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CApacity development and strengthening for energy policy formulation and implementation of Sustainable energy projects in INDOnesia

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Author:
Harrie Knoef

BTG biomass technology group BV
P.O. Box 835
7500 AV Enschede
Tel. +31-53-4861186
Fax +31-53-4861180
www.btgworld.com
office@btgworld.com

Contents

1 Summary

Within the Casindo project, training of senior staff at MEMR, the Ministry of Energy and Mineral Resources, and staff at TEDC, the Technical Education Development Centre in Cimahi, Bandung on renewable energy technologies is part of the work program. Training on solar PV, micro-hydro and biogas were already conducted and the aim of this project was to train the staff on biomass and bioenergy.

This requires the transfer of knowledge to MEMR and TEDC staff, concerning biomass resources and conversion in general, and especially regarding the production and utilisation of biofuels. The latter subject is of special interest for the Indonesian energy situation. Indonesia is a biomass-rich country, and wishes to be explore further development of applications for biofuels, produced from various and abundant available resources from agricultural activities, palm plantations, the wood and timber industry, etc.

The approach was to first develop a course that could be used to instruct staff the reasons for and the principles of biomass conversion. Secondly, some experimental work and exercises were prepared to gain hand-on experience on the various subjects of biomass resources, conversion and utilisation.

The importance of biomass and bio-energy as the only renewable technology containing a carbon source was emphasized, which in particularly is important with the depletion of natural resources like coal, oil and natural gas. Moreover, it was emphasized that the bio-energy field covers many different routes and possibilities to produce biofuels from different biomass resources. As an example, anaerobic digestion producing biogas is only one option of the whole bio-energy chain; besides this biochemical conversion route, there are also chemical conversion routes, physical chemical routes and of course the thermo-chemical routes. As such, the training course was quite complex to the previous training sessions. This was also confirmed and understood by the participants. They will need sufficient time to absorb the theory and there is a urgent need for experimental training facilities at TEDC.

At the moment there is hardly any equipment available and therefore a listing of equipment and apparatus for conducting laboratory analyses and experimental work has been prepared. Most of the equipment and apparatus it can be bought locally, but an experimental facility to conduct and/or simulate thermal conversion processes should be purchased from the Netherlands.

The existing idea of constructing a separate renewable energy department fits very well in the overall profile of the TEDC institute and should be supported. Such RE-centre should also incorporate a bio-energy department with experimental and laboratory facilities to instruct SMK teachers and possible other stakeholders within the Casindo project.

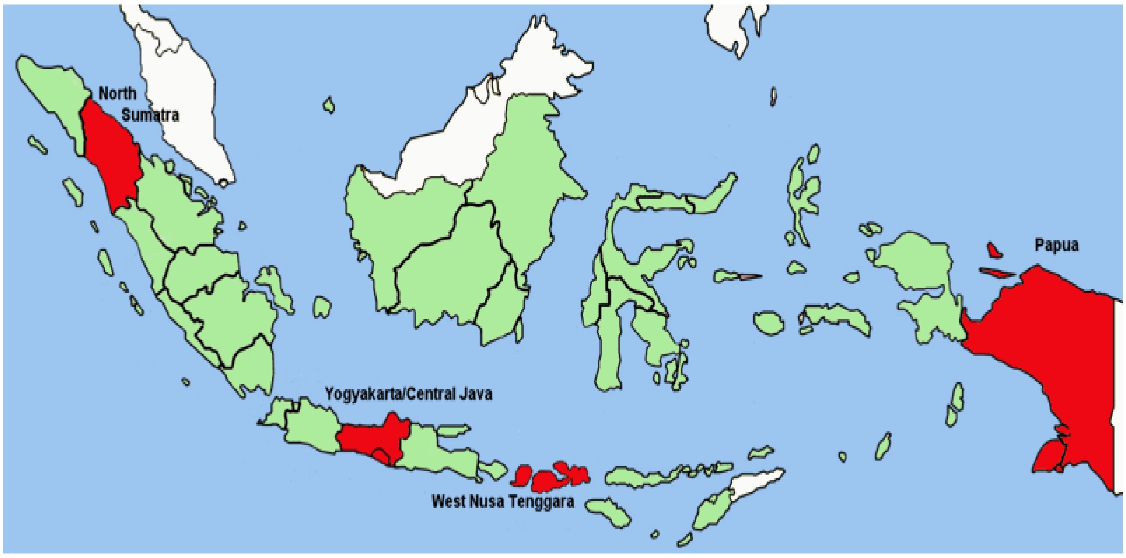
2 Introduction

2.1 Background

CASINDO is a capacity development programme that aims to build and strengthen institutional and human capacity for energy policy formulation and development of renewable energy and energy efficiency projects both at the national and regional level. The programme has been developed in close collaboration with the Indonesian partners and SenterNovem.

CASINDO has started in June 2009 and will run till 31 December 2011. The programme is financed by SenterNovem and is part of a bilateral energy co-operation Indonesia Netherlands. The consortium that executes the programme consists of 8 Indonesian and 5 Dutch partners. The programme co-ordination is shared between ECN and the Indonesian Ministry of Energy and Mineral Resources.

The programme involves activities both at the national level and in the provinces of Central Java, North Sumatra, West Nusa Tenggara, Yogyakarta and Papua. These provinces were selected by the Ministry of Energy and Mineral Resources based on the identified need for assistance in the province.



A key background component of CASINDO is the ongoing reforms in Indonesia regarding the decentralisation of autonomy. Regional governments are now becoming responsible for formulating and implementing regional energy policies. CASINDO aims to contribute to this process through developing the professional capacity that will enable the regional government to formulate and implement a regional energy strategy and that will improve regional academic and educational knowledge by introducing energy research and education programmes and training modules at the local universities and technical high schools (SMK) To ensure that these knowledge levels can be maintained also in the longer term, strong institutional government structures are set up by CASINDO.

In CASINDO an institutional model will be introduced that aims to set up specific programmes at the local university to train the teachers of technical schools (SMKs) in renewable energy technologies. This includes micro hydropower (MHP), solar PV, biomass (BM), biogas (BG) and wind energy (WE). Such model should significantly alleviate the heavy logistical burden of the Technical Education Development Centre (TEDC) to provide this training for the whole of Indonesia from their offices in Bandung.

Selected vocational schools (Sekolah Menegah Kejuruan, SMK) will need to develop a curriculum, syllabi and training modules on renewable energy and energy efficiency technologies. SMK teachers will be trained by TEC staff to be enable them to teach these subjects to students. A plan will be developed to roll out this model to other SMKs in the provinces.

2.2 Objective

The objective of the subcontracting work of BTG is to train MEMR and TEDC staff on biomass and bio-energy, and to instruct TEDC staff on practical and experimental work in this field. The TEDC staff will have to instruct (teach) the teachers of the SMKs, who should then be able to develop the curriculum, syllabi and training modules on biomass and bio-energy in the five selected regions.

2.3 Work conducted

BTG provided two major consulting services in the framework of the CASINDO project:

1. Development and implementation of one-week in-depth training course on biomass for senior staff of the Ministry of Energy and Mineral Resources (MEMR) in Jakarta in February 2010. The detailed program is given in Annex 1 and covered the following main topics:
    1. Introduction in the biomass-to-energy chain
    2. Bioenergy technologies
    3. Bioenergy end uses and applications
    4. Biomass policies and sustainability issues
    5. Development of a national biomass energy strategy
    6. Institutions and key elements for implementation & replication of bioenergy projects

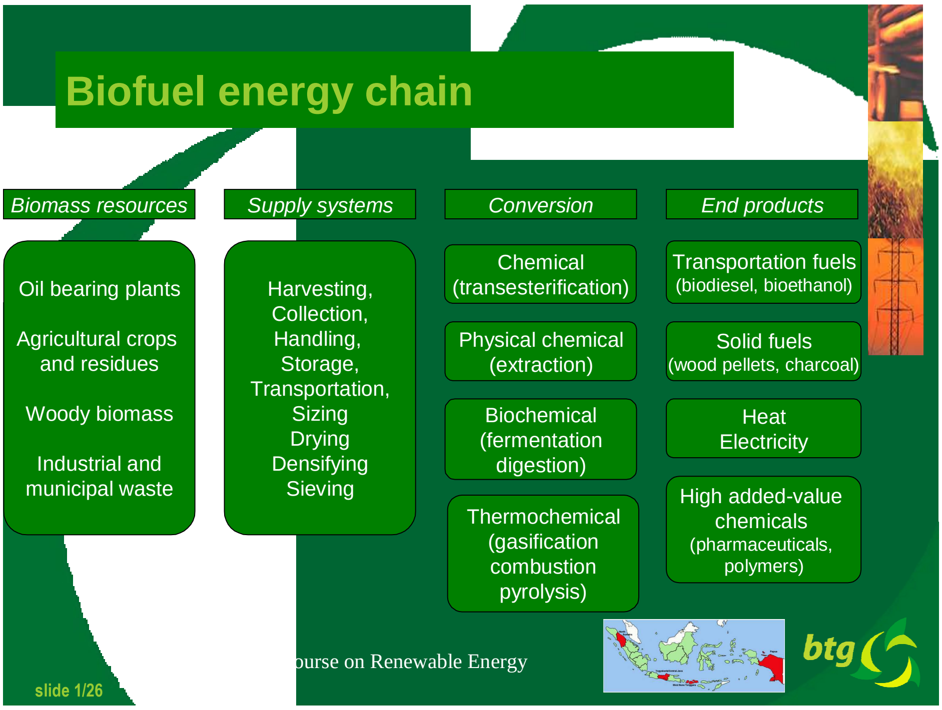
2. Development and implementation of two-week training course on biomass for senior staff of the TEDC in Cimahi, Bandung in February 2010. The training course covered basically the same topics as for the MEMR staff but also included several exercises, practical work, case studies and field visits. Annex 2 provides the program of the training course at TEDC.

In summary, the training material developed by BTG for the two training courses included:

- Power point presentations for each module as explained in the next chapter, about 20 in total
- Videos on various subjects
- Questions, exercises and practicum; after each presentation some (open) questions were formulated, and/or exercises to practice the theoretical part. At TEDC, also practical work was included.
- Case studies; there are a large number of existing case studies and success stories on bioenergy projects and plants in western and developing countries. It concerns realized projects and systems, of a similar nature and in a similar setting, that can serve as flagship projects, success stories, showcases and good practices. Information on such plants in the form of plant descriptions and case studies are included in the course from CHP Best Practise but many more examples can be found from literature and the internet. Therefore, this information package also contains useful links to internet sites, which is by no means complete.
- Site visits; at the training of TEDC staff, site visits to facilities using thermal conversion technologies were made to the Chemical Engineering Department of ITB, Bandung and Lemigas in Jakarta. Students were asked to make a summary report, discuss them in a plenary session, and/or answer specific questions.
- Information package on the different subjects covered in the training sessions.

3 Development and content of the course

Biomass has been utilised as an energy source already since the discovery of fire, and its use remained high, even after the discovery of fossil fuels, such as oil, coal and gas. In the last one or two decades, more and more attention is given to biomass because it is, under certain conditions, a renewable and sustainable energy source, which does not contribute to global warming. Besides, concerns on the supply security of fossil fuel and its future depletion, boosted the interest in biomass as a large alternative resource. The field of biomass energy is large and diverse as sown in the figure. Biomass energy is used globally, at scales ranging from the smallest (e.g. domestic cooking) to the largest possible (e.g. co-firing in large scale power stations). Issues pertaining to biomass are availability and exploration of resources, sustainability, conversion technologies, transport, economics and finance, just to name a few. The course on biomass and bio-energy provides an introduction into the many aspects of biomass energy.



The biomass energy course consists of four main modules, concerning the following subjects:

Module 1: Biomass and Bioenergy

- a. Introduction
- b. Resources
- c. Biomass characteristics
- d. Biomass pretreatment
- e. Biomass to energy chain
- f. Municipal solid waste
- g. Biofuels

Module 2: Primary conversion technology to biofuels

a. Carbonisation and agglomeration

b. Biomass gasification

c. Anaerobic digestion

d. Biomass pyrolysis

e. Biomass combustion

Module 3: Secondary conversion of biofuels

a. Household energy

b. End-use and applications

c. Transportation fuels and bio-refineries

Module 4: General issues

a. The need for biomass energy strategies

b. Competing us of biomass

c. CDM and portfolio projects

` d. Sustainability and policy issues

e. The project cycle

f. Example of developing a national bio-energy strategy

g. Biomass CHP – Example from Czech Republic

h. CHP Best Practise

The first three modules follows the bio-energy chain while the fourth module is a more general or horizontal module, applicable to all three previous modules. Hereafter, the content for each module is briefly discussed:

3.1 Module 1: Biomass and Bioenergy

In this module, the most important "driving forces" behind biomass energy are explained. It is shown that practically all energy comes directly from the sun. That is true also for all fossil fuel- and biomass derived energy.

The global carbon cycle is shown, to illustrate the effect of fossil fuel use on the amount of CO_2 in the atmosphere, and the effect it has on the average temperature on earth, the "Global Warming". Biomass can be considered as a renewable fuel, that does not contribute to global warming, because the CO_2 released from biomass conversion to energy is equally consumed during the plant lifetime. This is called the "short carbon cycle", in contrast to the "long carbon cycle" of fossil fuel use.

Various advantages and disadvantages of biomass are illustrated, followed by a first important distinction: "dry" biomass versus "wet" biomass. The moisture content of biomass is an important parameter, which determines to a large extent the costs and technology of conversion.

The biomass-to-energy chain is schematically shown in the figure on the final page. It shows the many different routes for producing energy and biofuels from all sorts of biomass materials. This may be important to the demands and possibilities for the five different regions, i.e. one region may be very suitable for lignocelluloses material while another region is more suitable for oil containing crops like Jatropha.

Biomass resources are traditionally dispersed by nature and occur in numerous relatively small, local sources. With the exception of municipal and industrial wastes, these resources tend to be available in rural areas. The diversity of biomass energy technologies is partly based on its wide range of feedstock: biomass energy originates from forests, agriculture or organic waste streams.

There are a great many ways to classify biomass types. Biomass feedstock can be classified according to:

- Physical and chemical properties (moisture content, calorific value, etc.)
- Source (energy crop, by-product/residue, waste product)
- Sector of origin (agriculture, industry, waste processing sector)
- Potential energy applications (electricity, heat, CHP or transport fuel)
- Legal status (waste or product).

Table 1 Main biomass resources

Biomass resources	Examples
Forest arisings (residues)	
Wood wastes	Sawmill and wood processing waste (sawdust, shavings, off-cuts, bark), construction residues
Crops residues	Bagasse, straw, rice husks, coconut shells, palm fibre)
Vegetable crops (herbaceous lignocelluloses crops)	*Miscanthus*, canary grass
Short rotation forests	Salix, poplar, eucalyptus
Sewage sludge	
Animal manures	
Wet processing wastes	e.g. food industry residues (such as coffee processing)
Green crops	
Municipal solid waste (MSW)	i.e. the organic fraction
Sugar crops	Sugar beet, sugar cane, sweet sorghum
Starch crops	Maize (corn), wheat, barley, potatoes
Oil crops	Rape seed, sunflower, oil palm, jatropha
Meat processing residues	Slaughterhouse residues

Biomass can be used as a solid fuel, or converted into liquid or gaseous forms, for the production of electrical energy, heat, chemicals or fuels. Biomass conversion technologies convert biofuels into a form usable for energy generation. Usually a distinction is made between primary and secondary bioenergy conversion processes and likewise between primary and secondary biomass resources. *Primary (unprocessed) biofuels* are those where the organic material is used essentially in its natural form (as harvested). Such fuels are directly combusted, usually to supply cooking, space heating or electricity productions needs, although there are also small- and large-scale industrial applications for steam raising and other processes requiring low-to-medium temperature process heat. *Secondary (processed) biofuels* in the from of solids (e.g. charcoal), liquids (e.g. alcohol, vegetable oil) or gases (e.g. biogas as a mixture of methane and carbon dioxide), can be used for a wider range of applications with higher efficiency rates on average, including transport and high-temperature industrial processes.

The aim of processing biofuel (= fuel produced directly or indirectly from biomass) is to provide fuels with clearly defined fuel characteristics and ensure a technically simple and environmentally sound conversion into useful energy. Such clearly defined fuels can then be used with fewer problems to meet a supply task efficiently and comfortably. The upgrade fuels can be used in specially adapted engines, turbines, boilers or ovens to provide thermal and/or mechanical energy, which in turn can be converted into electrical energy. Additionally, liquid and (potentially) gaseous fuels can be used directly, or after treatment, as transportation fuels.

Main emphasize in this module is on bioenergy resources and the biomass characteristics. Bioenergy resources can be classified as woody and non-woody biomass, residues and wastes, Jatropha, Algae, etc. Biomass characteristics include heating values, energy quality, efficiency, morphology, density, composition, ash content, moisture content. These parameters are used to describe biomass from a technical (energy conversion) point of view. The moisture content, and the various ways to describe this, are explained. Analysis methods are indicated, and the important aspect of heating values is elaborated upon. Typical values of properties for some biomass types are given. Some equipment and tests will be presented for characterisation of biomass. During the course, some exercises and practical tests will be performed on these aspects.

In the biomass-to-energy chain, logistics and pre-treatment are important steps, mainly because of the relatively low energy density (MJ/m^3) and because of the diverse properties of biomass. The usual pre-treatment steps, such as drying, sizing, and densification are very briefly discussed. Some indications are given regarding the costs of transport.

3.2 Module 2: Primary biomass conversion technologies

In primary bioenergy conversion processes primary biofuels are upgraded to, or converted into, secondary biofuels in various ways such as:

- Mechanical (e.g. comminution, densification, extraction)
- Thermo-chemical (e.g. pyrolysis, gasification, carbonisation, liquefaction),
- Biological (e.g. anaerobic digestion, ethanol fermentation)
- Chemical (e.g. esterification, i.e. biodiesel production).

As a result of the various available primary bioenergy conversion technologies, there is a wide range of solid, liquid or gaseous secondary biofuels.
Table 2 presents a comprehensive list.

Table 2 Secondary bioenergy resources

Solid	• Mechanical conversion without compression: chips, sawdust etc. • Mechanical conversion with compression: pellets, briquettes, bales etc. • Thermo-chemical conversion: charcoal (wood)
Liquid	• Alcohols o biological conversion (fermentation): ethanol (sugar crops, starch crops) o biological conversion (enzymatic hydrolysis, fermentation): ethanol (wood) o thermo-chemical conversion (FT): ethanol (all solid biomass) o thermo-chemical conversion (several processes): methanol (wood, crops, waste) o chemical conversion: methanol (biomethane) • Ethers o chemical conversion: ETBE (ethanol) o chemical conversion: MTBE (methanol) • Plant oils and biodiesel o mechanical conversion (extraction): pure plant oils ((oil crops) o chemical conversion (esterification): biodiesels (plant oil, waste fat and industrial waste based) • Pyrolysis oils o Thermo-chemical conversion: biocrude, bio-oil (all solid biomass)

	o Thermo-chemical conversion (thermal depolymerisation, hydrous pyrolysis): bio-oil (wet biowaste) o chemical conversion of bio-oil: various synfuels (syndiesel, syngasoline, synmethanol, syncrude • Liquefaction o thermochemical conversion - (FT process (indirect liquefaction via synthesis gas to synfuels): diesel, gasolin, kerosene and other synfuels (all solid biomass, black liquor) o thermochemical conversion - Bergius process (direct liquefaction/hydrogenation): various synfuels (all solid biomass) o thermochemical conversion – hydrothermal cracking, HTU process etc. (direct liquefaction): various synfuels (wet biowaste, all solid biomass)
Gaseous	• Biogas (and landfill gas o biological conversion (anaerobic digestion): methane, hydrogen (biowaste, crops) • Synthesis gas and synfuels o Thermo-chemical conversion (gasification) to syngas (wood gas): hydrogen, carbon monoxide, methane (all solid biomass) o Thermo-chemical conversion of syngas to synfuels (FT process): methane, LPG, DME • Other o Thermo-chemical, electrochemical and biological conversion: hydrogen (wood, crops, waste, water) o Chemical conversion: DME (methane, methanol) o Thermo-chemical conversion: pyrolysis gas (wood, crops) (wood gas, syngas)

For the further conversion of these secondary biofuels into usable energy i.e. electricity, heat and mechanical energy devices such as steam turbines, steam piston engines, Stirling engines, ORC turbines, micro turbines, gas turbines, spark ignition engines and compression ignition engines are used. Table 3 presents options for the conversion of primary and secondary biofuels into heat.

Table 3 Conversion of primary and secondary biofuels into heat.

Solid fuel combustion	• Fixed grate o open fire (3 stones etc.): P < 10 kW, ηth < 10% o improved cooking stoves: P < 10 kW, ηth < 40% o modern heating boilers: 5 kW-100 MW, ηth < 90% o steam generator o electricity/CHP, ηe < 20% • Other grate types: 100 kW – 500 MW, ηe < 25% • Fluidised bed (BFB and CFB): 1 MW – 500 MW, ηe < 40% • Pulverised: 10 MW – 1500 MW, ηe < 45%
Solid fuel gasification	• With integrated gas combustion o BIGCC: 1 kW – 500 MW, ηe < 50%
Liquid fuel combustion	• 1 kW – 500 MW, ηe < 60%
Gaseous fuel combustion	• 1 kW – 1000 MW, ηe < 70%

As an example, a well-known conversion technology for biomass is **gasification**. The principle of gasification is already known for ca. 100 years, and interest in it has always been high. The most quoted advantage of gasification is the promise of high efficiencies and low emissions. That is claimed for small-scale electricity generation with a gas engine, as well as for large scale electricity production with turbines (IGCC: gasification integrated with a combined cycle of gas and steam turbine). Over the years a large number of concepts have been developed, and some of these are shown in the modules.

Commercial gasification is, until now, limited to simple technology, in which the producer gas is burnt directly for heat production. Gasification for power production or other more advanced purposes, is however experiencing a number of significant problems. The most severe ones are tar contamination and ash melting. A large number of tar conversion/elimination concepts have been developed over the years, but not a single one has emerged as the clear “winner”.

In the course, non-technical problems which play a role in gasification (and in many other bioenergy implementation projects) are identified. The course will incorporate some exercises and probably some field visits, dependent on the possibilities and availability.

Biomass **combustion** can be considered the "work horse" of bio-energy. The technologies are robust and proven, and are commercially available from a large number of suppliers. Most biomass combustion systems are for heat only, although combination with a steam cycle is possible allowing for electricity generation as well. Such systems are however seldom applied at a small scale (<1 MW_e). Some fundamentals, process parameters and combustion efficiencies are discussed in the course, and an example of a small heat boiler system is given.
In "Combustion Theory", a typical mass balance calculation associated with biomass combustion is illustrated through an example. The course will contain some basic exercises on biomass combustion

One of the very few technologies which allow electricity generation from wet biomass is **anaerobic digestion**. This concerns a biological process, in which a combustible gas is extracted from wet biomass, such as manure. It is furthermore a commercially available technology, which can be applied at the very small to the medium (few MW) scale.
Fast pyrolysis is a promising technology is near commercialisation, with a small number of plants commercially sold. The principle of making a uniform, versatile liquid from a diverse fuel such as biomass is explained in the course. This process is carried out with an efficiency of about 75% on an energy basis. If the char and non-condensable gas can be utilised, the efficiency even rises to 95%.
Pyrolysis oil can play an important role as a biomass fuel commodity, being produced at locations were biomass has a low or even negative value, and subsequently transported to large-scale, highly efficient conversion installations located where a demand is for electricity. Countries with an abundance of biomass available are sometimes called "green OPEC" countries in this respect. The process of biomass fast pyrolysis is elaborated, with emphasis on the reaction mechanisms, oil composition and emerging reactors.
Bio-oil, the main product of biomass fast pyrolysis, can be utilised in a number of applications. Co-firing in power plants for the production of green electricity has already been mentioned in the previous module. The application as a boiler fuel is also more or less proven, but there is still no boiler manufacturer offering bio-oil boilers under full guarantees. Many other applications are identified and examined in research laboratories, like syngas or hydrogen production from bio-oil, upgrading to transportation fuel, and separation of chemicals from bio-oil.

Other biomass technologies which are widely applied are **carbonisation** (charcoal production) and **landfill gas** generation. Production of bio-diesel from rape seed oil and bio-ethanol from starch and sugars, is proven but expensive technology. It is not economically viable without the help of subsidies. Moreover the feedstock types suitable for these technologies are limited.

Part of this module is also processing Municipal Solid Waste (MSW) for energy generation. MSW is available is very large quantities and contains considerable amounts of energy (in average MSW contains about 50% organic material). The MSW is becoming available very widely and needs to be collected and processed at a central location to make it economically feasible. Furthermore, it contains substantial amounts of contaminants which needs to be considered in producing energy from it. The course will contains some exercises on MSW treatment and energy production from it.

3.3 Module 3: Secondary conversion processes

In this module energy production from biofuels are presented. First there will be a section on household energy production and application. Some calculation examples will be presented and practical tests conducted, dependent on the availability of material.

Main emphasis will be on the production from heat and power. Table 4 presents a list of commercial and emerging devices (engines and turbines) that convert heat into mechanical power (for transport use) and electricity.

Table 4 Conversion of heat into mechanical power and electricity,

ICE reciproating engines	• Otto (4-stroke and 2-stroke): 100 W - 10 MW, ηe < 35% • Diesel (4-stroke and 2-stroke): 1 kW - 50 MW, ηe < 45% • Wankel: 1 kW - 500 kW, ηe < 30%
ECE reciprocating engines	• Stirling: 50 W - 500 kW, ηe < 50% • Steam engine: 10 kW - 1 MW, ηe < 15%
Internal combustion (IC) turbines	• Gas turbine (GT): 500 kW - 500 MW, ηe < 45% • Microturbine: 10 kW - 500 kW, ηe < 30%
External combustion (EC) turbines	• Steam turbine (ST): 100 kW - 1500 MW, ηe < 50% • ORC turbine and other vapour turbines: 10 kW - 10 MW, ηe < 25% • Hot air turbine, 100 kW-10 MW
Combined Cycle	• Combined cycle: 0.5-1000 MW, ηe < 80%

Transportation fuels and bio-refineries will be elaborated as one of the most emerging technologies. The opportunities and the various concepts will be presented and the status of the various routes.

3.4 Module 4: General issues

In this module, several aspects are outlined which is related to the whole bio-energy chain, and can therefore not be allocated to one of the previous modules.

The implementation of large bioenergy projects requires that an environmental impact assessment study be made. Many types of biomass feedstocks and conversion technologies are available; each of which have specific environmental effects. The impact of these effects depends on the location of the plant. For instance, environmental effects like traffic movements, noise, dust will lead to less impacts if the biomass plant is located in an industrial area far from residences or areas with high nature conservation value. National and local legislation specifies what effects are considered acceptable or not. Commercial bioenergy technologies for the small-to-medium scale range is illustrated in Table 5.

Table 5: Commercial bioenergy technologies, small-to-medium scale range

Energy product	Technology	Bioenergy resource
Direct heat	Various types	All solid biomass
	Gaseous or liquid fuel burners	All gaseous & liquid secondary biofuels
Solid secondary biofuel production	Charcoal by carbonisation	All solid biomass
	Briquettes/pellets by densification	All solid biomass
	Chips by comminution	All solid biomass
Electricity	Steam engine	All solid biomass
	Gasification with Otto or Diesel engine	All solid biomass
	Otto and Diesel engines	All gaseous & liquid secondary biofuels
Gaseous and liquid secondary biofuels for transport traffic, CHP and work engine use	Methane (upgraded biogas) by anaerobic digestion	Animal and human manure and sludge, kitchen biowaste, straws, non-wood energy crops, food industry waste
	Ethanol by fermentation *)	Sugar and starch crops
	Pure plant oil by mechanical extraction	Oil crops
	Biodiesel by esterification	Oil crops, kitchen waste fat, industrial waste fat, ethanol

Environmental impacts occur during the production of biomass, during the construction of a bioenergy plant and during the operation of a bioenergy plant

Key environmental concerns during the **production** of biomass include: soil erosion, water and air pollution, chemical contaminants, landscape (monoculture, deforestation), biodiversity, and archaeology. Factors that determine the nature of the impact include the type of bioenergy feedstock grown, the management of the biomass crop, the nature of the land-use the bioenergy crops replace and the scale of bioenergy development and its spatial distribution.

Lately, the environmental and social impact of biomass production has been receiving a lot of international attention. Many government, NGO's and multilateral organizations work on the development of sustainability criteria that can be used to assess if biomass is produced in an environmentally and socially acceptable manner. A well-known example is the set of Cramer sustainability criteria developed by the Netherlands' Government.

The use of biomass for energy production also leads to environmental effects during the **construction** of a bioenergy plant. Impacts to be considered when building a biomass combustion plant include effects on existing archaeology, ecology and public rights of way; potential noise nuisance; dust; light pollution; pollution of water courses and the restoration of the site following construction.

Last but certainly not least the use of biomass for energy production leads to environmental effects during the **conversion** of biomass into energy. Typically environmental effects to consider include: emissions to air, emissions to soil, emissions to water, (internal) energy use, noise, odour, vehicle movements.

To make a first assessment of the potential of bioenergy, entrepreneurs and other target group members need not just technology **information** *sec* but also information on technology-related subjects such as
Investment and operation costs
Equipment suppliers (manufacturers, etc.)
Case studies/reference projects

It is recommend to integrate these four categories, with assistance of others. A summary of bioenergy information on the web is given below at the end of this information package

Biomass energy receives considerable stimulants from a variety of governments and institutions, because it is mostly a renewable and sustainable energy source. This can help projects which are not yet feasible or entail a high risk. In this module some international facilities are discussed, but it should be noted there are many more available.

The key to the implementation of biomass-to-energy concepts is the **finance and economics**. If an investment in a bioenergy plant generates sufficient return-on-investment (ROI), the plant will materialise.
Using a biomass fast pyrolysis plant as an example, an application case is developed. Important aspects are total investment, annual costs and annual income. If the investment can be paid back within a certain number of years, the project is feasible. Payback times which are considered feasible vary from country to country and, more important, from investor to investor.
As with all investment projects, the feasibility of biomass energy plants is strongly connected to local circumstances. A multitude of factors influences the feasibility, but there are a few ones always recurring:
availability and price of biomass;
prices for heat and electricity;
permits, taxes and duties.

The main driving forces behind the use of bioenergy are the reduction of greenhouse gas emissions and a reduction of the dependency on fossil fuels. These two impacts are therefore often emphasised in environmental assessments on sector level. Furthermore, use of bioenergy should not lead to other negative environmental impacts.

On a sector level, countries using biomass for energy purposes are becoming increasingly aware of the environmental effects of large-scale biomass use for energy production. The production of energy crops like eucalyptus for charcoal, sugar cane for bio-ethanol production, jatropha for biodiesel production consumes a certain amount of fossil energy, thereby reducing the net greenhouse gas and energy savings of the produced biofuel. Moreover, if not properly managed, increased production of biomass in plantations could lead to loss of biodiversity, competition with food, loss of soil quality etc. These impacts have been studied in a great number of studies, and within Europe there's a tendency for biomass certification on project level to prevent the environmental (and social) negative by-effects of biofuel production.

On the individual project level, initiators of larger bioenergy projects generally have to perform a separate Environmental Impact Assessment (EIA), when applying for an environmental permit, showing that the project or plant has reasonable energy use, emissions of greenhouse gases, pollutants, etc. compared to other options. In general, the types of potential impacts to be studied as prescribed by law.

Smaller bioenergy projects generally need to apply for an environmental permit as well. Project owners have to show that the environmental impacts are below certain legal limits (e.g. emissions of nitrous oxide) and that sufficient measures are taken to avoid or reduce local environmental damage (e.g. to prevent leaking of oil into the soil).

A question that entrepreneurs typically raise at an early stage concerns the investment and operation costs of the technology under consideration. Unfortunately there is no easy answer to this question, as these costs depend on many different factors. When overview studies discuss costs they normally present price ranges and stress that due to the variability of data in the data sources and conditions assumed all cost figures should be considered as *indicative*.

Competition between and integration of biomass for energy applications and for other end uses is an important issue. Various types of biomass can be utilized for different end-uses other than energy, e.g. as raw material for the pulp and paper industry, as raw material for the (chemical) industry (e.g. tall oil or ethanol), as animal fodder (e.g. straw) or for humans consumption (e.g. ethanol or palm oil). This competition can be directly for biomass, but is also often focussed on land availability.

Throughout human history biomass in all its forms has been the most important source of all our basic needs, often summarized as the six "Fs": Food, Feed, Fuel, Feedstock, Fibre and Fertiliser. Biomass products are also frequently a source of a seventh "F" - Finance. Until the early 19th century biomass was the main source of energy for industrial countries, and indeed, still continues to provide the bulk of energy for many developing countries biomass. Food versus fuel is a very old issue that is frequently brought up despite the fact that a large number of studies have demonstrated that land availability is not the real problem. While theoretically large areas of (abandoned/degraded) crop land are available for biomass cultivation, biomass production costs are generally higher due to lower yields and accessibility difficulties.

Deforested areas may be easier as they may have more productive soil, but is generally considered unsustainable in the long term. Food security, i.e. production and access to food, would not probably be affected by large energy plantations if proper management and policies were put in place. However, in practice food availability is not the problem, but the lack of purchasing power of the poorer strata of the population. A new element to take into account is climatic change, which introduces a high degree of uncertainty. Increasing competition for wood will increase the price of wood and lower the supply of wood for raw material of forest industry and decreasing competitiveness of European Pulp and paper industry

A major part of the training will be the sustainability and policy issues related with bioenergy. This subject gains an increasing interest from the world community. The challenges and barriers will be presented and possible solutions (strategies) to solve them. Furthermore, some more general aspects as CDM (Carbon Development Mechanism) and a typical biomass project cycle are presented. The module will also include some examples from the practice or success stories. It depends on the available time whether these can be presented or not. They will be anyway available on the CD-rom and the report, which will contain hardcopies of all presentations.

3.5 Useful information

In the preparation of the training course, also a lot of reference material and information was collected like literature, useful documents and websites. These are collected in Annex 3.

The various questions and exercises concerning the different modules are compiled in Annex 4.

4 Research findings

4.1 Introduction

Both, MEMR and TEDC have dedicated training centres. Details of the actual training dates are listed in the following table.

Training	Date	Location
MEMR	2 – 8 February 2010	Jakarta
TEDC	10 – 26 February 2010	Cimahi, Bandung

During both training courses, not all the above subjects in de different modules could be given due to time constraints. For MEMR the focus was more on the policy and strategy issues, while at TEDC the focus was on biomass energy, biomass conversion, exercises, applications and practical work.

At both training courses (MEMR and TEDC) about 20 participants were present. In both cases, participants received a certificate for successful completion of the training.

4.2 Training at MEMR

The actual training at MEMR took place according to the schedule as given in Annex 1. The relative importance of bio-energy in the field of Renewable Energy Technologies was emphasized and this was quite well understood. The wide variety of subjects and the limited available time made it difficult for the MEMR to understand all the theory. It was difficult to interact with the participants and only a few participants took actually part in the discussions and in asking questions. The most interesting subject of discussion was on the strategy and national policy towards the deforestation or the increase of palm oil plantations and the dependency of national income on the oil and gas reserves. This was perhaps also due to the fact that at the time of the training, there was an intensive national debate on whether palm plantations belongs to the Ministry of Agriculture or Forestry and whether new plantations could be implemented.
The concept and meaning of “biofuels” was further elaborated. In the Indonesian context, biofuels means biodiesel made from CPO (crude palm oil) or bioethanol from sugar containing resources. However, biofuels can also be solid and gaseous bioduels. Moreover, it was explained that there is a discussion in western countries regarding first and second generation biofuels, a subject which seems to be not addressed or understood well yet.
In summary, it is not clear in how far the participants understood the wide variety of biomass and bio-energy topics; the evaluation forms might give more insight on the success of the training at MEMR.

4.3 Training at TEDC

The training at TEDC was given at the Basic Engineering department. There was no detailed training schedule prepared as for MEMR staff because it was not clear what kind of experimental work could be conducted and whether or not field visits could be included. Therefore, the first morning was spent to check on the availability of suitable equipment and materials and to discuss various options for field trips. The actual training schedule is given in Annex 2.

Practical work at TEDC was limited due to the availability of materials and equipment. Successful use was made of equipment of other departments, like Mechanical department, Chemistry, Electronics and Information, Building Engineering and Energy Conversion Mechanical department (automotive). TEDC wishes to develop a new department on Renewable Energy Technology and a concrete location is already identified and selected. The building is expected to be ready in 2011 and should incorporate various RET like solar PV, micro hydro, wind and biomass.

Compared to the first training at MEMR, the TEDC staff seemed to be more interested from the frequent questioning, discussions and interactions. It was clear that the staff was keen to learn about this topic, as they have to train the SMK teachers afterwards. This also meant that the presentation of the modules took much more time, with the consequence that also in this case, not the complete set of modules were covered. However, for the TEDC staff, the subjects on (inter)national strategy and policy issues are of less importance.

The training sessions at TEDC were performed with the assistance of a junior consultant of PPE, Pusat Penelitian Energy, the renewable energy and policy centre of ITB. This appeared to be very beneficial as several subjects could be explained once more in Bahasa, the local language.

However, the same problem as for the MEMR staff appeared as well, i.e. the wide variety of subjects made it hard for the participants to understand all topics and issues. It was emphasized that the staff should co-operate in future on further developing the training program for the SMK teachers and it can be expected that from 20 participating staff members, at least one or a few have understood a certain topic. So, by working closely together, they should be able to instruct the teachers in future training programmes.

The videos on experiences in the Czech Republic, on the wickless stove project in Mali, the pyrolysis technology and the “roadmap to bioenergy” were helpful in explaining the theory to the practice. Also the questions and exercises were good opportunities to further clarify the theory, and were also helpful in getting a better understanding whether the material was understood well enough. Similar to the training at MEMR, the concept of first and second generation biofuels was explained; for the TEDC staff biofuels means biodiesel or bioethanol and 2^{nd} generation biofuels was new to them.

One very useful trip was the visit to ITB laboratories which included a visit to two gasifier plants, a biodiesel plant and a chemical analyses laboratory. For the TEDC staff it was very useful to see a well equipped laboratory and an experimental facility. They were also very interested to see how such building should look like, also with the idea to design and erect a new renewable energy centre at TEDC in Cimahi.

One major concern is the availability of equipment and apparatus at TEDC in order to instruct SMK teachers with experimental and laboratory work. Therefore, during the training course a separate document was prepared on this subject, which included a list of equipment and possible experiments, see Annex 5.

For the field trips to ITB and Lemigas, a short document of the findings was prepared for TEDC, which they can use in combination with their own findings. These notes are listed in Annex 6.

5 Conclusions

From both training course, the following conclusions can be drawn:

1. The training was completed successfully at MEMR and TEDC. All participants received a certificate for successful completion.
2. The training course on biomass and bio-energy is a very wide field and covers many different subjects. Participants also felt that the scope of this training course was much wider than the previous courses on anaerobic digestion, solar PV and micro-hydro. This complicates the question, whether all material is well understood.
3. This is in particularly of importance to the TEDC staff, who have to instruct the SMK teachers, ToT. These teachers subsequently have to develop the curriculum, syllabi and training material for the students. It is therefore recommended to ask the participants for their feedback and determine whether further training is required and in which subjects.
4. The participants understood the relevant importance of biomass as a renewable energy source because it is the only renewable source containing carbon, which is essential when oil, gas and coal are further depleting. Carbon is essential for food production, building materials, and is the chemical building block for the organic chemistry. Without carbon, no batik shirts can be made in future!
5. Participants became well aware of the fact that the national strategy and policy towards renewable energy (and bio-energy in particularly) should be more focused towards the promotion of bio-energy and the introduction of stimulating measures to develop and implement renewable energy technologies. However, this does not mean that other renewable energies should be disregarded; in many ways the focus should be on creating a win-win situation.
6. There is a urgent need for TEDC to develop practical facilities at their premises. There are facilities on renewable energies like biogas, micro-hydro and solar PV. A list of equipment was prepared and given to TEDC, most of it can be bought locally, but an experimental facility to conduct and/or simulate thermal conversion processes should be purchased from the Netherlands.
7. The existing idea of constructing a separate renewable energy department fits very well in the overall profile of the TEDC institute and should be supported. Such RE-centre should also incorporate a bio-energy department with experimental and laboratory facilities to instruct SMK teachers and possible other stakeholders within the Casindo project.

6 Annex 1: training schedule at MEMR

Curriculum for two-week training course on Renewable Energy for MEMR staff

Part I : 8-12 February 2010

Day	Module	Sessions/ Presentations
Day 1	**8 February 2010**	
8h45-10h00	**Opening Ceremony**	
Coffee break		
	1: Basic concept of Renewable Energy Development	
10h30-11h30	Mr. Nico van der Linden Msc	Background of project & training and Introduction to renewable energy
11h30-13h00	Mr. Xander van Tilburg MSc.	Why renewable energy? *Drivers (Global), Drivers (National), Some success stories* *Challenges; o.a. technology costs and enabling policy environment*
LUNCH: 13h00-14h00		
	2:Renewable Energy Policy	
14h00-16h00	Mr. Oetomo Tri Winarno Msc.	Renewable Energy in Indonesia
Day 2		**9 February 2010**
	2:Renewable Energy Policy (continued)	
9h00-11h00	Mr.Dr. Tatang Hernas Soerawidjaja	Renewable Energy Targets in Indonesia: How to develop them and can they be achieved ?
Coffee Break		
11h00-12h30	Mr. Xander van Tilburg MSc.	Renewable Energy support mechanisms *Why are there support schemes in the first place?* *Overview of different types of support schemes, Some case studies* *Renewable obligation, Feed-in* *Case study: costing a 20 MW wind project*
LUNCH: 12h30-13h30		
	3: Biomass: Module 1: Introduction	
13h30-15h00	Mr. Ir.Harrie Knoef	Biomass and Bioenergy, *Introduction, Resources*
Coffee Break		
15h30-17h00	Mr. Ir.Harrie Knoef	*Biomass to energy chain* *Characteristics* *Pretreatment*
Day 3		**10 February 2010**
	4:Renewable Energy Policy; continuation support mechanisms	
9h00-10h30	Mr. Xander van Tilburg MSc.	Experiences with RE support mechanisms in Europe *Germany – EEG feed in support* *UK – ROC renewable obligation*

Day	Module	Sessions/ Presentations
		The Netherlands – feed in
Coffee Break		
11h00-12h00	Mr. Xander van Tilburg MSc.	Suitability for Indonesian situation *Analysis of the current situation*
Lunch: 12h00-13h00		
	5 Biomass: Module 2: Primary conversion technology to biofuels	
13h00-15h00	Mr. Ir.Harrie Knoef	Bioenergy technologies *Solids (carbonisation, agglomeration, briquettes, pellets)* *Liquids (fermentation, esteirifcation, pyrolysis)*
		Coffee Break
15h30-17h00	Mr. Ir.Harrie Knoef	*Gaseous (gasification, anaerobic digestion)*
Day 4		**11 February 2010**
	6. Biomass: Module 3: Secondary conversion of biofuels	
9h00-12h30	Mr. Ir.Harrie Knoef	*Heat, Power, Transportation Fuels, Bio refineries*
Lunch: 12h30-13h30		
	7. Biomass : Module 4: General issues	
13h30-15h00	Mr. Ir.Harrie Knoef	*Competing use of biomass* *Sustainability and policy issues*
Coffee Break		
15h30-16h30	Mr. Ir.Harrie Knoef	CDM
Day 5		**12 February 2010**
	8. Biomass: Module 4: General issues (continued)	
9h00-10h00	Mr. Ir.Harrie Knoef	*Biomass energy strategies and policies (objectives, challenges, barriers)*
Coffee Break		
10h00-10h30		Feedback from participants on course content and suggestions for possible follow up training
Closure & Concluding remarks		
Lunch & Prayers: 12h00-14h00		

7 Annex 3: training schedule at TEDC

Curriculum for two-week training course on Biomass Energy for TEDC staff

15 – 25 February 2010

Day	Module	Sessions/ Presentations
Day 1	**15 February 2010**	
8h00-10h00	**Opening Ceremony**	
Coffee break		
10h00-12h00		Introduction to TEC facilities
LUNCH: 12h00-13h00		
13h00-16h00	Introduction	Introduction to the course Introduction to biomass and bio-energy
Day 2		**16 February 2010**
8h00-12h30	Biomass	Biomass resources and harvesting
LUNCH: 12h30-13h30		
13h30-15h00	Practicum	Discussion on practical part and possibilities to conduct experimental work
15h30-17h00	Biomass	Biomass Pretreatment
Day 3		**17 February 2010**
08h00-12h30	Bio-energy	The Bioenergy chain
Lunch: 12h00-13h00		
13h30-16h30	Information	Discussion on information package Exercises Information on useful websites and literature
Day 4		**18 February 2010**
08h00-12h00	Biomass	Municipal Solid Waste
Lunch: 12h30-13h30		
13h30-15h00	Practicum	Determination of moisture content Preparation of briquettes and pellets
Day 5		**19 February 2010**
08h00-12h00	Biofuels	First and second generation biofuels
Lunch: 12h30-13h30		
13h30-16h30	Practicum	Determination of moisture content Determination of bulk density
Day 6		**22 February 2010**
08h00-12h00	Bio-energy conversion	Biomass gasification
Lunch: 12h30-13h30		
13h30-	Bio-energy	Biomass gasification, including exercises

Day	Module	Sessions/ Presentations
16h30	conversion	
		23 February 2010
08h00-12h00	Bio-energy conversion	Combustion, including exercises
Lunch: 12h30-13h30		
13h30-16h30	Bio-energy conversion	Pyrolysis, including video
Day 5		24 February 2010
08h00-14h00	Bio-energy conversion	Visit ITB work facilities and laboratory
Lunch: 12h30-13h30		
15h00-16h30	Bio-energy conversion	Anaerobic digestion
Day 5		25 February 2010
Visit Lemigas, Jakarta		

8 Useful information: Literature and websites

Useful resources on bioenergy conversion technologies

Bioenergy (biomass conversion in general)

Title: Advancing Bioenergy for Sustainable Development. Guideline for Policymakers and Investors. Volumes I, II, and III
URL: http://www.esmap.org/filez/pubs/30005BiomassFinawithcovers.pdf
(or http://www.energycommunity.org/documents/SustainableBioenergyFinal.pdf)
Authors: Sivan Kartha, Gerald Leach and Sudhir Chella Rajan
Publisher: Energy Sector Management Assistance Program (ESMAP), World Bank, Washington DC (April 2005)
Relevance: Volume II contains bioenergy technology introduction, technical fiches and developing country case studies

Title: Biomass energy production in Australia: status, costs and opportunities for major technologies.
Authors: C.R. Stucley, S.M. Schuck, R.E.H. Sims, P.L. Larsen, N.D. Turvey and B.E. Marino
Publisher: Rural Industries Research and Development Corporation RIRDC (Feb 2004), Barton, ACT, Australia
Relevance: Examines in some detail the elements of bioenergy, from the nature of biomass as a fuel source, issues related to its production, harvesting and transport, its conversion into primary and secondary products and services, costs and economics of bioenergy in its various forms, and co-values and co-products associated with bioenergy.

Title: Leitfaden Bioenergie: Planung, Betrieb und Wirtschaftlichkeit von Bioenergie-anlagen. (Zweite Auflage)
URL: www.fnr-server.de/pdf/literatur/pdf_189leitfaden_2005.pdf
Publisher: Fachagentur Nachwachsende Rohstoffe (FNR), Gülzow, 2005
Relevance: General manual / standard book on the use of bioenergy. In German

Title: Clean Energy for Development and Economic Growth: Biomass and other renewable energy options to meet energy and development needs in poor nations
URL:
http://www.energyandenvironment.undp.org/undp/indexAction.cfm?module=Library&action=GetFile&DocumentAttachmentID=1030
Author: Daniel M. Kammen, Robert Bailis and Antonia V. Herzog
Publisher: UNDP, 2002
Relevance: Explores linkages between renewable energy, poverty alleviation, sustainable development, and climate change in developing countries. Special emphasis on biomass-based energy systems.

Title: Modern biomass conversion technologies
URL: http://www.accstrategy.org/simiti/Faaij.pdf
Author: André Faaij
Publisher: Presented at Abrupt Climate Change (ACC), 30.9-1.10 2004, Paris, France

Title: Bioenergy Technology Evaluation and Potential in Costa Rica
URL: ebooks.jyu.fi/1795_6900/9513921549.pdf
Author: Suvi Huttunen and Ari Lampinen
Publisher: University of Jyväskylä, Finland (April 2005). Research Reports In Biological And Environmental Sciences #81
Relevance: Includes an introduction on many conversion technologies

Title: Planning and Installing Bioenergy Systems. A Guide For Installers, Architects And Engineers
Publisher: German Solar Energy Society and Ecofys (January 2005). BN 1844071324
Relevance: Planning manual for bioenergy plants. Contents include: Biomass Overview • Anaerobic Digestion • Biofuel • Small-scale Heat Ovens • Large-scale Boilers • Gasifiers

Title: Manual for biofuel users
URL: www.cbss.st/basrec/documents/bioenergy/dbaFile10431.pdf
Author: Villu Vares (ed.)
Publisher: Tallinn University of Technology (TUT), Tallinn, 2005. Produced in the frame of Baltic Sea Region Energy Co-operation (BASREC)
Relevance: Manual on the use of solid biofuels

Title: Bioelectricity Vision: Achieving 15% of Electricity from Biomass in OECD Countries by 2020
URL: www.wwf.de/fileadmin/fm-wwf/pdf_misc-alt/klima/biomassereport.pdf
Author: Ausilio Bauen, Jeremy Woods and Rebecca Hailes
Publisher: WWF International and AEBIOM, April 2004

Tile: The Brilliance of Bioenergy - In Business and In Practice
Author: Ralph E H Sims
Publisher: James & James (Science Publishers) Ltd, London (UK). February 2002
Relevance:

Title: Wood fuels basic information pack. 2nd edition 2002.
Author: Varpu Savolainen and Håkan Berggren (ed.)
Publisher: BENET Bioenergy Network of Jyväskylä Science Park Ltd (Finland). ISBN 952-5165-19-1
Relevance: Covers i.a. production techniques of woodfuels

Title: Wood for Energy Production: Technology - Environment - Economy.
URL: http://www.videncenter.dk/uk/engwood.htm
Author: Helle Serup
Publisher: Centre for Biomass Technology. ISBN: 87-90074-28-9. 2nd Revised Edition, 2002
Relevance:

Title: Renewable Energy from Biomass
URL: http://ehs.sph.berkeley.edu/krsmith/publications/Kaltschmitt%20Biofuel%20final.pdf
Authors: Martin Kaltschmitt, Daniela Thrän and Kirk R. Smith
Published in: Encyclopedia of Physical Sciences and Technology, Third edition, Volume 14. Academic Press/Elsevier, Burlington, USA (2002)
Relevance: Overview article. Extensive reference to Kaltschmitt's German language *Energie aus Biomasse* (see below).

Tile; Energie aus Biomasse. Grundlagen, Techniken und Verfahren
Authors: M. Kaltschmitt & H. Hartmann (eds.)
Publisher: Springer Verlag, Heidelberg, 2001, ISBN 3-540-64853-4
Relevance: In German. Very exhaustive overview on technologies and processes for producing energy from biomass.

Title: RWEDP Wood Energy Database
URL: http://www.rwedp.org/d_database.html
Publisher: FAO's Regional Wood Energy Development Programme in Asia
Relevance: Database containing a wealth of data on various aspects related to wood energy for the 16 RWEDP member countries. RWDEP operated from 1985 through 2001, and the website was maintained until December 2002.

Title: Bioenergy Primer: Modernised Biomass Energy for Sustainable Development
URL: http://www.energyandenvironment.undp.org/undp/index.cfm?module=Library&page=Document&DocumentID=5029
Authors: Sivian Kartha and Erid D. Larson (2000)
Publisher: United Nations Development Programme, New York, USA,
Relevance: Selected web resources on bioenergy / biomass conversion in general are mentioned in the main body of the report.

Comminution

Title: Production Technology of Forest Chips in Finland.
URL: www.bio-south.com/pdf/ForestRes_Prod.pdf
Author: Markku Kallio & Arvo Leinonen
Publisher: VTT Processes, Project report PRO2/P2032/05, September 2005

Title: Developing technology for large-scale production of forest chips
URL: www.tekes.fi/english/programm/woodenergy.
Author: P. Hakkila
Publisher: TEKES Wood Energy Technology Programme. Technology Report 5/2004.

Title: Forest Residue Harvesting Systems.
Author: C.P. Mitchell and C.M. Hankin
Publisher: Wood Supply Research Groups, University of Aberdeen, UK, 1993. ETSU report B/W1/00136/REP.

Densification

Books

Title: Briquetting biomass wastes for fuel. Summary report
Authors: Sören Eriksson and Mike Prior
Publisher: SEBRA, Trosa, Sweden, February 1989
Relevance: Summary of project results. Short overview of main briquetting technologies. Country reviews. Economics. Markets.

Title: The briquetting of agricultural wastes for fuel
URL: http://www.fao.org/docrep/T0275E/T0275E00.htm
Authors: Sören Eriksson and Mike Prior
Publisher: FAO Environment and Energy Paper no. 11, FAO, Rome, 1990
Relevance: Good overview document. Discusses different presses (mechanical piston, hydraulic piston, screw extruders, pelletisers). Economics. Includes 5 country reviews.

Title: Briquetting of Vegetable Residues
Author: Y. Schenkel, J. Carré and P. Bertaux, CRA, Gembloux (Belgium)
Publisher: Centre for the Development of Industry ACP – EU (1995)
Relevance: Technology assessment, case studies, agri-residues, questionnaire, manufacturers

Title: Biomass Briquetting: Technology and Practices
URL: www.rwedp.org/acrobat/fd46.pdf
Authors: P.D. Grover & S.K. Mishra
Publisher: Regional Wood Energy Development Programme (RWEDP) in Asia, FAO, Bangkok, 1996.

Relevance: Contains some information on screw press and piston press technologies. Book is often quoted by recent authors.

Title: Briquetting of biomass: A compilation of techniques and machinery
Author: Magnus Petterson
Details: Students' reports no. 22 (1999), Swedish University of Agricultural Sciences, Umeå, February 1999
Relevance: Compilation of technical information on binderless briquetting techniques. Contacts of 44 manufacturers worldwide

Title: Wood pellets in Finland – technology, economy and market
URL: www.tekes.fi/opet/pdf/OPET_report5_june2002.pdf
Authors: Eija Alakangas and Paavo Paju
Publisher: OPET Report 5, VTT Processes, Jyväskylä, Finland, 2002
Relevance: Chapter 3 covers production technologies

Short articles and fact sheets

Title: Refined Bio-Fuels Pellets and Briquettes. Characteristics, uses and recent innovative production technologies
URL: wip-munich.de/downloads/dissemination/newsletters_brochures/Leaflet_2_Pellets.pdf
Publisher: ETA / WIP / EUBIA
Relevance:

Title: Biomass pelleting / The pelleting of wood
URL: www.eubia.org/111.0.html & www.eubia.org/196.0.html
Publisher: European Biomass Industry Association (EUBIA)
Relevance: Fact sheet type information on pelleting technologies and economics

Mechanical extraction

Title: Short note on Pure Plant Oil (PPO) as fuel for modified internal combustion engines
URL: valenergol.free.fr/dossiers/IPTS/Short%20note%20on%20pure%20plant%20oil.pdf
Author: Peder Jensen
Publisher: Institute for Prospective Technological Studies, Seville, Spain
Relevance: short summary of main characteristics of pure plant oil (PPO) as a fuel for internal combustion engine automotive applications.

Title: Equipment For Decentralised Cold Pressing Of Oil Seeds
URL: www.folkecenter.net/mediafiles/folkecenter/pdf/dk/efdcpos_ef.pdf
Author: Erik Ferchau
Publisher: Folkecenter for Renewable Energy. November 2000.

Title: Coconut Oil for Power Generation by EPC in Samoa (website)
URL: http://www.sopac.org/tiki/tiki-index.php?page=CocoGen
Moderator: Jan Cloin
Publisher: SOPAC Secretariat, Suva, Fiji.

Combustion

As the most common way of converting biomass to energy, combustion is often covered to a smaller or larger extent in general biomass technology publications. Sources that specifically focus on aspects of (industrial) biomass combustion include:

Title: The Handbook of Biomass Combustion and Co-firing. 2nd edition
Author: Sjaak van Loo and Jaap Koppejan (ed.)
Publisher: Earthscan. To be published in October 2007. ISBN: 1844072495
Relevance: This handbook presents both the theory and application of biomass combustion and co-firing, from basic principles to industrial combustion and environmental impact. First edition published in 2002

Title: Bioheat Applications in the European Union: an Analysis and Perspective for 2010
URL: www.jrc.nl/publications/scientific_publications/2004/EUR%2021401%20EN.pdf
Author: B. Kavalov and S. D. Peteves
Publisher: Joint Research Centre, 2004
Relevance:

Title: IEA Bioenergy Task 32: Biomass Combustion and Co-firing
URL: http://www.ieabcc.nl/
Leader: Sjaak van Loo
Relevance: A technology expert network o biomass combustion operating under IEA Bioenergy

Title: European Biomass Combustion Network (CombNet)
URL: http://www.combnet.com/index2.php?p=homepage
Leader: Sjaak van Loo
Relevance: A technology expert network on biomass combustion operating under ThermalNet

Gasification

An up-to-date overview of documents on biomass gasification technology is presented at URL www.gasnet.uk.net/sections.php?name=Qm9va3M=

Title: Handbook Biomass Gasification
Author: Harrie Knoef (ed.)
Publisher: BTG Biomass Technology Group BV (September 2005)
Relevance: Covers a wide range of themes relevant to biomass gasification

Title: Small-scale biomass gasifiers for heat and power; a global review
Author: H. E.M. Stassen
Publisher: World Bank, TechnicalPpaper no. 296 (1995), ISBN 0-8213-3371-2
Relevance:

Title: Wood gas as engine fuel
URL: ftp://ftp.fao.org/docrep/fao/t0512e/t0512e00.pdf
Publisher: FAO, Forestry Paper 72 (1986), Rome, ISBN 92-5-102436-7
Relevance: Summary of modern wood gasification technology and the economics of its application to internal combustion engines.

Title: Biomass Gasification in Developing Countries.
Author: Foley, G., and Barnard, G.,
Publisher: Earthscan, London (183), ISBN 0-905347-39-0 174 pp
Relevance: Detailed appraisal of the prospects for biomass gasification in developing countries, based on a World Bank study. Topics covered include economics, commercial status, practical considerations affecting gasifier feasibility in specific applications.

Title: An assessment of the possibilities for transfer of European biomass gasification technology to China
URL: ec.europa.eu/energy/res/sectors/doc/bioenergy/final_report_for_publication.pdf
Author: A.V. Bridgwater, A.A.C.M. Beenackers, K. Sipila

Publisher: European Commission, 1999, ISBN 92-828-6268-2
Relevance: Assessment of the opportunities in China for European biomass gasifier manufacturers

Title: Biomass Gasification in Europe
Author: M. Kaltschmitt, C. Rösch, L. Dinkelbach (eds.)
Publisher: European Commission, October 1998. Report EUR 18224. ISBN: 92-828-4157-X
Relevance: Contains country reviews on research, development, demonstration and deployment of biomass gasification technologies.

Title: IEA Bioenergy Task 33: Thermal Biomass Gasification
URL: www.gastechnology.org/iea
Leader: Suresh Babu
Relevance: A technology expert network on biomass combustion operating under IEA Bioenergy

Title: European Biomass Gasification Network (GasNet)
URL: www.gasnet.uk.net
Leader: Hermann Hofbauer
Relevance: A technology expert network on biomass gasification operating under ThermalNet

Carbonisation

Books

Title: Industrial charcoal making
URL: www.fao.org/docrep/x5555e/x5555e00.htm
Publisher: FAO Forestry Paper 63, FAO, Rome, 1985
Relevance: Practical manual on industrial technologies for charcoal making. Discusses charcoal properties, modern carbonising retort systems, environmental considerations, cost and quality control etc.

Title: Simple technologies for charcoal making
URL: www.fao.org/docrep/X5328e/x5328e00.htm
Publisher: FAO Forestry Paper 41, FAO, Rome, 1987 (reprint)
Relevance: Practical manual on labour-intensive methods for charcoal making. Discusses charcoal properties, traditional carbonising methods (pits, mounds, beehives, metal kilns, etc.), retort systems, cost and quality control etc.

Title: Charcoal production and pyrolysis technologies.
Author: Per Thoresen (ed.)
Publisher: REUR Technical Series no. 20, FAO, Rome (1991), 180 pg.
Relevance: Workshop proceedings covering selected carbonisation technologies applied around the world. Contains a chapter by M Trossero on Evaluation of charcoal making technologies in developing countries.

Title: Charcoal Production - A Handbook
Authors: A.C. Hollingdale, R. Krishnan & A.P. Robinson
Publisher: Commonwealth Secretariat, 1999 (reprint), 159 pg, ISBN 0 85092 380 8
Relevance: This handbook covers methods of charcoal manufacture; details on traditional and modern kilns; the uses of charcoal and its by-products; techniques for analysing charcoal to facilitate product control and standardisation.

Title: Charcoal making in developing countries
Author: Gerald Foley
Publisher: International Institute for Environment and Development (IIED) / Earthscan Publications Ltd (1986), 100 pg, ISBN: 0905347608
Relevance: Comprehensive charcoal production technology overview

Title: The Art, Science, and Technology of Charcoal Production

Author: Michael Jerry Antal, Jr. and Morten Grønli
Published: *In*: Ind. Eng. Chem. Res., Vol. 42, No. 8, pg.1619-1640 (2003)
Relevance: Article summarises the knowledge of the production and properties of charcoal. A similar article is published as chapter 9 in Fast Pyrolysis of Biomass: A Handbook. Volume 3. (A V Bridgwater, ed.) CPL Press (2005), 221 pg, ISBN: 1872691927

Other data sources

Title: SSRSI Charcoal Making Page
URL: www.ssrsi.org/sr2/Indust/charcoal.htm
Description: This site contains many relevant links to charcoal making. Operated by the Survival & Self Reliance Studies Institute
Relevance: Contains many relevant links. Seems up-to-date.

Title: Developments in charcoal production technology
URL: http://www.fao.org/docrep/005/y4450e/y4450e11.htm
Author: Hubert E.M. Stassen
Relevance: Short article

Title: Charcoal production and use in Africa: what future?
URL: http://www.fao.org/docrep/005/y4450e/y4450e10.htm
Author: Philip Gerard
Relevance: Short article

Anaerobic digestion

General

Title: Biogas Production and Utilisation
URL: www.iea-biogas.net/Dokumente/Brochure%20final.pdf
Author: Members of IEA Bioenergy Agreement Task 37
Publisher: IEA, Paris, 2005
Relevance: General introduction, prepared by international expert group

Title: IEA Bioenergy Agreement Task 37
URL: http://www.novaenergie.ch/iea-bioenergy-task37/
Moderator: Nova Energie, Switzerland
Relevance: IEA working group covering biological treatment of the organic fraction of municipal solid waste (OFMSW) as well as the anaerobic treatment of organic rich industrial waste water.

Anaerobic digestion technology briefs:
www.btgworld.com/technologies/anaerobic-digestion.html
www.biogas-energy.com/docs_en/BiogasEnergy.pdf

The Anaerobic Digestion Archives
http://listserv.repp.org/pipermail/digestion_listserv.repp.org/
General discussion about technical aspects of anaerobic digestion, moderated by Paul Harris, University of Adelaide.

Title: Beginners Guide to Biogas
URL: www.adelaide.edu.au/biogas/
Note: Provides some introductory material. Moderated by Paul Harris

Title: Anaerobic Digestion and Biogas
URL: http://www.mrec.org/anaerobicdigestion.html

Author: Midwest Rural Energy Council (Wisconsin, USA)
Relevance: Links to resources on the topic of anaerobic digestion

Title: Anaerobic Digestion Systems Web Site
URL: http://www.anaerobic-digestion.com/index.php
Moderator: Enviros (consulting company)
Relevance: Supplier independent information on AD and related subjects.

Dairy manure

Titles: **Biogas Digest**. Vol. 1: Biogas Basics. Vol.2: Biogas – Application and Product Development. Vol. 3: Biogas - Costs and Benefits and Biogas – Programme Implementation. Vol. 4: Biogas – Country Reports
URL: www.gtz.de/de/dokumente/en-biogas-volume1.pdf
www.gtz.de/de/dokumente/en-biogas-volume2.pdf
www.gtz.de/de/dokumente/en-biogas-volume3.pdf
www.gtz.de/de/dokumente/en-biogas-volume4.pdf
Publisher: GTZ (German Agency for Technical Cooperation)
Relevance: Extensive documentation on household and village scale biogas plants in developing countries, prepared in the frame of GTZ's Information and Advisory Service on Appropriate Technology

Title: Biogas technology: A training manual for extension
URL: http://www.fao.org/sd/EGdirect/EGre0021.htm
Publisher: FAO / Consolidated Management Services, Kathmandu, 1996
Relevance: Training manual for Nepal

Title: Handreichung Biogasgewinnung und –nutzung (3rd edition)
URL: www.fnr-server.de/pdf/literatur/HR_Biogas.pdf
Author: Fachagentur Nachwachsende Rohstoffe, Gülzow, Germany (2006)
Relevance: Written in German. Chapter 3 by P. Scholwin, T. Wiedele, & H. Gattermann, discusses biogas plant technology

Title: Biogas – Praxis. Grundlagen - Planung - Anlagenbau - Beispiele - Wirtschaftlichkeit. 3rd edition.
Authors: Heinz Schulz and Barbara Eder:
Publisher: ökobuch Verlag, Staufen bei Freiburg (2006), ISBN: 3-936896-13-5
Relevance: Written in German. Chapter 3 discusses biogas plant technology. chapter 7 biogas plant planning and economics

Title: Dairy Waste Anaerobic Digestion Handbook. Options for Recovering Beneficial Products From Dairy Manure
URL: www.makingenergy.com/Dairy%20Waste%20Handbook.pdf
Author: Dennis A. Burke P.E.
Publisher: Environmental Energy Company, Olympia WA (June 2001)
Relevance: Introduction to the anaerobic digestion of daily manure

Organic waste / Municipal solid waste

Title: Anaerobic Reactors. Volume 4 in the Biological Wastewater Treatment series
Author: Carlos Augustos de Lemos Chernicharo
Publisher: IWA Publishing (March 2007), UK. ISBN 1843391643
Relevance: Presents fundamentals of anaerobic treatment in detail, including its applicability, microbiology, biochemistry and main reactor configurations.

Title: An introduction to Anaerobic Digestion of Organic Wastes. Final Report
URL: www.bioenergywm.org/documents/Anaerobic%20Digestion.pdf
Author: Fabien Monnet (Remade Scotland), November 2003

Relevance: Discusses i.a. AD processes, by-products, types of facilities

Title: Methane production by anaerobic digestion of wastewater and solid wastes
Authors T.Z.D. de Mes ; A.J.M. Stams,; J.H. Reith, and G. Zeeman.
In: Bio-methane & bio-hydrogen : status and perspectives of biological methane and hydrogen production, J.H. Reith, R.H. Wijffels and H. Barten (eds)
URL: www.biohydrogen.nl/publicfiles/16_20804_2_Bio_methane_and_Bio_hydrogen_2003.pdf
Publisher: Dutch Biological Hydrogen Foundation, 2003
Relevance: Chapter 4 of the publication reviews and evaluates various anaerobic digestion technologies. Discusses the situation in the Netherlands as well as international developments

Title: Anaerobic digestion of biodegradable organics in municipal solid wastes
URL: http://www.seas.columbia.edu/earth/vermathesis.pdf
Author: Shefali Verma (thesis)
Publisher: Columbia University, May 2002
Relevance: In-depth examination of the status of anaerobic digestion technologies for the treatment of the organic fraction of municipal solid wastes (MSW).

Title: Biogas and More! Systems & Markets Overview of Anaerobic Digestion
URL: http://websrv5.sdu.dk/bio/pdf/biogas.pdf
Author: AEA Technology Environment, Culham, Abingdon, UK, July 2001
Publisher: IEA Bioenergy Agreement Task 24 Energy From Biological Conversion Of Organic Waste
Relevance: Special attention to digestion of municipal solid waste (MSW). A prior edition (Feb 1998) was published by Resource Development Associates, Washington DC, USA

Title: Review of Current Status of Anaerobic Digestion Technology for Treatment of Municipal Solid Waste
URL: http://ns.ist.cmu.ac.th/riseat/documents/adreview.pdf
Author: Regional Information Service Center for South East Asia on Appropriate Technology (RISE-AT), Chiang Mai University, Thailand (November 1998)
Relevance: Summarises the current status of Anaerobic Digestion Technology for Treatment of Municipal Solid Waste (MSW). Review of systems in operation worldwide.

Title: Biogas from Municipal Solid Waste. Overview of Systems and Markets for Anaerobic Digestion of MSW
Author: IEA Bioenergy Anaerobic Digestion Activity
Publisher: Danish Energy Agency (Copenhagen) & Novem (Utrecht, The Netherlands)
Relevance: Discusses technology, market and suppliers for MSW digestion

Title: Anaerobic Granular Sludge Bed Technology Pages (website)
URL: www.uasb.org/index.htm
Moderator: Jim Field & Reyes Sierra
Relevance: Aims to inform the public on the application of anaerobic bioreactor systems for wastewater treatment and sustainable environmental technology

Landfill gas

Title: International Perspective on Energy Recovery from Landfill Gas (REV-3)
URL: http://www.caddet.org/public/uploads/pdfs/Report/ar06.pdf
Publisher: IEA Bioenergy and IEA CADDET Cenbtre for Renewable Energy (Feb 2000)
Relevance: Reviews of the status of energy from landfill gas in IEA countries. Chapter 2 discusses landfill gas utilisation, collection and treatment technologies.

Title: Comparative Analysis of Landfill Gas Utilization Technologies
URL: http://www.nrbp.org/pdfs/pub07.pdf
Author: SCS ENGINEERS, March 1997

Publisher: Northeast Regional Biomass Program (USA)

Title: Landfill Gas Web Site
URL: http://www.landfill-gas.com/index.php
Moderator: Enviros (consulting company)
Relevance: Devoted to scientific and technical issues in landfill gas.

Liquid biofuel production

Note: This category covers technologies for the production of pure plant oil by mechanical extraction, the (trans-)esterification of vegetable oil into biodiesel, and the alcoholic fermentation of sugar and starch crops into bio-ethanol.

Title: GAVE: Climate neutral gaseous and liquid energy carriers (website)
URL: http://gave.novem.nl/gave/index.asp
Leader: SenterNovem
Relevance: GAVE supports climate neutral gaseous and liquid energy carriers. The website hosts hundreds of documents on this subject

Title: VIEWLS: Clear Views on Clean Fuels (website)
URL: www.viewls.org
Leader: SenterNovem
Relevance: The VIEWLS website covers Data, Potentials, Scenarios, Markets and Trade of Biofuels. Restrcited access to hundreds of documents on these subjects

Title: IEA Bioenergy Task 39 "Commercializing 1st- and 2nd-Generation Liquid Biofuels from Biomass"
URL www.task39.org
Leader: Jack Saddler, University of British Columbia, Canada
Relevance: Global network dedicated to the development and deployment of biofuels for transportation fuel use.

Title: Biofuels for Transport - Global Potential and Implications for Sustainable Energy and Agriculture
Author: Worldwatch Institute in association with BMELV, FNR and GTZ
Publisher: Earthscan, July 2007, ISBN: 1844074226
Note: Circulated earlier in a restricted audience under the title "*Biofuels For Transportation. Global Potential and Implications for Sustainable Agriculture and Energy in the 21st Century*"
Relevance: A comprehensive analysis, which takes the reader from an introduction to specific biofuels, through the prospects for technology and agriculture, to the economic, social and environmental implications

Title: Biofuel Technology Handbook
URL: www.biofuelmarketplace.com/Files/545fdcfd-5b78-4a24-b443-679fef162b6c/technology_handbook_v1.pdf
Authors: Dominik Rutz and Rainer Janssen
Publisher: WIP Renewable Energies, Munich, Germany, 2007
Relevance: This document gives an overview of relevant technological aspects of biofuels

Title: Biofuels for Transportation - Global Potential and Implications for Sustainable Agriculture and Energy in the 21st Century. Conference Handout
URL: www.gtz.de/de/dokumente/en-biofuels-conference-handout-2006.pdf
Publisher: BMELV, GTZ and Worldwatch Institute
Relevance: Summarises the findings of the *Biofuels for Transport* study

Title: Biofuels for transport. An international perspective
URL: www.iea.org/textbase/nppdf/free/2004/biofuels2004.pdf
Authors: Lew Fulton, Tom Howes, and Jeffrey Hardy (IEA)
Publisher: International Energy Agency (IEA), Paris, 2004
Relevance: Excellent treatment of biofuels technologies, costs, benefits, market issues, and existing and past policies from around the world. Bibliography of more than 150 references.

Title: Biofuels. Technologies Status and Future Trends. Feedstock and Product Valorisation. Assessment of Technologies and DSTs. Pre-Print
Author: A. Sivasamy, P. Foransiero, S. Zinoviev, S. Miertus, F. Mueller-Langer, D. Thraen & A. Vogel
Publisher: International Centre for Science and High Technology, UNIDO, Italy
Relevance:

Title: International Resource Costs of Biodiesel and Bio-ethanol
URL: www.senternovem.nl/mmfiles/Costsofbiobioethanol_tcm24-187060.pdf or www.dft.gov.uk/pgr/roads/environment/research/cqvcf/internationalresourcecostsof3833
Author: AEA Technology Environment
Publisher: UK Department for Transport, United Kingdom, June 2003
Relevance: Good overview of the sources of biofuels around the world and their likely costs.

Title: GEF-STAP Biofuels Workshop: Summary, Findings & Recommendations
URL: www.gefweb.org/Documents/council_documents/GEF_30/documents/C.30.Inf.9.Rev.1ReportoftheGEF-STAPWorkshoponLiquidBiofuels.pdf
Author: Scientific and Technical Advisory Panel (STAP) of the Global Environment Facility
Relevance:

Title: A Review of LCA Studies on Liquid Biofuel Systems for the Transport Sector (Final Version 11 October 2005). Background Paper
Author: Eric D. Larson (Princeton Environmental Institute)
Note: Originally presented at the GEF/STAP Workshop on Liquid Biofuels for the Transport Sector, 29 August – 1 September 2005, New Delhi, India
Relevance:

Title: Review of existing and emerging technologies for the large-scale production of biofuels in developing countries. Technology state-of-the-art. Background Paper
Authors: Philippe Girard, Abigaïl Fallot, Fabien Dauriac (CIRAD)
Publisher: Energy for Sustainable Development, Vol 10 No 2 (2006), ISSN 0973-0826
Note: Paper originally presented at the GEF/STAP Workshop on Liquid Biofuels for the Transport Sector, 29 August – 1 September 2005, New Delhi, India
Relevance: Describes various routes for converting biomass into transport fuel.

Title: Liquid Biofuel in South East Asia: Resources and Technologies
URL: www.ris.org.in/article3_v8n2.pdf
Authors: Linoj Kumar, Prabha Dhavala, Anandajit Goswami, & Sameer Maithel
Relevance:

Title: Liquid biofuels in Pacific Island countries
URL: http://www.sopac.org/tiki/tiki-download_file.php?fileId=1064
Author: Jan Cloin
Publisher: SOPAC Secretariat, Suva, Fiji. Miscellaneous Report 628 (April 2007)
Relevance: Discusses the potential use of PPO, biodiesel and bio-ethanol in the Pacific

Title: Small-scale Production and Use of Liquid Biofuels in Sub-Saharan Africa: Perspectives for Sustainable Development
URL: http://www.un.org/esa/sustdev/csd/csd15/documents/csd15_bp2.pdf

Publisher: UN Dep't of Economic and Social Affairs (UN-DESA), New York, April 2007
Relevance: Background paper no. 2 to the 15th Session of the Commission on Sustainable Development (CSD), held 30 April-11 May 2007 in New York. The paper assesses the status and analyses the perspectives of small-scale biofuel production and use in sub-Saharan Africa. Contains 5 case studies on liquid biofuel production in developing countries

Title: Biodiesel Production and Economics
URL: www.agric.wa.gov.au/content/SUST/BIOFUEL/BiodieselProductandEconvs12vs111.pdf
Publisher: Department of Agriculture and Food, Gov't of Western Australia (May 2006)
Relevance: Provides comprehensive info & WWW resources for bio-diesel. Covers >1000 relevant web links on biodiesel related topics. Intended to be a one-stop biodiesel resource, both for information and for WWW links, for use by beginners and experts alike.

Title: Biodiesel: The Comprehensive Handbook
Author: Martin Mittelbach and Claudia Remschmidt
Publisher: Martin Mittelbach (2004), ISBN: 3-200-00249-2
Relevance: First comprehensive handbook on biodiesel. Covers feedstocks, process technologies, fuel properties, quality specifications, exhaust emissions, environmental impacts and non-energy uses.

Title: BDPedia - Biodiesel WWW Encyclopedia
URL: www.bdpedia.com
Relevance: All the answers & links.

Production of (combined heat and) power

Title: Energy from Biomass: A review of combustion and gasification technology
Authors: Peter Quaak, Harrie Knoef, Hubert Stassen
Publisher: World Bank, Technical Paper No. 422 (1998), ISBN 0-8213-4335-1
Relevance Describes gasification and combustion technology in general terms. Compares steam-cycle and gasifier-engine concepts.

Title: Wood energy through steam engines. Draft report
Authors: TARGET Technologia e Servizi S.r.k., Rome (October 1987)
Publisher: FAO Forestry Department , Rome
Relevance: Discusses small-scale biomass-based power generation

Title: Techno-Economic evaluation of selected decentralised CHP plants based on biomass combustion in IEA partner countries.
URL: http://www.ieabcc.nl/publications/IEA-CHP-Q2-final.pdf
Author: Ingwald Obernberger and Gerold Thek
Publisher: BIOS Bioenergiesysteme, Graz, Austria (March 2004)
Notes:

Title: Small-scale biomass CHP technologies
URL: www.opet-chp.net/download/wp2/small_scale_biomass_chp_technologies.pdf
Author: M. Kirjavainen, K. Sipilä, E. Alakangas, T. Savola and M. Salomon
Publisher: VTT Processes, Espoo (April 2004)
Relevance:

Title: Energetische Nutzung von Biomasse durch Kraft-Wärme-Kopplung: Tagungsband zu der Veranstaltung am 16./17. Mai 2000 in Gülzow
URL: http://www.fnr-server.de/pdf/literatur/pdf_95gfg14_kwk.pdf
Publisher: Fachagentur Nachwachsende Rohstoffe (FNR), Gülzow (2000)
Relevance: In German

9 Annex 4: Exercises and questions for various modules

Note: the answers in the various boxes are handed to TEDC as excel sheets

Introduction

Why is biomass one of the most important RET (Renewable Energy Technologies)?
What are the advantages and disadvantages of bioenergy compared to other RET's like solar, wind, geothermal, hydro?

It is the only renewable energy source containing carbon, can be stored, transported and utilized at different places

Resources:

In the Netherlands, a small amount of the electricity is produced by combustion or gasification of biomass. Most from this biomass is from forestry residues.
How much hectares is needed to provide sufficient fuel for a 1 Mega Watt (MW) wood-fired power station? Give a global indication in the order of 1, 10, 100 or 1000 hectare.
To answer this question, you need to know the moisture content and heating value of the biomass. Furthermore, you need to estimate the wood yield of one hectare.
Mega = 1,000,000
Watt = J/s

Power plant		Land area	
1	MW	20	GJ/t
1	MJ/s	15	t/ha.yr
8.000	h/yr	300	GJ/ha.yr
3.600	s/h	300.000	MJ/ha.yr
28.800.000	s/yr		
28.800.000	MJ/yr	96	ha

assumptions
So, look carefully to the units
MJ/yr divided by MJ/ha.yr = ha
(28800000 / 300000)

Characteristics:

Do have pellets improved combustion characteristics over raw material and why?
Yes, because they are very uniform and can be fed automatically like a fluid

Why does sawdust not burn?
Because the material is very fine, which does not allow for oxygen to penetrate inside a pile of sawdust

Determine moisture content and bulk density of various samples

Density

Sample	1	2	
diameter	5	5	cm
thickness	1,8	1,8	cm
volume	35,34	35,34	cm3
	0,000035	0,000035	m3
weight	30,36	28,7	g
	0,030	0,029	kg
density	859	812	kg/m3

Moisture content

Sample	Material+lid	Material	
empty lid	43,81		
wet	47,73	3,92	g
dry	47,02	3,21	g
moisture	0,71	0,71	g
MCw	1,49%	18,1%	
MCd	1,51%	22,1%	
	Wrong		

Bioenergy chain:
Combined heat and power (CHP) is a very important bioenergy route. Is this also valid for Indonesia?
Open question for discussion

MSW
How much energy can be produced from the MSW generated in Bandung and how much covers this from the energy demand?
Answer can be found from the presentation on MSW

What can MSW contribute in your region

- How much MSW is generated
- How many inhabitants
- How much energy does it contain
- What technology is suitable for energy production
- How much energy can be generated from this MSW amount
- What percentage of the energy demand does this cover

Biofuels:
What are the (dis)advantages of various fuels:
Solid
Liquid
Gas

Biofuels are high on the political agenda of Indonesia. Is the discussion on 1st and 2nd generation fuels included in this discussion? *Clearly not yet*

Pyrolysis
What can you do with the pyrolysis oil?
What happens if you fuel your car with it?
What happens in a gas turbine?
What happens in a boiler?
What happens if the process is not fast but slow?

Why do I want to convert my biomass into pyrolysis oil? Answers:

- Intermittent energy source: The production and the application of the bio-oil can take place at different locations and different moments in time.
- Availability: Pyrolysis oil can be stored for long periods of time, and is therefore available when necessary.
- Transportation: Transportation of pyrolysis oil is very convenient. Existing infrastructure can be used for transportation of pyrolysis oil;
- Second generation biofuel: Pyrolysis oil produced from non-food related biomass is a second generation biofuel and therefore does not compete with the food industry.
- Reducing dependency on fossil fuels: Pyrolysis oil can be used in applications where it substitutes for crude oil, doing so it offers a unique way to reduce your dependency on fossil fuels.
- Applications: Pyrolysis oil can easily substitute fossil fuels as oil and gas in existing boiler and turbine applications. Refitting the systems requires limited investments and therefore pyrolysis offers a unique opportunity to make your energy supply sustainable.

Gasification

What happens if you gasify sawdust or fluffy material in a fixed bed gasifier?
Sawdust: blocking the air, so the process will die
Fluffy material: it will combust, too less compaction inside the bed

Can rice husk be used as fuel for entrained flow gasifiers?
No, this requires extremely fine material

Calculations of gasification processes:

1. heating value of gas
2. density of gas
3. efficiency of overall process

Reactions of gas compounds

$2CO + O_2 = 2\ CO_2$

$CH_4 + 2O_2 = CO_2 + 2\ H_2O$

$2H_2 + O_2 = 2\ H_2O$

$C_2H_4 + 3O_2 = 2CO_2 + 2H_2O$

Some calculations

Data	LHV	M	Composition	LHV	density	Heat in gas	kmol oxygen to combust
	kcal/kmol	kg/kmol	vol%	KJ/kmol	kg/kmol	kJ/kmol	
CO	67636	28	0,200	284,1	5,592	56,7	0,100
CH4	191759	16	0,013	805,4	0,214	10,8	0,027
H2	57798	2	0,193	242,8	0,385	46,8	0,096
C2H4	31600	28	0,001	132,7	0,036	0,2	0,004
CO2		44	0,140		6,160	0	
N2		28	0,453		12,684	0	
			0,407				
						total	0,227 kmol O2
							0,853 kmol N2
							1,080 kmol air

1 kcal = 4,2 kJ
1 Nm3 is at 273 K (or 0 ^{o}C) and 1013 mbar (or 1 bar) (= STP)
1 kmol = 22,4 liter

Heat in combustible gas		114,4	kJ/kmol
Heating value (kJ/Nm3)		5,1	kJ/Nm3
Total	1,000	25,07	kg in 1 kmol
Density at 273 K =		1,12	kg/Nm3
Density of gas at 400 K =		0,764	kg/m3

Wood --> gasifier--> engine ---> generator ---> power

Wood	50	kg/h
LHV	18	MJ/kg
	Efficiency	
Gasifier	0,80	
engine	0,25	
generator	0,90	
Gas out	720	MJ/h
Gasflow	141	Nm3/h
Power out	45	kWe
Spec. Gasflow	3,13	Nm3/kWhe
Spec. Wood consumption	1,11	kg/kWhe

Normal m3 per kWhour electric

gasflow to the engine at
Tgas = 40 oC
Pgas = - 20 mbar
165 m3/h

Calculate the theoretical amount of oxygen and air to combust tar at STP, at 220 °C and at 100 mbar under-pressure according the artificial formula:
Tar + 0,6 O2 → 0,5 CO + 0,5 CO2 + 0,4 H2 + 0,2 H2O

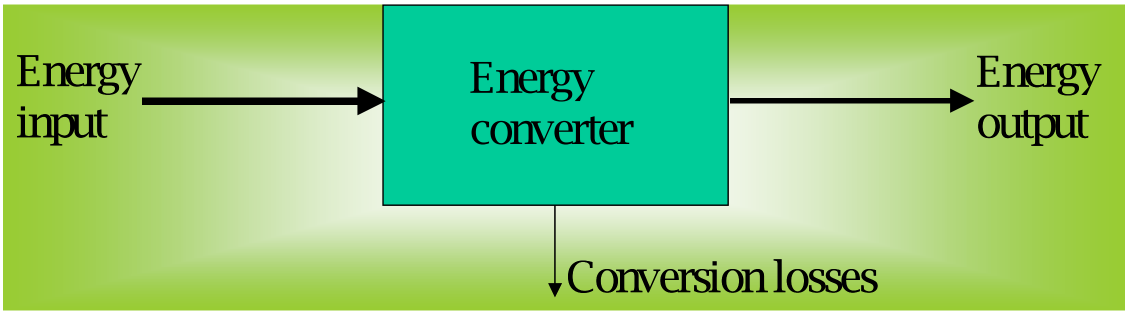
Tar = $CH_{1,2}O_{0,5}$								
Molecular weight	kg/kmol	32			28	44	2	18
1 kmol = 22,4 Nm3	Tar	O2		=	CO	CO2	H2	H2O
at STP: Normal m3								
kmol	1	0,6			0,5	0,5	0,4	0,2
kg	21,2	19,2			14	22	0,8	3,6
total kg		40,4						40,4
volume O2		13,44	Nm3					
volume N2		49,92	Nm3					
volume air		63,36	Nm3					
Per kg tar		2,99	Nm3/kg					
If air factor = 1,6		101	Nm3					
Volume at 220 ^{0}C		183	m3					
Per kg tar		8,64	m3/kg					
Volume at 220 ^{0}C		203	m3					
and 100 mbar underpressure								

Calculate Heating value of gas-air mixtures

			Assumption		Total amount	Heating value
	Amount gas	Heating value	Air amount	Air amount	mixed gas	mixed gas
	m3	MJ/Nm3	air-gas ratio	m3	m3	MJ/Nm3
Natural gas	100	32	8	800	900	3,56
Biogas	100	19	5	500	600	3,17
Producer gas	100	5	1	100	200	2,50

Much more air is needed to combust natural gas compared to producergas
So, the heating value of air-gas mixture entering the gas engine is almost equal
Example of air needed for a certain type of gas is given in excel sheet *Gasification calculations.xls*

Mass and energy balance for a gasifier



Mass balance
Mass in should be equal to *mass out*

In practice, the *mass in* is determined by weighing the amount of biomass over a certain period. So this is expressed as g/s or kg/h or ton/day dependent on the scale of the gasifier

Mass out is the total mass of each gas products (CO, H2, CO2, N2, H2O, etc.). So, the gas composition must be know.
The mass of each gas product (like CO) is the vol% of the compound multiplied by the mass flow of the gas. The gasflow can be measured by a flowmeter or calculated as shown in the other excel sheet "gasification calculations".

Energy balance
Energy in = Energy out – Energy losses

Energy in = mass flow times heating value
In units MJ/s = kg/s * MJ/kg
And MJ/s = MW

Energy out = chemical energy of combustible products + sensible heat in the gas
Chemical energy for each compound:
For CO: vol% CO times heating value of CO (= 284 KJ/kmol)
For H2: vol% H2 times heating value of H2 (= 805 KJ/kmol)
For CH4: vol% CH4 times heating value of CH4 (= 243 kJ/kmol)

Sensible heat is gas flow times specific heat of gas times delta temperature
Specific heat of gas = total of vol% each component times the specific heat of the component
Delta temperature is the temperature of the gas at the exit of the gasifier minus the ambient temperature (for instance 600 ^oC – 28 ^oC)

Example of calculation efficiency:
Suppose Energy in = 100 kW
Chemical energy in the gas is 80 kW
Sensible heat in the gas is 10 kW
Difference = 10 kW is lost

Cold gas efficiency = 80 / 100 = 80%
Overall efficiency = 90 / 100 = 90%

Data on calorific value, specific heat, etc can be found in for instance Perry's Handbook of Physics or through the internet.

Calorific value	kJ/kmol	MJ/Nm3
H2	242,8	10,768
CO	284,1	12,696
CH4	805,4	35,866

spec. heat H2	1,34	kJ/Nm3 K
spec. heat O2	1,50	kJ/Nm3 K
spec. heat N2	1,34	kJ/Nm3 K
spec. heat CH4	2,44	kJ/Nm3 K
spec. heat CO	1,38	kJ/Nm3 K
spec. heat CO2	2,19	kJ/Nm3 K
spec. heat H2O	1,67	kJ/Nm3 K

Homework

1. Consider an average family of four living in the northern half of the United States. If the family saved all of its municipal solid waste (MSW) and burned it, could the family harvest enough energy to heat its home? What conclusions can you draw? Use the following assumptions:
    - The family uses about 125 million BTU[1] of heat energy annually to heat its home
    - MSW production is about 3 dry pounds per person per day (assume 365 days / year)
    - MSW has heat content of 8,000 BTU per pound

2. Dry waste wood biomass is found to have a sulfur content of 0.1% (percent of its dry weight) and a heating value of 8,000 BTU per pound. Colorado coal-fired power plants burn Wyoming sub-bituminous coal which has a sulfur content of 1.0% and a heat content of 10,000 BTU per pound. If dry wood waste were used to replace coal at a power plant, how much would sulfur dioxide emissions be reduced? Express your answer as a percentage change in sulfur emissions. What conclusions can you draw? (Sulfur dioxide is a pollutant implicated in the creation of acid rain.)

3. US residents consume roughly 10 million barrels (42 gallons per barrel) per day of gasoline for transportation fuel. Advanced cellulosic fermentation technologies are projected to produce about 110 gallons of ethanol from a ton of cellulosic biomass (e.g., switchgrass) or about 275 gallons of ethanol from an acre of energy cropland. How many acres of land would need to be devoted to cellulosic biomass production if ethanol replaced 10% of gasoline consumed in the US? Compare your answer with the total land area of France and the state of California. What conclusions can you draw? **Hint:** Recall that ethanol provides only about 2/3 the miles per gallon attainable from gasoline.

4. The US has a lot of federally owned land. Unfortunately, uncontrolled natural forest fires destroy large areas in the western US every summer. In 2002, about 1 million acres of standing timber in national forests were consumed. Some consideration is being given to improved management practices that could produce electrical power from residual forest thinnings. Estimate the lost energy content of burned US forests during 2002. Assuming the US average electricity demand load is about 300,000 MW, how much forested land would be needed to produce all of the country's power? Is this a sustainable alternative? A few facts to consider:
    - The total forested area on US federal lands in the lower 48 states is about 600 million acres with a standing stock density of about 100 dry metric tonnes of wood per acre.
    - Woody plants and trees capture solar energy via photosynthesis at an average rate of about 0.8 W/m2 which corresponds to producing about 5-10 dry tons of biomass per acre annually with an average heating value of 8,000 BTU/lb (dry). Note that 1 acre = 43,560 ft2 = 0.405 hectare = 4,047 m2.
    - A representative heat-to-work conversion efficiency of a biomass fired electric power plant is about 35%

[1] A BTU (British Thermal Unit) is a measure of heat energy and is defined as of heat required to raise the temperature of one pound of liquid water by 1 degree Fahrenheit. 1 BTU is equal to 1,055 joules or 0.00029 kWh, so it doesn't represent much energy. 1 Therm is equivalent to 100,000 BTUs. BTU and Therm units are commonly used in the heating and air conditioning trades.

Bioenergy applications
Following statements present six modern bioenergy applications that may be relevant for developing the bioenergy market in developing countries. What is your opinion of, or experience with, each of these applications?

1. Electricity from combustion of solid biomass
   - Modern biomass fired power (or CHP) plants can supply electricity to industry or the national grid
   - Main benefits are substitution of energy imports and improving the grid
   - Depending on the circumstances, such power plants are generally economic from 1 MWe upward
   - At large scales, production becomes more efficient and cost effective but the logistics (and sustainability) of the biomass supply gets more complicated
   - Larger installations may greatly benefit from CDM

2. Industrial biogas (including landfill gas)
   - Biogas plants are generally small or medium scale (up to several MWe)
   - The economics are often connected to the benefits from waste treatment and other environmental benefits
   - CDM prospects are often good for this type of project

3. Transport fuels (import substitution / export)
   - Resources for the production of ethanol or biodiesel can be obtained from residues (e.g. from agro-industries) but most often require production on dedicated plantations
   - Given quality requirements of liquid biofuels, processing is only feasible on large scales
   - An alternative is the local use or export of straight vegetable oils
   - Sustainability of liquid biofuel production is an important aspect
   -

4. Vegetable oil for small scale power production
   - Vegetable oils can be used in modified diesel engines for (off grid) electricity or shaft power generation
   - This type of project has a high potential for MFP applications (as already done in Mali) and as such for improving energy access to the poor
   - Energy access and local oil production can provide an economic impulse in rural areas.

5. Modern cooking fuels
   - Ethanol based cooking fuels or charcoal from crop residues are convenient and clean household fuels that contribute to the fight against deforestation
   - Their production may induce economic impulse in rural areas.

6. Family scale biogas
   - Digestion of animal manure in small digestion units, providing biogas for cooking and lighting, are highly successful in Asia
   - The application could provide energy to millions of households in the region but depends on several requirements at household level
   - A key issue is the development of companies for construction and maintenance of biogas units

General exercises (after module 2)

1. If biomass is applied on a large-scale, a number of barriers will have to be overcome. Give at least five of these barriers.

Answer: Transportation, Fire, Diseases, Water-demand competition, Food competition, Erosion, Need of agricultural-pesticides, Growth limitation, Bio-Diversity, Landscape infraction.

2. How can you determine the higher heating value(HHV) of Bio-fuels? Describe the process.

Answer: By using a bomcaloriemeter. A sample of dry Biomass is placed inside a closed container in a oxygen rich environment and will be ignited by a sparkspiral. The energy released in the combustion of this sample is transferred to an enclosed water container which will absorb this heat. The amount of water is known, together with the rise in temperature. Therefore it is possible to calculate the higher heating value on the basis of energy preservation with use of:

*Mbr*HHV = Mw*Cw*dTw (note: the wall of the water container is properly isolated).*

3. During combustion, all thermal conversions take place. Which order is right?

a) Combustion → Pyrolysis → Gasification
b) Pyrolysis → Gasification → Combustion
c) Pyrolysis→Combustion → Gasification
d) Gasification → Pyrolysis → Combustion
e) Gasification → Combustion → Pyrolysis

4. Is it useful to blend substrate with wood during anaerobic digestion for the purpose of increasing the gas production? Elaborate on why or why not.

Answer: No not useful, because wood contains a lot of lignin which is hard to break down for anaerobic bacteria's and thus goes of the cost of the volume of the digester and the on that related gas yield.

5. Which two processes are most used with anaerobic digestion?

Answer: Continue process and Batch process.

6. A cattle breeder wants to install an anaerobic digesting installation on his farmyard and asks you for advice. Name at least five points that need attention to see whether this is useful.

Answer: Amount of available dung, composition of the dung (max. yield), amount of available co-substrates, parasitic electrical consumption, use of waste heat, end-use digestate, available subsidies, contracts (like suppliers co-substrate), permits, location, quotations (turn key installation?), feed-in tariff electricity, financing (bank loan, investors).

Basic principles of combustion (after module combustion)

Combustion chemistry

If the matter is a gas, 1 kmol of this gas has the volume of around 22.4 m_n^3 (normal cubic meter). The unit of volume, the normal cubic meter (m_n^3), is defined at a temperature of 273.15K and a pressure *p* = 1013.25 mbar.

For every matter the mass of 1kmol can be calculated from its composition. For the components that are important in combustion, these are:

H_2 = 2 kg/kmol N_2 = 28 kg/kmol
S = 32 kg/kmol O_2 = 32 kg/kmol
C = 12 kg/kmol

In example C_3H_8 (propane gas) consists of 3 carbon atoms and 8 hydrogen atoms. Per kmol, this gives:

$$C_3H_8 \rightarrow 3 \cdot 12 + 8 \cdot 1 = 44 \text{ kg.}$$

General combustion equations

The conversions that take place during a combustion process are shown in figure 1.

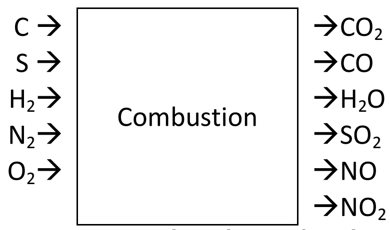


Figure 1: conversions in combustion

Theoretical oxygen demand

Elaborating on the combustion equation of carbon at complete combustion gives:

$$1 \text{ kmol C} + 1 \text{ kmol } O_2 \rightarrow 1 \text{ kmol } CO_2$$

Written out in the mass equation:

$$12 \text{ kg C} + 32 \text{ kg } O_2 \rightarrow 44 \text{ kg } CO_2$$

Because the volume of the gaseous components is 22.4 m_n^3 under normalised circumstances, the equation will be shown as follows:

$$12 \text{ kg C} + 22.4 \; m_n^3 \; O_2 \rightarrow 22.4 \; m_n^3 \; CO_2$$

or for 1 kg C:

$$1 \text{ kg C} + 1.867 \; m_n^3 \; O_2 \rightarrow 1.867 \; m_n^3 \; CO_2$$

A preceding approach gives the following for H_2 and S:

$$1 \text{ kg } H_2 + 5.6 \; m_n^3 \; O_2 \rightarrow 11.2 \; m_n^3 \; H_2O$$

and

$$1 \text{ kg S} + 0.7 \; m_n^3 \; O_2 \rightarrow 0.7 \; m_n^3 \; SO_2$$

Higher heating value: water in vapour phase

Lower heating value: water is condensed in a liquid
The condensation heat is also called latent heat
The temperature at which the flue gas condensates is called the dewpoint

Module Combustion:
How much wood is needed to bring one litre of water to the boil?

Data
Specific heat capacity of water = 4200 J kg-1 K-1
Mass of 1 litre of water = 1 kg
Heat value of wood = 15 MJ kg-1
Density of wood = 600 kg m –3
1 cubic centimetre (1 cm3 = 10-6 m3)
Calculation
Heat energy needed to heat 1 litre of water from 20 ºC to 100 ºC = 80 x 4200 J = 336 kJ
Heat energy released in burning 1 cm3 of wood = 15 x 600 x 10-6 MJ = 9.0 kJ
Volume of wood required = 336 + 9.0 = 37 cm3.
Experience suggests that on an open fire much more than two thin 20 cm sticks would be needed. But a well-designed stove using small pieces of wood could boil the water with as little as four times 'input' – an efficiency of 25%.

Theoretical air amount and flue gas amount

The air we inhale is moist. Thus the combustion air is also moist. If we want to determine the theoretical air amount and flue gas amount, we use the following air composition in volume percentages (vol. %) in combustion calculations:

Nitrogen (N_2)	78.1 vol.%
Oxygen (O_2)	20.7 vol.%
Hydrogen (H_2O)	1.2 vol.%

1 m^3 air contains 0.207 m^3 oxygen. To gain 1 m_n^3 oxygen for the combustion, 4.83 m_n^3 is needed. The theoretical air amount L_0, the theoretical flue gas amount V_0 and the volume dry flue gas V_{0d} is calculated in the following example. The used method of calculation can also be used with other fuels.

Example (to be calculated by the teachers)

Given:

1 m_n^3 of a gaseous fuel with the following composition in volume percentages:

Methane (CH_4)	82 vol.%
Nitrogen (N_2)	14 vol.%
Carbon oxide (CO_2)	4 vol. %

Question:

Calculate the theoretical combustion air demand L_0 and the theoretical flue gas volume V_0.

Answer:

It is most useful to presume volumes, so do not calculate in reverse from volume through kmol to mass C and H.

The reaction equation is:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

We assume that the other components do not join the combustion. If we further assume that the volume of 1 kmol gas is 22.4 m_n^3, we are allowed to replace the unit kmol by 1 m_n^3. In the preceding reaction equation this will show as follows. The oxygen demand for 0.82 m_n^3 gas (methane) will be:

$$0.82\ m_n^3\ CH_4 + 0.82 \cdot 2\ m_n^3\ O_2 \rightarrow 0.82\ m_n^3\ CO_2 + 0.82 \cdot 2\ m_n^3\ H_2O$$

Thus, 1.64 m_n^3 O_2 is needed for this combustion. Furthermore, 0.82 m_n^3 CO_2 and 1.64 m_n^3 H_2O are produced.

Questions combustion technology

If not given otherwise, the combustion calculations have to be based on the air composition according to

	Nitrogen (N_2)	78.1 vol.%
	Oxygen (O_2)	20.7 vol.%
	Hydrogen (H_2O)	1.2 vol.%

1.
   a. Give the chemical combustion equation of ethane (C_2H_6).
   b. Calculate the theoretical air amount L_0 for the combustion of 1 m^3 ethane.
   c. Calculate the flue gas volume if the fuel combusts completely with an air factor 7%.
   d. Calculate the flue gas volume if the flue gasses have a temperature of 220°C.

2. Given is 1 kg wet pure carbon, it contains 10% water.
Calculate:
   a. The flue gas volume for the combustion of this amount of carbon at complete combustion with an air factor 1.
   b. The higher heating value of this kg of wet carbon.

3. The higher heating value of a certain wood-type is 20 612 kJ per kg dry fuel. The ash percentage is negligible small. The hydrogen level of this dry fuel is 6%.
Calculate the lower heating value of this wood-type if the water content is 40%.

4. Calculate the higher and lower heating value of a gas with the following composition per m_n^3: 82 % CH_4, 3% C_2H_6 and 15% N_2.
CH_4 : *higher heating value* = 39 850 kJ/m_n^3
C_2H_6 : *higher heating value* = 70 380 kJ/ m_n^3

5. Calculate the oxygen level in the flue gasses of a fuel if the level $CO_{2,max}$ = 18.6%, while they measure a CO_2-content of 13% and 0% CO during the flue gas analysis.

6. A combustion engine consumes 25kg fuel per hour. The lower heating value of this fuel is 42 MJ/kg and the composition expressed in mass percentages is 80% C and 20% H. The mass of the oxygen in the air is 23% and the combustion is completely with an air factor of 50%.
Calculate:
   a. The amount of combustion air required per hour.
   b. The total flue gas volume in m_n^3/hour.
   c. The CO_2-content in the flue gases.

7. Cokes are combusted on a grid. The coke composition in mass percentages is: 76% C, 14% ash and 10% water. The flue gases are and contains 12% CO_2 and 2% CO.
Calculate the volume of the flue gas in m_n^3 per kg fuel

8. Producer gas combusts completely in a boiler with an air surplus of 20%. The gas composition per m_n^3 is 60% H_2, 38% CO and 2% CO_2. The higher heating value of 1 m_n^3 H_2 is 12 745 kJ and of CO 5476 kJ. The condensation heat of water at 25 °C: r = 2443 kJ/kg.
Calculate:
   a. The total flue gas volume in m_n^3.

b. The lower heating value of the fuel.

9. The volume percentage O_2 and CO_2 of the flue gasses of a gaseous fuel are measured at two combustor modes (figure 1).

Measurements	1st	2nd
O_2 vol%	6	8.5
CO_2 vol%	10	8

Figure 2

The measured percentages are valid for dry flue gas samples.

Calculate:

a. $CO_{2,max}$ of the first measurement.
b. Whether the O_2-content of the second measurement is correctly measured. If not, what should be the correct value?
c. The air factor of the first measurement. Here it can be said that $L_0/V_{0d} = 1$.

L_0 = theoretical air demand
V_{0d} = theoretical dry flue gas amount

Basic principles of combustion

Combustion chemistry

If the matter is a gas, 1 kmol of this gas has the volume of around 22.4 m_n^3 (normal cubic meter). The unit of volume, the normal cubic meter (m_n^3), is defined at a temperature of 273.15K and a pressure *p* = 1013.25 mbar.

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General combustion equations

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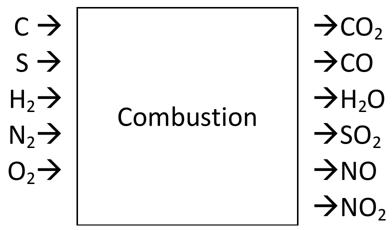

Figure 3: conversions in combustion

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1 kmol C + 1 kmol $O_2 \rightarrow$ 1 kmol CO_2

Written out in the mass equation:

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Because the volume of the gaseous components is 22.4 m_n^3 under normalised circumstances, the equation will be shown as follows:

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or for 1 kg C:

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and

$1\ kg\ S + 0.7\ m_n^3\ O_2 \rightarrow 0.7\ m_n^3\ SO_2$

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The reaction equation is:

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$$0.82\ m_n^3\ CH_4 + 0.82 \cdot 2\ m_n^3\ O_2 \rightarrow 0.82\ m_n^3\ CO_2 + 0.82 \cdot 2\ m_n^3\ H_2O$$

Thus, 1.64 m_n^3 O_2 is needed for this combustion. Furthermore, 0.82 m_n^3 CO_2 and 1.64 m_n^3 H_2O are produced.

Calculations of moisture content, ash content and heating values on various bases, assuming $W_m = W_{H2O} + W_{ash} + W_{daf}$

W_m = total weight
W_{H2O} = weight of water
W_{ash} = weight of ash
W_{daf} = weight of dry ash-free material

$$MC_w = \frac{W_{H_2O}}{W_{daf} + W_{ash} + W_{H_2O}} = \frac{W_{H_2O}}{W_{wm}}$$

$$MC_w = \frac{0.15}{0.80 + 0.05 + 0.15} = 0.15 = 15\%$$

$$MC_d = \frac{W_{H_2O}}{W_{daf} + W_{ash}} = \frac{W_{H_2O}}{W_{wm} - W_{ash} - W_{H_2O}}$$

$$MC_d = \frac{0.15}{0.80 + 0.05} = 0.176 = 17.6\%$$

$$MC_{daf} = \frac{W_{H_2O}}{W_{daf}} = \frac{W_{H_2O}}{W_{wm} - W_{ash} - W_{H_2O}}$$

$$MC_{daf} = \frac{0.15}{0.80} = 0.188 = 18.8\%$$

$$AC_w = \frac{W_{ash}}{W_{daf} + W_{ash} + W_{H_2O}} = \frac{W_{ash}}{W_{wm}}$$

$$AC_w = \frac{0.05}{0.80 + 0.05 + 0.15} = 0.05 = 5.0\%$$

$$AC_d = \frac{W_{ash}}{W_{daf} + W_{ash}} = \frac{W_{ash}}{W_{wm} - W_{H_2O}}$$

$$AC_d = \frac{0.05}{0.80 + 0.05} = 0.059 = 5.9\%$$

$$AC_{daf} = \frac{W_{ash}}{W_{daf}} = \frac{W_{ash}}{W_{wm} - W_{ash} - W_{H_2O}}$$

$$AC_{daf} = \frac{0.05}{0.80} = 0.063 = 6.3\%$$

$$HHV_{daf} = 20{,}400 \frac{kJ}{kg}$$

$$HHV_d = HHV_{daf} \cdot \frac{W_{daf}}{W_{daf} + W_{ash}}$$

$$= HHV_{daf} \cdot \left(1 - \frac{W_{ash}}{W_{daf} + W_{ash}}\right)$$

$$= HHV_{daf} \cdot (1 - AC_d)$$

$$= 20{,}400 \cdot (1 - 0.059)$$

$$= 19{,}196 \frac{kJ}{kg}$$

$$HHV_w = HHV_{daf} \cdot \frac{W_{daf}}{W_{daf} + W_{ash} + W_{H_2O}}$$

$$= HHV_{daf} \cdot \frac{W_{wm} + W_{ash} + W_{H_2O}}{W_{wm}}$$

$$= HHV_{daf} \cdot (1 - AC_w - MC_w)$$

$$= HHV_{daf} \cdot (1 - AC_d)(1 - MC_w)$$

$$= 20{,}400 \cdot (1 - 0.059)(1 - 0.15)$$

$$= 16{,}317 \frac{kJ}{kg}$$

$$LHV_{daf} = HHV_{daf} - [H]_{daf} \cdot 20{,}300 - MC_{daf} \cdot 2{,}260$$

$$= 20{,}400 - 0.06 \cdot 20{,}300 - 0.188 \cdot 2{,}260$$

$$= 18{,}757 \frac{kJ}{kg}$$

$$
\begin{aligned}
LHV_d &= LHV_{daf} \cdot \frac{W_{daf}}{W_{daf} + W_{ash}} \\
&= LHV_{daf} \cdot \left(1 - \frac{W_{ash}}{W_{daf} + W_{ash}}\right) \\
&= LHV_{daf} \cdot (1 - AC_d) \\
&= 18{,}757 \cdot (1 - 0.059) \\
&= 17{,}650 \frac{kJ}{kg}
\end{aligned}
$$

$$
\begin{aligned}
LHV_w &= LHV_{daf} \cdot \frac{W_{daf}}{W_{daf} + W_{ash} + W_{H_2O}} \\
&= LHV_{daf} \cdot \frac{W_{wm} + W_{ash} + W_{H_2O}}{W_{wm}} \\
&= LHV_{daf} \cdot (1 - AC_w - MC_w) \\
&= LHV_{daf} \cdot (1 - AC_d)(1 - MC_w) \\
&= 18{,}757 \cdot (1 - 0.059)(1 - 0.15) \\
&= 15{,}030 \frac{kJ}{kg}
\end{aligned}
$$

$$X_d = \frac{X_w}{(100 - MC_w)} \cdot 100\%$$

$$X_w = \frac{X_d}{(100 + MC_d)} \cdot 100\%$$

$$X_{daf} = \frac{X_d}{(100 - \alpha_d)} \cdot 100\%$$

$$X_w = \frac{X_d}{(100 + \alpha_{daf})} \cdot 100\%$$

$$Mass_{MC_2} = Mass_{MC_1} \frac{(100 - MC_1)}{(100 - MC_2)}$$

$$HHV_w = HHV_d \frac{(100 - MC_w)}{100\%}$$

$$LHV_{p,w} =$$

$$(HHV_{v,d} - 212.2[H^{non\text{-}H_2O}]_d - 0.775[O^{non\text{-}H_2O}]_d) \cdot \frac{(100 - MC_w)}{100\%} - 24.4$$

$$P = \frac{\Delta m_f \cdot B}{\Delta t}$$

$$\eta = \frac{Q_{water}}{Q_{fuel}} = \frac{m_s \cdot C_p \cdot (T_b - T_s) + m_v \cdot L}{m_f \cdot B}$$

10 Annex 5: Practikum at TEDC

Practical part: (1) at TEDC and (2) at SMK's in five regions of Casindo

Furnishing laboratory

A laboratory is needed to conduct experiments and perform analyses. Dependent on the availability at each SMK, a minimum set of requirements is needed. This includes lab-tables, fume hoods[2], chemicals, ovens, analytical balances, scales, etc. The laboratory at ITB will give some more ideas. The most relevant equipment must be considered for each region.

Possible tests during the training TEDC staff

- Moisture content
- Ash content
- Heating test-tube (tabung-reaksi) with biomass material and note the varying stages of drying, pyrolysis and gasification. Char (or charcoal) will be left in the end.
- Compaction or densifying like Agglomeration, Briquetting, Pelletizing
- Burning biomass in stove: difference between pyrolysis, gasification, combustion and carbonization
- Water boiling test and determining stove efficiency
- Collect different biomass resources and discuss the difference between them and their consequences for energy conversion
- Use simple briquetting press or extruder to densify biomass material. Determine bulk density before and after densifying.
- Prepare an open-fire outside of for instance wood. Ignite the wood and notice what happens (different stages of primary conversion). Discuss the results afterwards.
- Check on www.YouTube.com for various videos on all biomass related aspects and technologies. For instance, by the keyword "gasification" you will find many examples.

ISO or ASTM standards can be used for exact, accurate determination

Testing equipment

1. Bunsen burner
2. Stove for simple combustion tests
3. Press for making briquettes, pellets and oil extraction
4. Oil expeller for oil bearing biomass
5. "Garage-scale" biodiesel plant
6. Another useful equipment for testing could be a multi-purpose biomass conversion device, which can be used as carboniser, pyrolyser, gasifier, combustor and in different modes, i.e. fixed bed and fluid bed . There will be two installations based on the same principle but aiming a different purpose:
    - Cold flow model, an installation made of Perspex glass in which students can actually see the behaviour of the biomass under varying process conditions
    - cold testing of biomass for instance to determine the minimum fluidization velocity with different particle size

[2] A fume hood or fume cupboard is a type of local ventilation device that is designed to limit the user's exposure to hazardous or noxious fumes, vapors or dusts. A fume hood is typically a large piece of equipment enclosing five sides of a work area, the bottom of which is most commonly located at a standing work height.

- installation made of steel, surrounded by electrical heated oven, in which different products can be made (charcoal, gas, oil) using the different modes of operation.
  a. In carbonisation mode: determine char production
  b. In pyrolysis mode: determine oil yield
  c. In gasification mode: determine gasflow, gas can be burnt in gas engine or diesel engine (up to 80% gas and 20% diesel). For this, the renewable energy lab can cooperate with automotive department.
  d. In combustion mode: determine flue gas flow and composition, and efficiency

Laboratory equipment

1. Flue gas analyzer for measuring CO, O2, NOx, SOx, *CxHy*, HCl, temperature, etc. Cost depend on the amount of parameters to be measured but in the order of 500 to 1000 euro. Suppliers: Testo, Imbema, etc. But, such equipment can also be purchased in Indonesia
2. Analytical balance, accurate to 0.1 mg
3. Scale of 50 kg, with accuracy of 50 g (for bulk density)
4. Desiccator containing desiccant (for accurate moisture determination)
5. Ashing crucibles, 50 mL, porcelain, silica, or *platinum*
6. Convection drying oven, with temperature control of 105 ± 3oC (for moisture determination)
7. Ashing burner, ignition source, tongs, and clay triangle with stand
8. Muffle furnace, equipped with a thermostat, set to 575 + 10 °C (for ash determination)
9. Muffle furnace, equipped with a thermostat, set to 900 +/- 10 °C (for volatile matter content determination)
10. Fume cupboard (partly available)

Laboratory equipment but expensive

1. Analyses of all components of biomass: mass spectrometry. Data can be found in literature and data basis like www.ecn.nl/phyllis or http://www1.eere.energy.gov/biomass/analytical_procedures.html (this website contains also analytical procedures like international standards and other useful information). Another database is http://www.vt.tuwien.ac.at/Biobib/biobib.html
2. Gas chromatograph (GC)[3], for gas and/or tar analyses, also mobile (US$ 40,000)

Topics for the practical part include:

1. Biomass resources

   In each region, dedicated biomass crops can be grown for later usage in characterization, pretreatment and conversion. These can be
   - oil bearing plants, like rapeseed, sunflower, jatropha, EFB
   - agricultural crops and sugar/starch containing crops, like rice husk, rice straw, sugarcane bagasse, corn, soybeans, wheat
   - woody biomass like pine, willow, rubber wood, wood chips, sawdust
   - waste containing organic material like MSW, industrial waste
   - determine yield in ton ha per yr and energy in GJ per ha per yr. Compare to theoretical figures
   - conduct experiments to determine influence of fertilizers, water amount

[3] Gas-liquid chromatography (GLC), or simply gas chromatography (GC), is a common type of chromatography used in analytic chemistry for separating and analyzing compounds that can be vaporized without decomposition. Typical uses of GC include testing the purity of a particular substance, or separating the different components of a mixture (the relative amounts of such components can also be determined). Skilled personnel is needed for operation and maintaining the apparatus.

2. Biomass characterization:
   - determine moisture, ash, density, composition, heating value, volatiles, contaminants.
   - Discuss influence of morphology, density, ash, moisture on thermal conversion processes
3. Biomass pretreatment, for instance
   - storage, reception, handling (SRH)
   - briquetting, pelletising, agglomeration
   - sizing, sieving
   - carbonization: students can produce charcoal form the raw biomass grown under 1, which can then be subsequently used for conversion technologies
4. Biomass conversion technologies (biochemical and thermocemical processes)
   - Combustion: wood stoves (determine efficiency)
   - Combustion of biogas/producergas in gas and diesel engines
   - Combustion behavior under fixed bed and fluid bed conditions (minimum fluidization velocity, mixing behavior, etc.)
   - Fixed bed and fluid bed gasification (gas composition, tar sampling, efficiency determination, waste streams, safety related aspects)
   - Pyrolysis (oil yield, water content oil, pH determination of the oil, char content in the oil, ..)
   - Torrifaction (product yield, grindability of the product, product quality over time of exposure, …
5. Biomass utilization or application
   - Experiments can be done in second hand equipment like engines, steam turbines or boiler. Co-operation with automotive department can be considered
   - NO_x-formation at combustion
   - Emission measurements (dust/particles, CO, SOx, NOx, …
   - Efficiency determination
   - Product quality
   - Determination overall efficiency of the biomass-to-energy chain

ES&H Considerations and Hazards

- Use appropriate safety measures when handling open flame.
- When placing crucibles in a furnace or removing them, use appropriate personal protective equipment, including heat resistant gloves glasses, safety boots, CO indicator.

11 Annex 6: Notes on field visits

11.1 Some notes of visit to ITB, 24 February 2010

Outside the test facility building:
One fixed bed gasifier operating on wood, corn cobs and other agricultural waste residues. Downdraft type gasifier. The air amount to the gasifier is measured by an orifice plate (a pressure difference device). On top is a motor mounted, which drives a rotating shaft inside the reactor to secure an even bed distribution of the biomass material. The gas is first cleaned in a cyclone, next cooled in a condenser, then cleaned by a wet scrubber (the high small pipe) and finally by a fixed charcoal filter (the drum). The gas is flared but can also be used in the gas engine.

Left from this gasifier was a new dismantled gasifier. All parts were laying separately on the ground. On one of the photo’s you can see the air inlet holes above the restricted area; this is the oxidation zone. On another photo you can see a drain for condensate (tar and water condensate). If the gasifier operates well, there will be no liquids produced at this location, but there will be at start up when the installation is still cool or in case the gasifier operates not well.

Inside the test facility building:
Biodiesel and bioethanol test facilities
A reactor made of persplex to simulate the process at cold conditions.
The workshop shows also the typical room of a bioenergy workplace, which can be an example of the new renewable energy technology building at TEDC.
This building is characterized by:

1. a large entry door
2. a high two or three stage building
3. a partly second working floor
4. a separate room which acts as a office but could also be a control room
5. a separate storage room of biomass and/or chemicals.
6. the building was not ventilated optimal and can be approved
7. in the top is also a crane facility for heavy work.

In the laboratory:
Equipment and laboratory apparatus:
Fume hood with fan on the top
GC from Shhimadzu (costs 400 juta Rp)
Dessicator
Rotavapor
Orsat gasanalyser
Blowers, fans
Thermocouples and Pressure meters (U-tubes)
Catalytic tar cracking test equipment
Tar analyses using toluene
Metal washing table
Liquid gas vessels (N2, O2, He, Ar, H2)
First aid kit and shower (at the entrance) for safety

11.2 Some notes to visit Lemigas

The 10 t/d biodiesel pilot plant. The same principle is used as at ITB (transesterification of CPO [crude palm oil] with methanol with KOH as catalyst, see also presentation on biofuels), but the Lemigas plant was a more advanced pilot system. Somewhat between research plant (like at ITB) and a commercial industrial size plant. Clear is that to make CPO (the raw material in this case) needs several pretreatment steps before the actual reaction takes place. Also clear to notice is that a relative simple process of biodiesel production becomes quite complex at an industrial scale.

The 100 kg/d bioethanol was a typical research facility although a nice set-up. Steps involves fermentation, liquefaction, saccharification, distillation and condenser. Alone the fermentation process takes already 3 days. As I mentioned, the biological routes takes a number of days for conversion, while thermal routes take place in seconds to minutes. This is major difference for commercialization of technologies. My personnel opinion is that the traditional biochemical routes of biofuel production will never be able to compete to the thermal conversion routes with 2nd generation biofuels. Also note that Lemigas is investigating processes for 1st generation biofuels.

The micro algae process originates from the UK. The yield for one day is about 500 g, also rather low. Also note the amount of energy needed for the production process and the different fertilizers that needs to be added. The interest in Europe on algae is also very high, but there are many pessimists on the feasibility of such process, including myself.

11.3 Procedure for agglomeration

Use a cement mill and put the mill under a angle in such way that the charcoal is somewhere in the middle of the rotating drum
Insert the charcoal (start with the finest material first)
Add molasses by dropping slowly. Do not poor, but just dropping the liquid.
Mixture ratio is about 25% molasses and 75% charcoal (by weight)
If after some time the charcoal does not bind with the molasses add some more molasses, until the maximum of 25% is reached. If there are still no nicely ‘balls’ produced, it might be that the molasses is too thick (too viscous and in that case some small amount of water can be added). Maybe the amount of charcoal material is not sufficient, In that case add more charcoal and next more molasses.

When there are nicely agglo-briquettes are produced, put them in an oven at about 90 oC to allow them to dry and cure. After a few hours, you can test whether they are strong. If the quality is good, you can allow to drop the briquettes from 2 or meter height. They should not fall apart.

12 Annex 7: Units, conversion factors and some basics

Main components biomass

C	carbon
H	hydrogen
O	oxygen
N	nitrogen
S	sulphur
Cl	chloride
F	fluor

g	gram
ha	hectare
J	joule
kg	kilogram
kW	kilowatt
mg	milligram
MW	megawatt
ppb	parts per billion
ppm	parts per million
s	second
W	watt
yr	year

μ	micro
τ	residence time
λ	lambda = air factor
φv	volume flow (m3/s)
φm	mass flow (kg/s)

Abbreviations

BAT	Best available technology	PAC	Polycyclic aromatic carbons
BGP	Biomass gasifier plant	PPO	Pure plant oil
BtL	Biomass to liquid	RE	Renewable energy
CDM	Clean development mechanism	RES	Renewable energy sources
CHP	Combined heat and power	RET	Renewable energy technologies
EFB	Empty fruit bunches	SRC	Short rotation coppice
EfW	Energy from waste	SRF	Solid recovered fuel
GHG	Greenhouse gas	SVO	Straight vegatable oil
HHV	Higher heating value	V	Volume
IGCC	Intergrated gasification combined cycle	WID	Waste incineration directive
LHV	Lower heating value	WtE	Waste to energy
mc	Moisture content		

Websites:
http://www.onlineconversion.com/
http://scphillips.com/units/convfact.html

Parameters are defined and have units:

Velocity
Velocity = distance / time
V = m/s

Power
Power = energy / time
W = J/s

Heat of combustion
energy/mole of fuel (J/mol)
energy/mass of fuel (J/kg)
energy/volume of fuel (J/m3)

Concentration
Mass / volume (g/m3)

Mass flow
Volume / time (m3/s)
Mass / time (kg/s)