labor force, with 516.3 million people. In terms of output, the agricultural sector accounts for 28% of GDP while the service and industrial sectors make up 54% and 18% respectively. Major agricultural products include rice, wheat, oilseed, cotton, jute, tea, sugarcane, potatoes; cattle, water buffalo, sheep, goats, poultry and fish. Major industries include textiles,

[129] Indian Government: Know India – Profile. In: Official Portal of the Indian Government. http://india.gov.in/knowindia/profile.php, 27.6.2010
[130] Wikipedia: India. http://en.wikipedia.org/wiki/India, 27.6.2010

telecommunications, chemicals, food processing, steel, transport equipment, cement, mining, petroleum, machinery and software.

India lacks sufficient domestic energy resources and must import much of its growing energy requirements. India is not only experiencing an electricity shortage but is also increasingly dependent on oil imports to meet domestic demand. In addition to pursuing domestic oil and gas exploration and production projects, India is also stepping up its natural gas imports, particularly through imports of liquefied natural gas.
According to the World Energy Outlook 2007 India's total primary energy demand in 2005 was 537 Mtoe or 2.24 EJ and will grow in the reference scenario to 1,299 Mtoe or 5.43 EJ in 2030.[131]

India has a vast potential from renewable energy sources, especially in areas such as solar power, biomass and wind power. The current installed capacity of renewable energy is around 9.2 GW.[132] The country has an estimated small-hydro power potential of about 15 GW.[133]

Country statistics
Total area: 329 million hectares
Population: 1,028 million (2001 census)
Wood: total forest area about 69.8 million hectares (about 21.2% of total area)[134]
GDP/capita in US$[135]: 1,159.2 billion/1,124 (nominal), 3,358,5 billion/3,176 (PPP)
Total energy consumption in the transport sector was 44.5 Mtoe or 18.6 PJ in 1999 (10.5% of 421.6 Mtoe or 1.76 EJ - total energy consumption).[136] A total of 72.7

131 International Energy Agency: World Energy Outlook 2007 – China and India Insights. International Energy Agency, 2007
132 Mahajan, A.: India Energy Outlook – 2007. In KPMG Report. KPMG in India 2007
133 The Energy and Resources Institure: Indian Energy Sector: An Overview. In: India Energy Portal, http://www.indiaenergyportal.org/overview_detail.php, 27.6.2010
134 Minister of Statistics and Program Implementation: Agriculture, Table 6.1 Land utilisation statistics. Ministry of Statistics and Programme Implementation, mospi.nic.in, July 2010
135 World Bank: Gross Domestic Product 2008 & Gross Domestic Product 2008, PPP. In: World Development Indicators Database. Word Bank, April 2010
136 World Resources Institute: Country Profile – India. In: Earth Trends Country Profiles, Energy and Resource: India, 2003. http://earthtrends.wri.org/ 27.6.2010

million motor vehicles were registered in 2004 (of which 51.9 million were 2 wheelers)[137]

4.12.2 Biomass Resources

India's agricultural area is vast with total arable and permanent cropland of 170 million hectares in 2003- 2005. It has the second largest arable area in the world after the United States. OECD in its 2007 agricultural policy monitoring report notes that Indian agriculture is dominated by a large number of small-scale holdings that are predominantly owner occupied.

India is among the worlds leading producers of paddy rice, wheat, buffalo milk, cow milk and sugar cane. It is either the world leader or the second largest producer in eight out of its top ten products. Some of these are widely traded while others are more specialist products.

India is expected to consolidate its position among the world's leading exporters of rice (its number 1 export commodity), though the volume of exports has been erratic since the mid nineties (depending on the size of the crop and on domestic consumption). Currently it is the second largest rice producer after China and the third largest net exporter after Thailand and Vietnam. For sugar a big potential is seen and India forecast to switch from being a net importer to a net exporter (over 2 million tons).

India is a leading vegetable oils importer, absorbing one quarter of world soybean oil imports and 14% of palm oil imports.[138]

According to the National Portal of India[139] the total area under food grains in 2008-09 has been 123.22 million hectares against 124.07 million hectares in 2007-08. The agricultural output, however, depends on Monsoon, as nearly 55.7% of the production area is heavily dependent on rainfall as the only water resource.

An all time record in production of food grains of 233.88 million tons is forecasted in 2008-09. This is about 13.10 million tons more than last year's production of food grains. The production of rice is estimated at 99.15 million tons (which is about 2.46 million tons more), production of wheat is estimated at 80.58 million tons (which is

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[137] Minister of Statistics and Program Implementation: Statistical Data on Transport, Communication and Tourism. Ministry of Statistics and Program Implementation mospi.nic.in, July 2010

[138] Agricultural Trade Policy Analysis Unit: India's Role in World Agriculture. In: Newsletter MAP No. 03-07, DG Agriculture and Rural Development, December 2007

[139] Indian Government: Know India – Agriculture. In: Official Portal of the Indian Government. http://india.gov.in/citizen/agriculture/index.php, 27.6.2010

2.01 million tons more), production of coarse cereals is estimated at 39.48 million tons (a plus of 1.27 million tons) and production of pulses is estimated at 14.66 million tons. The sugarcane production is estimated at 27.13 million tons which is about 0.77 million tons less than the production during 2007-08.[140]

4.12.2.1 Forestry residues

The total area of recorded forests as per the latest State of Forest Report 2003 is 77.47 million hectares, which is 23.6 % of the total area. 51.6% or 39.99 million hectares are reserved forests. These are areas notified under the provisions of Indian Forest Act or State Forests Acts having full degree of protection. In reserved forests all activities are prohibited unless permitted. 30% or 23.84 million hectares are protected forests with the same restrictions as reserved forests. The rest (17.6%) is unclassified forest where ownership status varies from state to state. Productivity of the forests is low and estimated to be 0.7 m^3/ha/year.
Bamboo is one of the most important forestry species with wide distribution throughout the country. After China, India is the second richest country in terms of genetic diversity of bamboos. It is estimated that bamboo occupies about 10 million hectares of land (about 12.8% of the forest area).[141]

In 1997, the national logging quota was about 226 million m^3, although far less was actually harvested. Approximately 85% of the logged volume is sourced from natural forest. National log production is estimated to decrease from 63.5 million m^3 in 1997 to 47.9 million m^3 in 2000.[142]

4.12.2.2 Saw mill residues

The annual log production is about 65 million m^3, of which 40% to 50% are sawlogs. There are about 2,000 sawmills in China with a total capacity of about 25 million m^3. Most are small or medium size with annual processing capacities below 5,000 to 10,000 m^3. 60% of the milling equipment was installed during the 1950s and productivity is low.

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[140] Indian Government: Know India – Agriculture. In: Official Portal of the Indian Government. http://india.gov.in/citizen/agriculture/index.php, 27.6.2010
[141] Goyal, A.: India's Forests. Ministry of Environment and Forests, Government of India, 2007
[142] Enters, T.: Trash or Treasure? Logging and Mill Residues in Asia and the Pacific. In: RAP Publication: 2001/16. Food and Agriculture Organization of the United Nations, 2001

Wood residues are used for the production of parquet, toothpicks, chopsticks, and woodchips mainly for the domestic market.

The volume of mill residues is determined by log consumption and the recovery rates in the different processing sub-sectors. According to various studies, average recovery rates are 34.4 percent of the log production for processing. Taking log imports (about 4 million m^3) into account, the total production of wastes from processing in the whole country in 2000 is estimated to be 11.27 million m^3 of which about 80% (about 9 million m^3) can be used economically. [143]

4.12.2.3 Municipal waste

Due to rapid urbanization and uncontrolled growth rate of population, municipal solid waste management has become acute in India and is given low priority. Lack of financial resources, institutional weaknesses, improper choice of technology and public apathy towards municipal solid waste have made this service far from satisfaction. The current practices of the uncontrolled dumping of waste on the outskirts of towns/cities have created a serious environmental and public health problem. Studies have revealed that quantum of waste generation varies between 0.2-0.4 kg/capita/day in the urban centers and it goes up to 0.5 kg/capita/day in metropolitan cities.[144]

4.12.3 Summary

The table below gives a summary of the potentials for bioenergy in unused residues in India taking actual production figures into account. The calculation gives an overall potential of 252.28 million tons of unused biomass resources with an energy content of 2,562 PJ. This potential would theoretically supply more than the amount of the local energy demand in 2007.

The total Bioethanol potential derived from different waste sources is about 51.5 billion liters.

[143] Enters, T.: Trash or Treasure? Logging and Mill Residues in Asia and the Pacific. In: RAP Publication: 2001/16. Food and Agriculture Organization of the United Nations, 2001

[144] Kumar, S.: Municipal Solid Waste Management in India: Present Practices and Future Challenges. August 2005

Table 20: India's unused biomass potential

India	Source	production	unused biomass factor	unused biomass	energy content	bioenergy
		mio. t		mio. t	GJ/t	PJ
agricultural residues						
Cereals						
Wheat	2009	78.6	0.5	39.3	14.4	565.92
Coarse Grains	2009	39.6	0.5	19.8	14.4	285.1
Barley			0.5	0	14.4	0
Rice, paddy	2009	99.18	0.5	49.59	14.4	714.096
Buckwheat			0.5	0	14.4	0
Oats			0.5	0	14.4	0
Maize	2007	18.9	1.4	26.5	14.4	381
Sugar beet			0.05	0	14.4	0
Bagasse	2007	355.5	0.07	24.885	5	124.425
Oil crops						
Soybeans	2009	9.1	1.89	17.199	5	86.0
Rapeseed	2009	6.7	1.26	8.44	5	42.2
Cotton	2009	9.6	1.89	18.144	5	90.7
Vegetables						
Other	2007	41.6	0.45	18.72	5	93.6
Tomatoes	2007	10	0.9	9	5	45
Potatoes	2007	28.6	0.36	10.296	5	51.48
forestry residues						
		Mio. m^3			GJ/m^3	
roundwood	2008	23.2	0.195	4.524	4.285	19.4
saw mill	2008	14.8	0.4	5.92	10.71	63.4
Total				252.28		2,562.38
	51,500,400,000	l Ethanol				
	2.48%	of worldwide fuel consumption 2004				

Source:
2009: Source USDA FAS
2007: FAOStat, commodities by country
2008: FAOStat, forestry
5 = energy content of grass

Other vegetables include:
Onions and Vegetable fresh nes

4.13 European Union – EU – EU27

4.13.1 General Information[145, 146]

Europe is the world's second-smallest continent by surface area, covering about 10.18 million km^2 or 2% of the Earth's surface and about 6.8% of its land area. Of Europe's approximately 50 states, Russia is the largest by both area and population (although the country covers both Europe and Asia).

The European Union (EU) is an economic and political union of 27 member states, located primarily in Europe. The territory of the EU is not the same as that of Europe, as parts of the continent are outside the EU, such as Switzerland, Norway, European Russia, and Iceland.

Including the overseas territories of member states, the EU experiences most types of climate from Arctic to tropical, rendering meteorological averages for the EU as a whole meaningless. The majority of the population lives in areas with a Mediterranean climate (Southern Europe), a temperate maritime climate (Western Europe), or a warm summer continental or hemiboreal climate (Eastern Europe).

Since its origin, the EU has established a single economic market across the territory of all its members. If considered as a single economy, the EU generated an estimated nominal gross domestic product (GDP) of US$ 16.45 trillion in 2009, amounting to over 21% of the world's total economic output in terms of purchasing power parity, which makes it the largest economy in the world by nominal GDP and the second largest trade bloc economy in the world by PPP valuation of GDP.

Total primary energy consumtion in the EU in 2007 was 1,806.4 Mtoe or 7.56 EJ, of which 36.4% were from oil, 23.9% from natural gas, 13.4% from nuclear, 18.3% from solid fuels (coal), and 7.8% or 141 Mtoe (590 MJ) from renewable sources.

[145] Wikipedia: Europe, http://en.wikipedia.org/wiki/Europe, 5.7.2010
[146] Wikipedia: European Union, http://en.wikipedia.org/wiki/European_union, 5.7.2010

Renewable energy splits into 69.8% biomass, 18.9% hydro, 6.4% wind, 0.9% solar and 4.1% geothermal.[147]

European Union statistics

Total area: 432.47 million hectares

Population: over 501 million (2010 estimate)

Wood: FOWL (forest and other wooded land): 177 million hectares (about 42% of the land area); FASW (forests available for wood supply): 129 million hectares – in 2005[148]

GDP/capita in US$[149]: 16.45 trillion/ 33,052 (nominal), 14.79 trillion/ 29,729 (PPP)

Total energy consumption in the transport sector was 377.2 Mtoe or 1.58 EJ in 2007 (32.6% of 1157.7 Mtoe or 4.85 EJ - total final energy consumption). The EU reported 470 cars/100 people in 2008.[149]

4.13.2 Biomass Resources

Around half of the EU's land is agricultural land that is farmed. The main crops grown on arable land are cereals (including rice) followed by forage plants. Vegetable and fruit crops become increasingly important in terms of food consumption and of value.

Cereal production was 311.5 million tons in 2008 (wheat accounted for 149 million tons, barley for 65.1 million tons, Maize for 62.8 million tons, rye for 9.5 million tons and rice for 2.7 million tons). Sugar beet production was 101.5 million tons, rape 18.9 million tons and sunflower 7 million tons.[150]

4.13.2.1 Forestry residues[151]

The European Union of 27 Member states (EU27) has a total area of forests and other wooded land of 177 million hectares, covering 42% of its land area. Contrary

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147 European Commission: EU Energy and Transport in figures 2010. In: Statistical Pocketbook 2010. European Commission, 2010

148 European Commission: Forestry Statistics. In: Eurostat Pocketbooks, 2009 edition, European Commission, 2009

149 World Bank: Gross Domestic Product 2008 & Gross Domestic Product 2008, PPP. In: World Development Indicators Database. Word Bank, April 2010

150 European Commission: Agricultural Statistics – Main Results 2007-2008. In: Eurostat Pocketbooks, 2009 edition, European Commission, 2009

151 European Commission: Forestry Statistics. In: Eurostat Pocketbooks, 2009 edition, European Commission, 2009

to what is happening in other parts of the world, forest cover in the EU is slowly but steadily increasing at the rate of approximately 0.4% per year. Forests provide many benefits to society and the economy and play an important role in the preservation of natural biodiversity and in climate change mitigation.
The most densely forested Member States are Finland, Sweden and Slovenia, whereas the least forested are Malta, Ireland and the Netherlands. Not all forests in the EU27 are available for wood supply. On average, 13% of forest areas in the EU27 have protective functions.
Production comprises all quantities of roundwood removed from the forest or other felling sites and stripped of the bark.
There are two categories of roundwood namely industrial roundwood and fuelwood. The commodities included in industrial roundwood are logs, pulpwood and other industrial wood (the final use determines the commodity). Logs are used for the production of sawnwood (including sleepers) and veneer sheets. Pulpwood is wood in the rough used for the manufacture of pulp, particleboard and fiberboard. Fuelwood is wood in the rough (from trunks and branches of trees), to be used as fuel for cooking, heating and power production.

Total felling in the EU27 in 2008 were 420.5 million m^3 (453.9 million m^3 in 2005) of which 332.4 million m^3 (or 79%) were industrial roundwood, the rest is declared as fuelwood (88.1 million m^3).
The 3 biggest producers of industrial roundwood were Sweden with 62.1 million m^3, Germany with 46.8 million m^3 and Finland with 46 million m^3. The biggest producer of fuelwood was France with more than 29 million m^3.
Due to the fact, that almost all fellings in the EU27 are official the whole amount of fellings is taken into account.

4.13.2.2 Saw mill residues

Wood residues as reported in [European Commission, 2009a] describe the volume of roundwood that is left over after the production of wood products in the processing industry and that has not been reduced to chips or particles. It includes sawmill rejects, slabs, edgings and trimmings, veneer log cores, veneer rejects, sawdust, residues from carpentry and joinery production. It excludes wood chips either made directly in the forest from roundwood or made from residues. Wood residues also include agglomerated products such as logs, briquettes or pellets.

These residues had a volume of 37.6 million m^3 in the EU 27 in 2008[152]. According to Pellets-Briketts[153] total production capacity in all EU 27 states was estimated to be about 9 million tons for pellets and briquettes in 2007.
Therefore only 25 million m^3 will be taken into account for the total energy potential.

4.13.2.3 Municipal waste

In 2006 the total amount of municipal waste in the EU 27 was 215.2 million tons. (The total amount of waste was about 3 billion tons.). Organic waste (animal and crop waste) was about 233.3 million tons.[154]

The generation of municipal waste is projected to be 290 million tons in the EU 27 in 2010 with a further increase to 336 million tons in 2020. The diversion of municipal waste away from landfill is expected to continue and reach a level of around 34% in 2020. Recycling of waste is assumed to reach a level of 42% and incineration of waste with energy recovery 23% in 2020.[155]

Following [Nikolaou 2003][156] the energy potential of sewage sludge gas in EU 25 was estimated to be 94 PJ (22.4 Mtoe) per year, landfill gas 207.3 PJ (49.5 Mtoe) per year and demolition wood 254 PJ (60.6 Mtoe) per year.

4.13.2.4 Excursion: Environmentally compatible biomass potential

Due to the bioenergy study [European Environment Agency, 2006][157]significant amounts of biomass are technically available to support ambitious renewable energy targets. The environmentally compatible biomass potential increases from 190 Mtoe in 2010 to 295 Mtoe in 2030.

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[152] European Commission: Forestry Statistics. In: Eurostat Pocketbooks, 2009 edition, European Commission, 2009
[153] Pellets-Brickets.com: Production and Consumption of Wood Pellets and Briketts. http://pellets-briketts.com/, 9.7.2010
[154] European Commission: Abfallaufkommen von Haushalten bei Jahr und Abfallkategorie (Abfälle insgesamt). EuroStat, http://epp.eurostat.ec.europa.eu, 9.7.2010
[155] Skovgaard, M. et al.: Municipal Waste Management and Greenhouse Gases. In: ETC/RWM working paper 2008/1. European Topic Center on Resource and Waste Management, January 2008
[156] Nikolaou, A. et al.: Biomass Availability in Europe. In: Bioenergy's Role in the EU Energy Market. December 2003
[157] European Environment Agency: How much Bioenergy can Europe produce without harming the Environment? In: EEA Report No. 7/2006, European Environment Agency, 2006

The potential from agriculture can reach up to 142 Mtoe by 2030, compared to 47 Mtoe in 2010. About 85% of the potential can be found in Spain, France, Germany, Italy, UK, Lithuania and Poland.

The potential for bioenergy from forestry is estimated to be almost constant at around 40 Mtoe. An additional potential of more than 16 Mtoe has been identified coming from competing industries as a result of increasing energy and CO_2 permit prices. Countries with the highest potential for bioenergy are Sweden and Finland. Italy, Spain, France, UK and central Europe have potential for additional felling.

In the short term the largest potential for bioenergy comes from the waste sector with around 100 Mtoe.

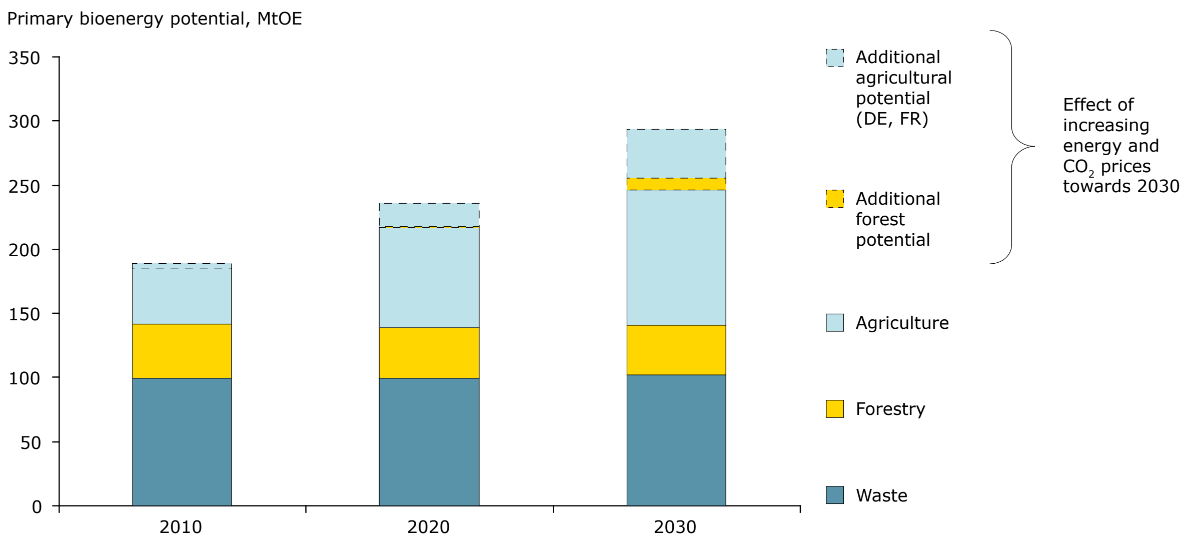

Figure 19: Environmentally-compatible primary bioenergy potential in the EU[158]

4.13.3 Summary

The table below gives a summary of the potentials for bioenergy in unused residues in European Union taking actual production figures into account. The calculation gives an overall potential of 354 million tons of unused biomass resources with an energy content of 3,777 PJ. This potential would theoretically supply more than double the amount of the local energy demand in the transport sector in 2007.

The total Bioethanol potential derived from different waste sources is about 82 billion liters.

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[158] European Environment Agency: How much Bioenergy can Europe produce without harming the Environment? In: EEA Report No. 7/2006, European Environment Agency, 2006

Table 21: European Union's unused biomass potential

EU	Source	production	unused biomass factor	unused biomass	energy content	bioenergy
		mio. t		mio. t	GJ/t	PJ
agricultural residues						
Cereals						
Wheat	2007	120.1	0.5	60.05	14.4	864.72
Coarse Grains			0.5	0	14.4	0,0
Barley	2007	57.7	0.5	28.85	14.4	415.44
Rice, paddy			0.5	0	14.4	0
Buckwheat			0.5	0	14.4	0
Oats	2007	8.6	0.5	4.3	14.4	61.92
Maize	2007	48.8	1.4	68.3	14.4	983.8
Sugar beet	2007	114.8	0.05	5.74	14.4	82.656
Bagasse			0.07	0	5	0
Oil crops						
Soybeans			1.89	0	5	0,0
Rapeseed	2007	18.4	1.26	23.18	5	115.9
Cotton			1.89	0	5	0
Vegetables						
Other	2007	23.2	0.45	10.44	5	52.2
Tomatoes	2007	16.2	0.9	14.58	5	72.9
Potatoes	2007	63.7	0.36	22.932	5	114.66
forestry residues						
		Mio. m^3			GJ/m^3	
roundwood	2009	420.5	0.195	81.9975	4.285	351.4
saw mill	2009	25	0.4	10	10.71	107.1
municipal waste						
demolition wood	2003	23.7	1	23.7	10.71	253.8
gas (landfill, sludge)	2003		1	0	5	301.3
Total				354.09		3,777.8
	82,388,450,000	l lignocellulosic Ethanol				
	3.96%	of worldwide fuel consumption 2007				

Source:
2009: Forestry Statistics Eurostat
2007: FAOStat, commodities by country
2008: FAOStat, forestry
2003: A.Nikolau

5 = energy content of grass

Other vegetables include:
Carrots, cabbages, onions and Vegetable fresh nes

4.14 Summary

This chapter summarizes the potential for residues for the investigated countries (the 10 wood richest countries in the world) and the EU 27.

The table below gives an overview of the total amount of unused residues and wastes. The by far biggest potential was found in the agricultural area. The leftovers (lignocellulosic material) of food and fodder production (during harvest) could play an important role in future energy supply especially for the production of 2nd generation biofuels (especially Bioethanol).

Table 22: Summary of unused residues and waste potential

Summary	unused biomass	bioenergy
	million tons	PJ
agricultural residues	**2,298.06**	**24,919.55**
forestry residues	**364.87**	**1,872.15**
municipal waste		
woody waste	**66.45**	**607.26**
gas (landfill)		**301.30**

Although 30% of the world's total land area is forestland the energy potential of existing residues from the wood industry is less than 10% of the amount from agriculture.

Due to the different felling policies and wood log demand that highly correlates with the economic situation the residue potential varies over time. Russia, as one example, has an allowable cut of 540 million m^3 per year. If the total amount would be cut this would lead to another 400 million m^3 of roundwood per year and would generate an additional 78 million m^3 of wood residues (generating an additional 20% of wood residues) or if the total additional fellings were used completely for bioenergy production, it would more than double the potential found. But when speculating about theoretical potentials sustainable use of forests has to be considered. At present deforestation occurs at 0.18% on average per year but varies dramatically over different areas. As long as no additional cut is caused because of biofuel production there will perhaps be no discussion about non-sustainable use of wood. But extending log production to a sustainable level could heavily increase the potential for biofuels from woody resources.

Figures for woody wastes could only be found for a few countries researched so there is some hidden potential, as there is potential for Bio-methane derived from landfill gas. But no realistic figures about actual potentials could be found.

The table below gives an overview by country about potentials found in comparison to energy used in the transportation sector (please note that actual figures might differ significantly from the figures found – especially data for China, India and Peru is quite old. The column year shows the actuality for each figure for the respective transportation energy demand).

The column for agricultural residues only summarizes the amount of cereal residues available (green boxes indicate that the energy demand for the transportation sector could theoretically be satisfied by the bioenergy potential found). These residues account for 60% of the total agricultural residues (in terms of volume) and account for 80% of the energy potential (20,116 PJ) in this sector. (For more details on the different crop potentials refer to table Annex E.)

Table 23: Country overview

		unused biomass					
	wood area	agricultural residues	forestry residues	waste residues	total bioenergy potential found	PJ	
Country	million ha	Cereals mio. t	mio. t	woody waste mio. t	PJ	transportation	year
Russia	808	50.8	34.4		1,020	343	1999
Brazil	477	34	52.2		1,680	2,400	2007
Canada	402	38.5	30.8	9.75	923	2,430	2008
US	283	504.6	67.2	30.9	8,793	29,300	2008
China	233	423.1	58.8		7,900	3,000	2002
Australia	149	20.3	10.1	2.1	468	5,722	2008
Congo	155	1.7	0		26	448	1999
Indonesia	100	23.5	8.8		672	117	2008
Peru	69	3.5	0		69	12.6	2002
India	70	135.1	10.4		2,562	18.6	1999
EU	306	161.5	92.0	23.7	3,777	1,580	2007

Assuming that the EU produces wood on a sustainable level a simple calculation estimates 300kg of wood residues per hectare (and year). If that result is taken to calculate a theoretical potential for wood residues the result calculated is almost triple the volume found. The table below shows the detailed result.

Table 24: Calculation of theoretical sustainable wood residues potential

	wood area	forestry residues	theoretical potential @ 300kg/ha
Country	million ha	million tons	million tons
Russia	808	34.4	242.9
Brazil	477	52.2	143.4
Canada	402	30.8	120.9
US	283	67.2	85.1
China	233	58.8	70.1
Australia	149	10.1	44.8
Congo	155	0	46.6
Indonesia	100	8.8	30.1
Peru	69	0	20.7
India	70	10.4	21.0
EU	306	92.0	92.0
Total		**364.9**	**917.6**

Theoretical potential of lignocellulosic ethanol

The residue potential shown in table 19 (from agricultural and wood sources) would theoretically lead to 589 billion liters of lignocellulosic Bioethanol. This amount would substitute more than 28% of the worldwide liquid fuel demand in 2007 (worldwide liquid fuel consumption - final consumption - in the transportation sector was 2.079 trillion liters.[159])

[159] International Energy Agency: Oil in the World. http://www.iea.org/stats/, 16.8.2010

5 Conclusion

The main question “Is there a serious potential for bio-energy based resources for biofuels (especially 2nd generation) taking into consideration that there is no competition with resources for food production or other existing production streams?” can be answered with: yes.

Residues and waste material could provide a significant amount of resources for the production of 2nd generation biofuels.

The fact that cereals provide a large potential the production of Bioethanol from straw seems to be a very promising pathway in the substitution of fossil fuels. These residues should be easily available.

The available potential for wood residues actually varies with roundwood production that depends on the economic situation. Additional potential could be found in the area of additional fellings where the whole amount of cutted wood could be used for bioenergy production provided that the use of forest is still sustainable and no deforestation takes place.

The available potential from municipal solid waste and landfill gas is hard to predict, as no qualified data was available, but it has to be considered.

When the discussion about electric mobility comes to realistic scenarios letting some space for the discussion about other alternatives in the transport sector a special focus should be set on biofuels from lignocellulosic sources. There is significant potential for a sustainable production from residues and waste.

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Annex

A - Unused biomass factors

Source: Jölli, D. et al: Unused Biomass Extraction in Agriculture, Forestry and Fishery. In: Seri Studies, Sustainable Europe Research Institute (SERI), March 2005

Agricultural residues

For the calculation of unused biomass as the potential for bioenergy, the following factors were taken to calculate actual potentials.

Table 25: Unused biomass factor - Cereal Residues

Cereals	Ratio Product: Total Biomass (1:x)	Unused	Unused Biomass Factor
Barley	1	0.5	0.5
Buckwheat	1	0.5	0.5
Canary Seed	1	0.5	0.5
Maize (grain maize)	1.4	1	1.4
Millet	1	0.5	0.5
Mixed Grain	1	0.5	0.5
Oats	1	0.5	0.5
Rice, Paddy	1	0.5	0.5
Rye	1	0.5	0.5
Sorghum	1	0.5	0.5
Triticale	1	0.5	0.5
Wheat (and spelt)	1	0.5	0.5
Cereals nec	1	0.5	0.5

Table 26: Unused biomass factor - Oilcrop Residues

Oil crops	Ratio Product: Total Biomass (1:x)	Unused	Unused Biomass Factor
Groundnuts in Shell	2.1	0.9	1.89
Hempseed	1.4	0.9	1.26
Linseed	1.4	0.9	1.26
Melon seed	1.4	0.9	1.26
Mustard Seed	1.4	0.9	1.26
Olives	1.4	0.9	1.26
Poppy Seed	1.4	0.9	1.26
Rapeseed	1.4	0.9	1.26
Safflower Seed	1.4	0.9	1.26
Seed Cotton	2.1	0.9	1.89
Sesame Seed	1.4	0.9	1.26
Soybeans	2.1	0.9	1.89
Sunflower Seed	2.1	0.9	1.89
Oilseeds nec	2	0.9	1.8

Forestry residues

Unused biomass in forestry can be divided into woody forest residues and primary timber processing mill residues.

Table 27: Unused biomass factor - Wood

Study	USA	China	Asia	Suggested average
total used roundwood [% of total production]	73,9	70	60	70
woody residues [% of total production]	36,1	30	40	30
coefficient of residues	0,361	0,429	0,667	0,429
unusable biomass [%]	10	45	40	35
coefficient of unusable residues	0,036	0,193	0,276	0,15

Total amounts of woody forest residues from the threes studies researched are quite similar and a value of 30% of the total roundwood production seemed to be an appropriate average value. However, the utilization rate varies significantly between the first study and the later two. [Jölli, D. et al, 2005] suggest using a mean value of 35% for material flow studies on the national level.

B - Heating values

Source: AgrarPlus: Heizwerte. http://www.agrarplus.at/kennzahlen.heizwerte.php, 16.8.2010

Table 28: Heating Value of Different Energy Carriers

Brennstoff	**Heizwert**	
(Energieträger)	**(Energievergleich)**	
1 kg Ofenöl (EL)	42 MJ/kg	11,67 kWh/kg
1 l Ofenöl (EL)	36 MJ/l	10,00 kWh/l
1 kg Heizöl (L)	41 MJ/kg	11,40 kWh/kg
1 m^3 Erdgas	37 MJ/kg	10,28 kWh/m^3
Flüssiggas Propan (kg)		12,9 kWh/kg
Flüssiggas Propan (l)		6,6 kWh/l
1 kg Steinkohle	29 MJ/kg	8,06 kWh/kg
1 kg Braunkohle	15 MJ/kg	4,17 kWh/kg
1 kg Koks	29 MJ/kg	8,06 kWh/kg
1 kg Holz-Pellets	18 MJ/kg	5,00 kWh/kg
1 kWh Strom	3,6 MJ	1,00 kWh
1 kg Holz (W = 20 %)	14,40 MJ/kg	4,00 kWh/kg
1kg Stroh (W = 15 %)	13 - 14,40 MJ/kg	3,6 - 4 kWh/kg
Getreide		4,20 - 4,80 kWh/kg
Ölsaaten		6,50 - 7,00 kWh/kg
Presskuchen		6,50 kWh/kg
Klärgas		6,0 - 7,0 kWh/m^3
Biogas aus landwirt. Reststoffen		5,5 - 7,5 kWh/m^3
Deponiegas		5,0 - 6,0 kWh/m^3
Rapsöl		10,0 kWh/kg
RME (Rapsmethylester)		10,3 kWh/kg
Rapskörner (Öl- und Faseranteil)		6,8 kWh/kg

C - Bioenergy potential

Source: European Environment Agency: How much Bioenergy can Europe produce without harming the Environment? In: EEA Report No. 7/2006, European Environment Agency, 2006

Table 29: Environmentally Compatible Bioenergy Potential (in Mtoe)

	2010				2020				2030			
	Agriculture	Forestry	Waste	Total	Agriculture	Forestry	Waste	Total	Agriculture	Forestry	Waste	Total
Austria	0.6	3.3	3.0	**6.9**	1.4	3.3	3.1	**7.8**	2.1	3.5	3.1	**8.7**
Belgium	0.1	0.1	2.1	**2.3**	0.1	0.1	2.1	**2.3**	0.1	0.2	2.0	**2.3**
Germany	5.0	6.3	14.9	**26.2**	13.7	5.3	14.8	**33.8**	23.4	4.8	15.0	**43.2**
Denmark	0.4	0.1	2.3	**2.8**	0.1	0.2	2.2	**2.5**	0.1	0.2	2.2	**2.5**
Spain	7.8	1.7	7.1	**16.5**	12.9	1.8	7.3	**22.0**	16.0	1.5	7.5	**25.1**
Finland	1.9	1.7	6.1	**9.6**	1.8	1.8	6.2	**9.8**	1.3	1.8	6.2	**9.4**
France	2.6	12.7	16.1	**31.4**	7.8	13.2	16.2	**37.2**	17.0	14.2	16.2	**47.4**
Greece	0.0	n.a.	1.6	**1.6**	1.7	n.a.	1.6	**3.4**	2.2	n.a.	1.7	**3.8**
Ireland	0.0	0.1	1.0	**1.1**	0.1	0.1	1.0	**1.2**	0.1	0.1	1.0	**1.3**
Italy	4.1	5.6	6.5	**16.2**	8.9	3.3	6.5	**18.7**	15.2	3.0	6.6	**24.8**
Luxembourg	n.a.	n.a.	0.0	**0.0**	n.a.	n.a.	0.0	**0.0**	n.a.	n.a.	0.0	**0.0**
Netherlands	0.2	0.1	2.4	**2.6**	0.5	0.1	1.6	**2.2**	0.7	0.2	1.6	**2.4**
Portugal	0.7	0.2	2.7	**3.6**	0.8	0.2	2.9	**3.9**	0.8	0.2	3.1	**4.1**
Sweden	0.6	2.2	8.9	**11.7**	1.1	2.4	9.5	**13.0**	1.4	2.4	9.7	**13.5**
United Kingdom	3.4	1.5	8.6	**13.5**	8.8	1.5	8.7	**19.0**	14.7	1.1	8.6	**24.5**
EU-15	27.2	35.7	83.3	**146.2**	59.8	33.2	83.7	**176.6**	95.0	33.3	84.7	**213.0**
Czech Republic	0.8	0.8	2.2	**3.8**	1.3	0.8	2.3	**4.5**	1.6	0.9	2.5	**5.0**
Cyprus	n.a.	n.a.	0.3	**0.3**	n.a.	n.a.	0.3	**0.3**	n.a.	n.a.	0.3	**0.3**
Estonia	0.4	0.2	0.9	**1.5**	1.1	0.2	0.9	**2.2**	1.3	0.2	1.0	**2.6**
Hungary	1.2	0.2	2.1	**3.6**	2.2	0.2	2.1	**4.5**	3.1	0.4	2.0	**5.6**
Lithuania	2.0	0.7	1.4	**4.1**	5.6	0.6	1.4	**7.6**	7.9	0.4	1.6	**9.9**
Latvia	0.4	0.6	0.3	**1.3**	1.0	0.6	0.2	**1.9**	1.5	0.6	0.3	**2.4**
Malta	n.a.	n.a.	0.05	**0.05**	n.a.	n.a.	0.05	**0.05**	n.a.	n.a.	0.04	**0.04**
Poland	14.5	2.0	7.3	**23.8**	24.1	1.5	7.4	**33.0**	30.4	1.2	7.8	**39.3**
Slovenia	0.0	1.3	0.5	**1.8**	0.1	1.1	0.5	**1.7**	0.2	1.0	0.5	**1.8**
Slovakia	0.2	1.0	1.0	**2.2**	0.6	0.9	1.0	**2.4**	1.2	0.9	1.5	**3.6**
New EU-10	**19.5**	**6.8**	**16.0**	**42.4**	**36.0**	**5.9**	**16.2**	**58.1**	**47.3**	**5.7**	**17.5**	**70.5**
EU-25	**46.8**	**42.5**	**99.3**	**188.5**	**95.8**	**39.2**	**99.8**	**234.7**	**142.4**	**39.0**	**102.1**	**283.4**
Net competition effect for forestry						2.1	− 0.8	1.3		16.2	− 6.3	9.9
EU-25	**46.8**	**42.5**	**99.3**	**188.5**	**95.8**	**41.3**	**99.0**	**236.0**	**142.4**	**55.2**	**95.8**	**293.3**

D - Top 20 commodities in selected countries

Russia/Russian Federation – Top 20 commodities, FAOStat, 24.5.2010

Table 30: Russian Federation - Top 20 Commodities

Rank	Commodity	Production (Int $1000)	Flag	Production (MT)	Flag
1	Wheat	4771406		49367973	
2	Potatoes	3067328		36784200	
3	Cow milk, whole, fresh	7699117		31914914	
4	Sugar beet	1249236		28836189	
5	Barley	344089		15559075	
6	Sunflower seed	1256991		5671389	
7	Oats	34667		5383539	
8	Cabbages and other brassicas	336809		3931830	
9	Rye	138504		3909392	
10	Maize	24232		3798020	
11	Vegetables fresh nes	477006		2542000	*
12	Apples	670084		2333000	*
13	Tomatoes	546346		2305900	
14	Hen eggs, in shell	1746104		2103300	*
15	Carrots and turnips	200400		1859010	
16	Onions, dry	342246		1857110	
17	Cucumbers and gherkins	233941		1386810	
18	Pumpkins, squash and gourds	232284		1318150	
19	Watermelons	64647		1060000	
20	Buckwheat	16443		1004433	

* : Unofficial figure
[ ]: Official data

Brazil – Top 20 commodities, FAOStat, 20.5.2010

Table 31: Brazil - Top 20 Commodities

Rank	Commodity	Production (Int $1000)	Flag	Production (MT)	Flag
1	Sugar cane	11375880		549707328	
2	Soybeans	12287500		57857200	
3	Maize	1510189		52112200	
4	Cow milk, whole, fresh	7093812		26944064	
5	Cassava	956279		26541200	
6	Oranges	3283702		18685000	
7	Rice, paddy	2309714		11060700	
8	Bananas	1011586		7098350	
9	Wheat	594643		4114060	
10	Potatoes	477188		3550510	
11	Tomatoes	812961		3431230	
12	Beans, dry	1314878		3169360	
13	Coconuts	256036		2831004	
14	Pineapples	517592		2676417	
15	Cottonseed	425310		2589820	*
16	Vegetables fresh nes	452236		2410000	F
17	Coffee, green	1838701		2249010	
18	Watermelons	218198		2092630	
19	Papayas	284067		1811540	
20	Hen eggs, in shell	1197523		1779190	

* : Unofficial figure
[ ]: Official data
F : FAO estimate

Canada – Top 20 commodities, FAOStat, 10.6.2010

Table 32: Canada - Top 20 Commodities

Rank	Commodity	Production (Int $1000)	Flag	Production (MT)	Flag
1	Wheat	2275904		20054000	
2	Maize	117679		11648700	
3	Barley	256967		10983900	
4	Rapeseed	2545259		9601100	
5	Cow milk, whole, fresh	2166081		8145000	*
6	Potatoes	677519		4999424	
7	Oats	185040		4696300	
8	Peas, dry	487658		2934800	
9	Soybeans	494571		2695700	
10	Tomatoes	194720		821850	
11	Sugar beet	34373		762000	
12	Lentils	159207		733900	
13	Linseed	143094		633500	
14	Apples	116349		405089	
15	Hen eggs, in shell	310293		398436	
16	Carrots and turnips	58537		306769	
17	Maize, green	58298		296245	
18	Beans, dry	116625		276700	
19	Mixed grain	31776		262600	
20	Rye	20233		252000	

* : Unofficial figure
[ ]: Official data

United States – Top 20 commodities, FAOStat, 10.6.2010

Table 33: United States - Top 20 Commodities

Rank	Commodity	Production (Int $1000)	Flag	Production (MT)	Flag
1	Maize	20891120		331175072	
2	Cow milk, whole, fresh	22270180		84189067	
3	Soybeans	14910080		72860400	
4	Wheat	7698642		55822700	
5	Sugar beet	1468909		31912000	
6	Sugar cane	541008		27750600	
7	Potatoes	2773520		20373267	
8	Tomatoes	3360895		14185180	
9	Sorghum	1029966		12635730	
10	Rice, paddy	1882144		8999230	
11	Oranges	1292919		7357000	
12	Grapes	2961579		6384090	
13	Cottonseed	335775		6163000	
14	Hen eggs, in shell	3991918		5395000	
15	Barley	361948		4574520	
16	Lettuce and chicory	1482449		4360400	
17	Apples	1217161		4237730	
18	Cotton lint	6207813		4181810	
19	Maize, green	771692		3921400	
20	Onions, dry	663829		3602090	

[ ]: Official data

China – Top 20 commodities, FAOStat, 10.6.2010

Table 34: China - Top 20 Commodities

Rank	Commodity	Production (Int $1000)	Flag	Production (MT)	Flag
1	Rice, paddy	35526760		187397460	
2	Maize	5818754		152418870	
3	Vegetables fresh nes	23777510		146902838	F
4	Sugar cane	2197070		113731917	
5	Wheat	15348160		109298296	
6	Sweet potatoes	4855120		75800197	
7	Potatoes	6743942		64837389	
8	Watermelons	6583176		62256973	
9	Cabbages and other brassicas	5101838		36530009	F
10	Cow milk, whole, fresh	9460634		35574326	
11	Tomatoes	7960108		33596881	F
12	Cucumbers and gherkins	4590038		28049900	F
13	Apples	8003659		27865889	
14	Hen eggs, in shell	18540600		21833200	
15	Onions, dry	3790347		20567295	F
16	Eggplants (aubergines)	2899273		18025820	F
17	Cottonseed	2025921		15248000	
18	Tangerines, mandarins, clem.	3438251		15184608	*
19	Other melons (inc.cantaloupes)	2300471		14210090	
20	Chillies and peppers, green	4840326		14026272	F

* : Unofficial figure
[ ]: Official data
F : FAO estimate

Australia – Top 20 commodities, FAOStat, 10.6.2010

Table 35: Australia - Top 20 Commodities

Rank	Commodity	Production (Int $1000)	Flag	Production (MT)	Flag
1	Sugar cane	755965		36397000	
2	Wheat	1382139		13039000	
3	Cow milk, whole, fresh	2436808		9583000	
4	Barley	353038		5920000	
5	Grapes	709970		1530439	
6	Sorghum	9232		1283000	
7	Potatoes	154621		1211988	
8	Rapeseed	301115		1065000	
9	Oats	28755		843000	
10	Oranges	82716		470673	
11	Wool, greasy	782805		464736	
12	Triticale	0		450000	
13	Cottonseed	73245		387800	
14	Lupins	788		331000	
15	Chick peas	124229		313000	
16	Tomatoes	70139		296035	
17	Cotton lint	406747		274000	
18	Carrots and turnips	50231		271464	
19	Apples	77686		270476	
20	Peas, dry	38578		268000	

[ ]: Official data

Democratic Republic of Congo – Top 20 commodities, FAOStat 11.6.2010

Table 36: DR Congo - Top 20 Commodities

Rank	Commodity	Production (Int $1000)	Flag	Production (MT)	Flag
1	Cassava	1070407		15004430	
2	Sugar cane	31002		1550000	F
3	Plantains	267250		1204860	
4	Maize	125073		1155720	
5	Groundnuts, with shell	157845		369370	
6	Vegetables fresh nes	65677		350000	F
7	Rice, paddy	63781		316180	
8	Bananas	44879		314920	
9	Sweet potatoes	23291		236510	
10	Papayas	34473		219840	
11	Mangoes, mangosteens, guavas	48698		200000	F
12	Pineapples	37711		195000	F
13	Oranges	31756		180700	
14	Palm oil	31487		180000	F
15	Roots and Tubers, nes	7125		120000	F
16	Beans, dry	46191		112250	
17	Potatoes	10641		93560	
18	Game meat	145657		88948	
19	Yams	17202		86990	
20	Taro (cocoyam)	6810		66110	

[ ]: Official data
F : FAO estimate

Indonesia – Top 20 commodities, FAOStat 28.6.2010

Table 37: Indonesia - Top 20 Commodities

Rank	Commodity	Production (Int $1000)	Flag	Production (MT)	Flag
1	Rice, paddy	11845150		57157436	
2	Sugar cane	525481		25300000	*
3	Cassava	1411516		19988058	
4	Coconuts	1774885		19625000	*
5	Palm oil	5116644		16900000	*
6	Maize	1044118		13287527	
7	Bananas	777281		5454226	
8	Palm kernels	534481		4090000	*
9	Natural rubber	1477819		2755172	
10	Oranges	461472		2625884	
11	Fruit, tropical fresh nes	270042		2359270	
12	Pineapples	432779		2237858	
13	Sweet potatoes	185891		1886852	
14	Mangoes, mangosteens, guavas	442815		1818619	
15	Groundnuts, with shell	367788		1384400	
16	Fruit Fresh Nes	212213		1330410	
17	Cabbages and other brassicas	189315		1288740	
18	Hen eggs, in shell	931317		1174600	
19	Chillies and peppers, green	389534		1128790	
20	Potatoes	137613		1003730	

* : Unofficial figure
[ ]: Official data

Peru – Top 20 commodities, FAOStat 28.6.2010

Table 38: Peru - Top 20 Commodities

Rank	Commodity	Production (Int $1000)	Flag	Production (MT)	Flag
1	Sugar cane	170908		8228623	
2	Potatoes	451810		3383020	
3	Rice, paddy	511252		2435134	
4	Plantains	406912		1834511	
5	Cow milk, whole, fresh	414822		1579834	
6	Maize	48592		1361656	
7	Cassava	83448		1158042	
8	Onions, dry	116912		634393	
9	Oranges	60501		344267	
10	Maize, green	65384		332255	
11	Mangoes, mangosteens, guavas	71693		294440	
12	Asparagus	452593		284103	
13	Hen eggs, in shell	196770		257621	
14	Roots and Tubers, nes	26682		253282	
15	Lemons and limes	59312		227000	F
16	Coffee, green	184762		225992	
17	Pineapples	41010		212059	
18	Grapes	91204		196604	
19	Tangerines, mandarins, clem.	43114		190410	
20	Sweet potatoes	16710		184765	

[ ]: Official data
F : FAO estimate

India – Top 20 commodities, FAOStat 28.6.2010

Table 39: India - Top 20 Commodities

Rank	Commodity	Production (Int $1000)	Flag	Production (MT)	Flag
1	Sugar cane	6833297		355519700	
2	Rice, paddy	29968800		144570000	
3	Wheat	11242260		75806700	
4	Buffalo milk, whole, fresh	29575400		55913000	
5	Cow milk, whole, fresh	11406170		43481000	
6	Vegetables fresh nes	5463880		29117400	
7	Potatoes	2856034		28599600	
8	Bananas	3101930		23204800	
9	Maize	1318521		18955400	
10	Mangoes, mangosteens, guavas	3287358		13501000	
11	Millet	2074595		12673000	
12	Onions, dry	1507179		12156200	
13	Soybeans	2264313		10968000	
14	Coconuts	1064388		10894000	
15	Tomatoes	2034234		10054600	
16	Groundnuts, with shell	4205879		9182500	
17	Cottonseed	895671		8805600	
18	Eggplants (aubergines)	1359130		8450200	
19	Cassava	607393		8232300	
20	Rapeseed	2100884		7438000	

[ ]: Official data

European Union – Top 20 commodities, FAOStat 9.7.2010

Table 40: European Union - Top 20 Commodities

Rank	Commodity	Production (Int $1000)	Flag	Production (MT)	Flag
1	Cow milk, whole, fresh	38069600	A	148166680	A
2	Wheat	9821794	A	120103234	A
3	Sugar beet	5272983	A	114813347	A
4	Potatoes	7393508	A	63778523	A
5	Barley	1609450	A	57659924	A
6	Maize	1299008	A	48798146	A
7	Grapes	12191010	A	25096075	A
8	Rapeseed	4819528	A	18431154	A
9	Tomatoes	3651099	A	16231681	A
10	Olives	6281902	A	12509084	A
11	Apples	2982318	A	10534587	A
12	Triticale	35651	A	9591737	A
13	Oats	177419	A	8759586	A
14	Rye	322914	A	7625037	A
15	Vegetables fresh nes	1103004	A	7085926	A
16	Hen eggs, in shell	5179734	A	6432147	A
17	Oranges	1039561	A	5960071	A
18	Carrots and turnips	1071736	A	5464343	A
19	Cabbages and other brassicas	784535	A	5463829	A
20	Onions, dry	1002763	A	5341074	A

A : May include official, semi-official or estimated data

E – Potentials of Agricultural Residues

The table below summarizes the potentials for different agricultural crop categories found in the countries researched.

Table 41: Potentials of agricultural residues

Summary	unused biomass	bioenergy
	million t	PJ
agricultural residues		
Cereals	1396,96	20331,24
Sugar beet	8,81	126,86
Sugar cane (bagasse)	78,21	391,04
Oil crops	455,70	2278,49
Vegetables	270,54	1352,70
Roots & Tubers (potatoes)	87,84	439,22