forebiom POTENTIALS FOR REALIZING NEGATIVE CARBON EMISSIONS

Pyrolysis: A sustainable way from Waste to Energy

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Outlines

- Energy, Consumption of Fossil Fuels
- Environmental Effects of Fossil Fuel Consumption
- Renewable Energy
- Biomass, Types, Advantegeous and Limitations
- Thermochemical Conversion Methods
- Pyrolysis
- Pyrolysis Parameters
- Bio-oil, Products from bio-oil
- Economic Aspects of bio-oil production
- Bio-char production
- Application of Bio-char
- The future

The situation of **ENERGY**

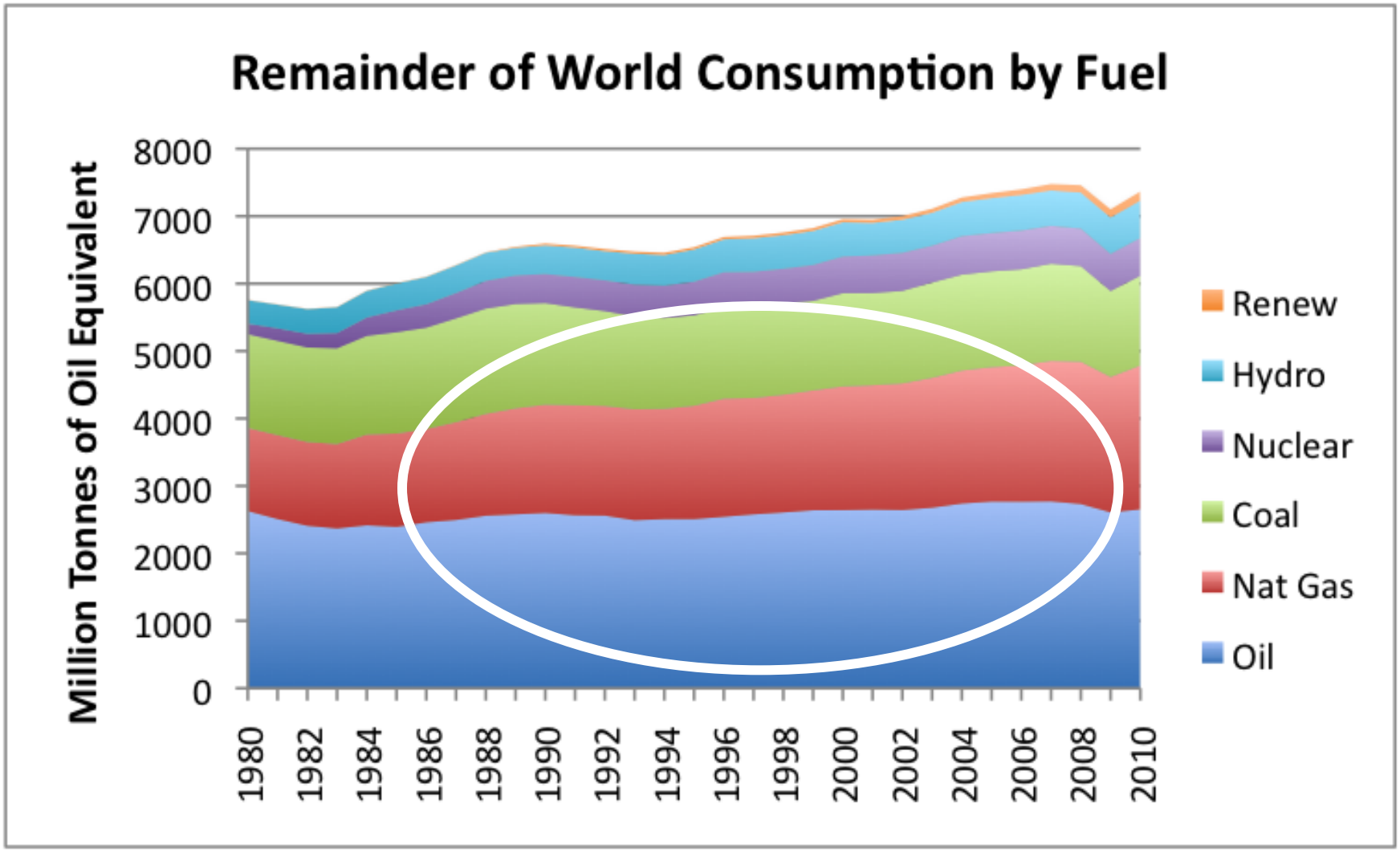
Demand for energy and its resources, is increasing continuously due to the rapid outgrowth of population and urbanization.

Present sources of energy are not sufficient to overcome the increasing needs.

The major energy demand is fulfilled from the conventional energy resources like coal, petroleum and natural gas.

The huge amount usage of fossil fuels creates environmental threads.

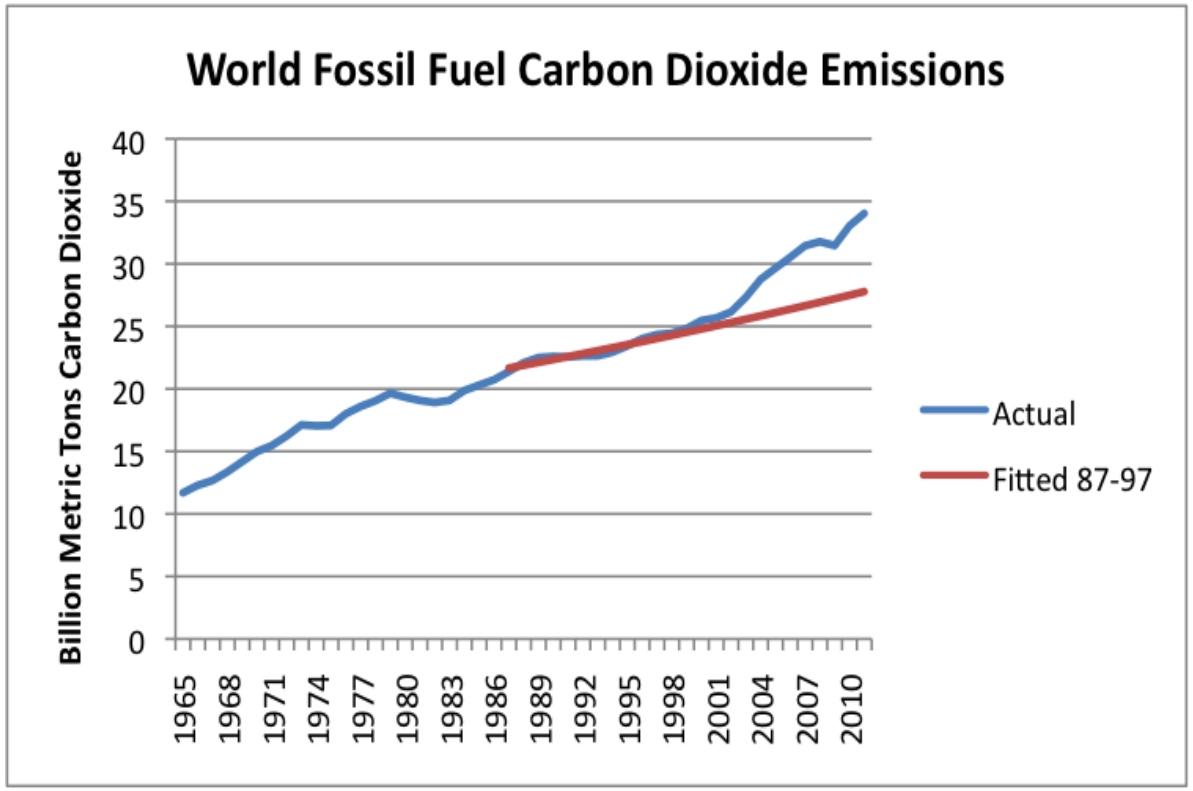
H.B. Goyal, Diptendu Seal and R.C. Saxena, *Renewable and Sustainable Energy Reviews*, *2008*, 504-517,Vol 12



More than 85 % of energy demands are supplied by fossil fuels.

http://ourfiniteworld.com/2011/11/30/thoughts-on-why-energy-use-and-co2-emissions-are-rising-as-fast-as-gdp/

Effects of **Fossil Fuel Consumption**



Actual world carbon dioxide emissions from fossil fuels, as shown in BP's 2012 Statistical Review of World Energy. Fitted line is expected trend in emissions, based on actual trend in emissions from 1987-1997, equal to about 1.0% per year.

Greenhouse Effect

Global Warming

Climate Change

http://ourfiniteworld.com/2012/09/17/the-close-tie-between-energy-consumption-employment-and-recession/

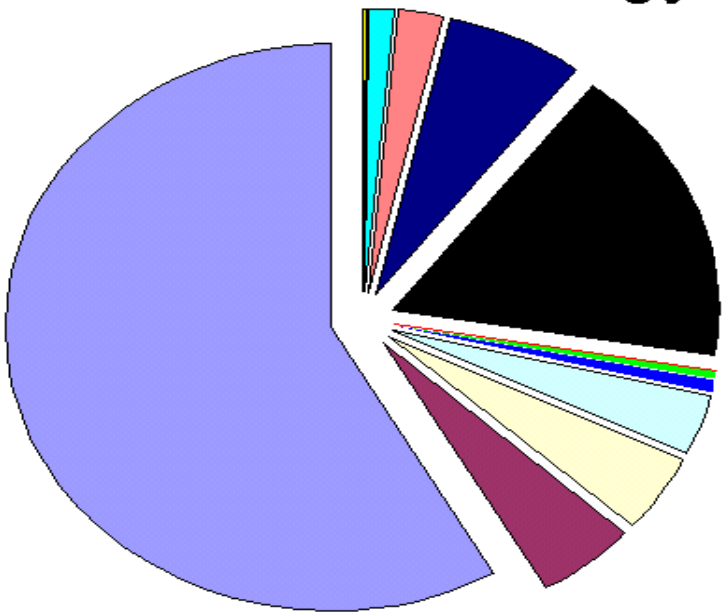
Renewable Energy

- BIOMASS
- GEO-ENERGY
- HYDROELECTRIC
- SOLAR
- WIND
- WAVE

A renewable energy system converts the nature energy (sun, wind, wave etc.) into a form we can use, such as heat or electricity.

Using renewable sources of energy promotes sustainable living due to being pollution free and economically feasible.

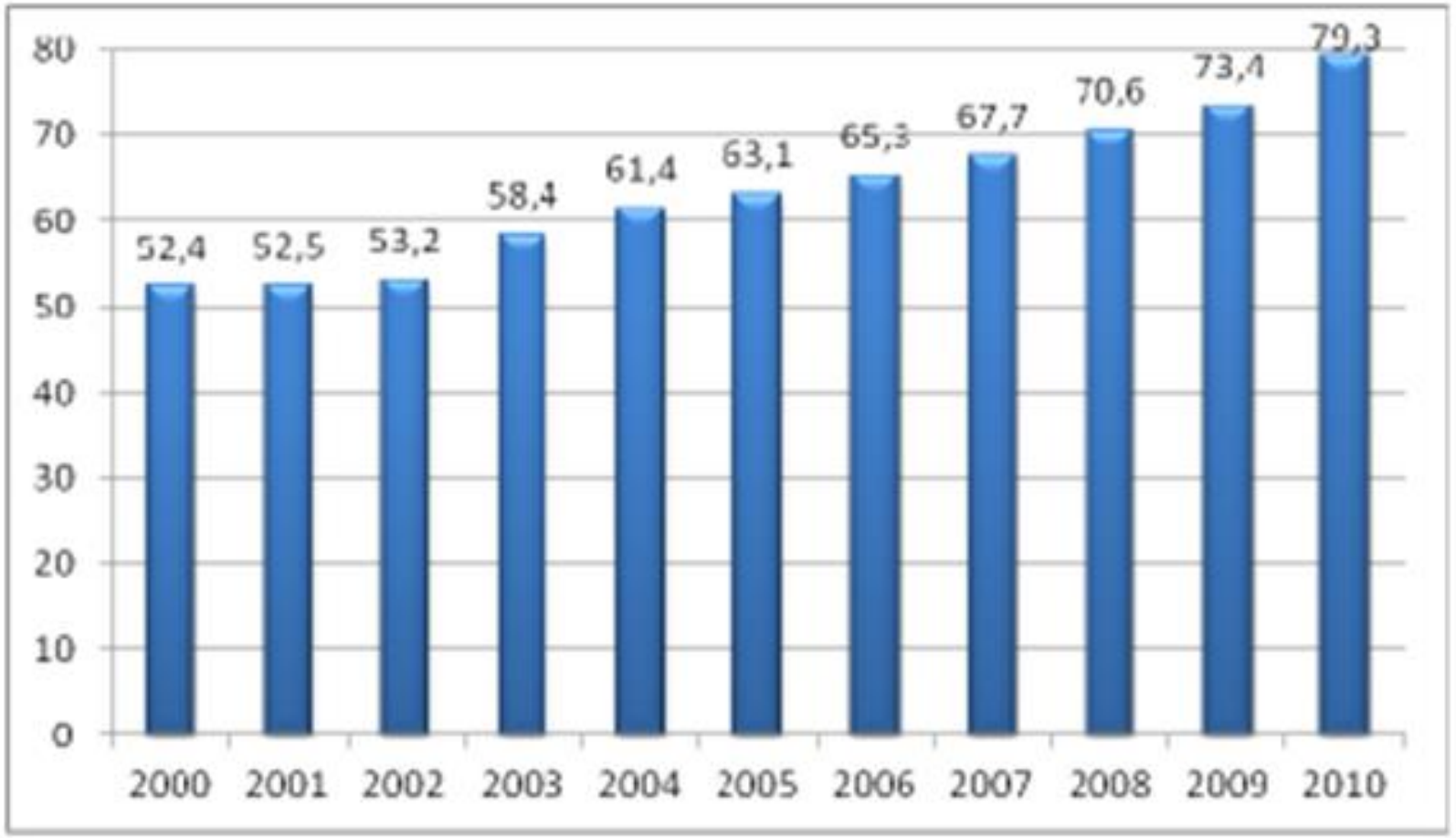
World Renewable Energy 2005



Large hydro 58.23%	Small hydro 5.12%	Wind power 4.58%	Biomass elec 3.42%
Geothermal elec 0.72%	Photovoltaic 0.42%	Other elec** 0.05%	Biomass heat* 17.08%
Solar heat 6.83%	Geothermal heat 2.17%	Biodiesel fuel 1.21%	Bioethanol fuel 0.16%

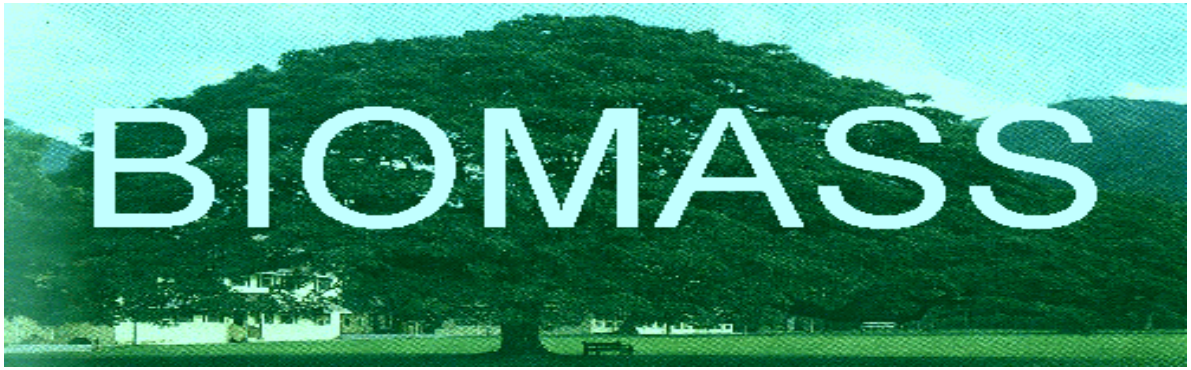
Approximately, 23 % of energy needs are supplied by biomass.

http://www.current2current.com/CURRENT2CURRENT_new_site/World_Renewable_Energy_2005.html



Solid biomass primary energy production for the EU since 2000 (in Mtoe)

http://www.biomassenergy.gr/en/articles/technology/biomass/901-increase-utilization-of-solid-biomass-in-europe



What is biomass?

All organic material produced by plants or any conversion process involving life is called biomass.

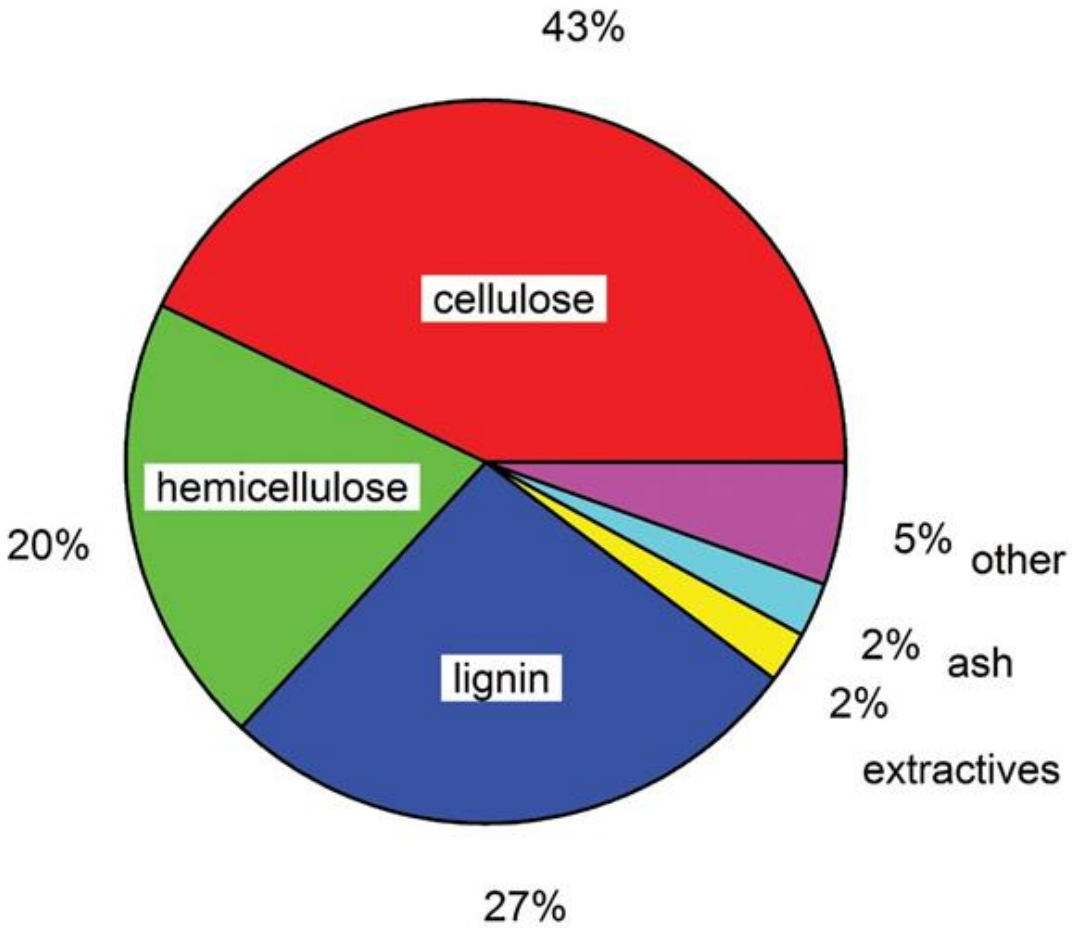
Biomass, also known as biofuels or bioenergy, is obtained from organic matter either directly from plants or indirectly from industrial, commercial, domestic or agricultural products.

Why Biomass?

Biomass is a green house gas emission neutral energy source!!

http://www.ecn.nl/biomassa/waarom.en.html

Biomass Composition



http://crf.sandia.gov/index.php/thermochemical-integration-key-to-improving-the-efficiency-of-bio-ethanol-production/

Types of Biomass

Forest Residues

Tree branches, tops of trunks, stumps, branches, and Leaves

Agricultural Residues

Primarily stalks and leaves, not harvested or removed from the fields, includes corn stover, wheat husk and rice straw

Industrial Waste

Citrus peels, sugarcane bagasse, milling residues,olive husks

Energy Crops

Switch grass, miscanthus, bamboo, sweet sorghum, tall fescue, kochia, wheatgrass, and others

Conversion Methods

Biomass can be converted into heat and electricity in a number of ways. Depending on its source, these processes include: combustion, pyrolysis, gasification, liquefaction, anaerobic digestion or fermentation.

Thermo-chemical processes convert biomass into higher-value or more convenient products. The process releases a gas (~6 MJ/kg), a liquid (~17-22 MJ/kg) and/or a char (~18MJ/kg), and depending on the technology one of these is the final product.

Mohan et. al, Energy & Fuels, Vol. 20, No. 3, 2006

Thermochemical Methods

Co-firing

Direct combustion

Liquefaction

Pyrolysis

Gasification

Pyrolysis

- Pyrolysis is a thermochemical decomposition of organic material at temperatures between 400 ° C and 900 ° C without the presence of oxygen or other reagents.
- The pyrolytic breakdown of wood produces a large number of chemical substances.
- Some of these chemicals can be used as substitutes for conventional fuels.
- The distribution of the products varies with the chemical composition of the biomass and the operating conditions.

A.V. Bridgwater et al. / Organic Geochemistry 30 (1999) 1479-1493

Slow Pyrolysis : Primarily to produce Char through Carbonization

Utilizes low temperatures around 400 ^{0}C over a long period of time to maximize char formation.

Product yields from slow pyrolysis are approximately

35% biochar,

30% bio-oil, and

35% gaseous products.

Rapid/Fast Pyrolysis : Primarily to produce Bio-Oil and Gas

-Biomass is very rapidly heated (~1000-10,000 ^{0}C/s) to a temperature around 650 ^{0}C-1,000 ^{0}C depending if bio-oil or gas products are desired.

-Product gases are quickly removed and quenched (t<2s)

Fast pyrolysis product yields are typically 50–70% bio-oil, 10–30% bio-char, and 15–20% syngas by mass.

Biomass must first be dried and ground to <2 mm particle size before entering a fast pyrolyzer.

Pyrolysis Parameters

- Biomass type and preparation of feeding
- Pyrolysis temperature
- Catalyst
- Sweeping gas velocity
- Particle size
- Reactor geometry
- Heating rate

Bio-Oil

Bio-Oil is not stable as conventional fuels.

- Highly oxygenated compounds
- High density
- High viscosity
- Low pH
- Low heating value
- CO_2 neutral
- No SOx and low NOx

Bio-Oil can be combusted directly in boilers, gas turbines and slow and medium speed diesels for heat and power applications.

Comparison of pyrolysis liquid and conventional fuel oil characteristics*

	Pyrolysis liquid	Diesel	Heavy fuel oil
Density kg/m^3 at 15°C	1220	854	963
Elementel Composition			
% C	48.5	86.3	86.1
% H	6.4	12.8	11.8
% O	42.5	---	---
% S	---	0.9	2.1
Viscosity cSt at 50°C	13	2.5	351
Flash point °C	66	70	100
Pour point °C	-27	-20	21
Ashwt.%	0.13	0.01	0.03
Sulphur %wt	----	0.15	2.5
Water %wt	20.5	0.1	0.1
LHV(MJ/kg)	17.5	42.9	40.7
Acidity	3	---	----

*Renewable and Sustainable Energy Reviews, 6 (2002) 181–248

APPLIED ANALYSES

Raw material

Drying, Grounding, Milling, sieving

Proximate Analysis

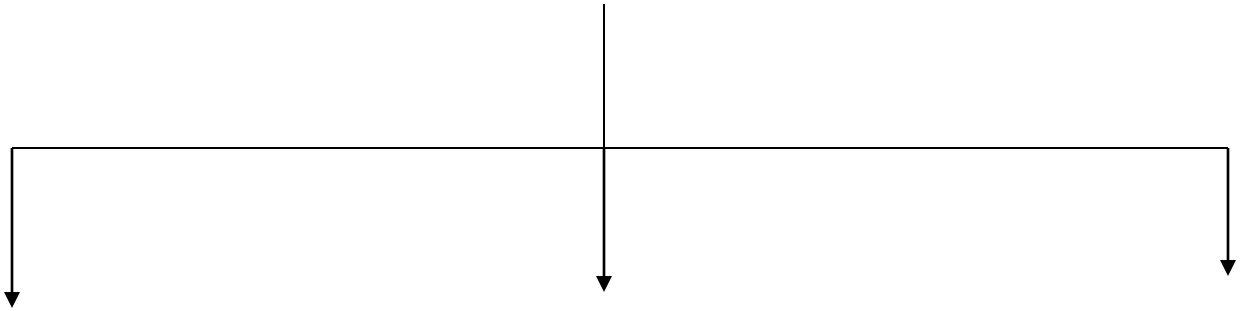
Ultimate Analysis

Content Determination

- Cellulose
- Hemicellulose
- Lignin
- Extractives
- Oil
- Protein

Thermal Analysis
To determine the thermal behaviour of the material or kinetic study

Analyses Applied on Products



Bio-oil

*Elementel analysis/ Bomb Calorimetry
*FT-IR
*H-NMR
*GC-GC/MS
*Adsorption Chromatography
*Karl Fischer titration-water separation
*ICP

Bio-Char

*Elementel Analysis/ Bomb Calorimetry
- FT-IR
- BET
- SEM
- C^{13}-NMR
- ICP

Gaseous product

*Bomb Calorimetry
*GC

Compositions of Products

Contamination of bio-oil

Acids, Esters, Alcohols, Ketones, Aldehydes, Phenols, Alkenes, Aromatics, Nitrogen compounds, Furans, Syringols, Sugars, Miscellaneous oxygenates Inorganics such as Ca, Si, K, Fe, Al, Na etc.

Composition of gaseous products

CO, CO_2 ,CH_4, H_2,propane, propylene, butane, butenes, C5, ethane, etc.

Composition of Char

Char contains elemental carbon along with hydrogen and various inorganic species.

BIO-CHAR

Biochar carbon-rich solid produced at low pyrolysis temperatures.

- process heat
- activated carbon
- soil amendment

http://www.biochar-international.org/sites/default/files/biochar_in_soils.pdf

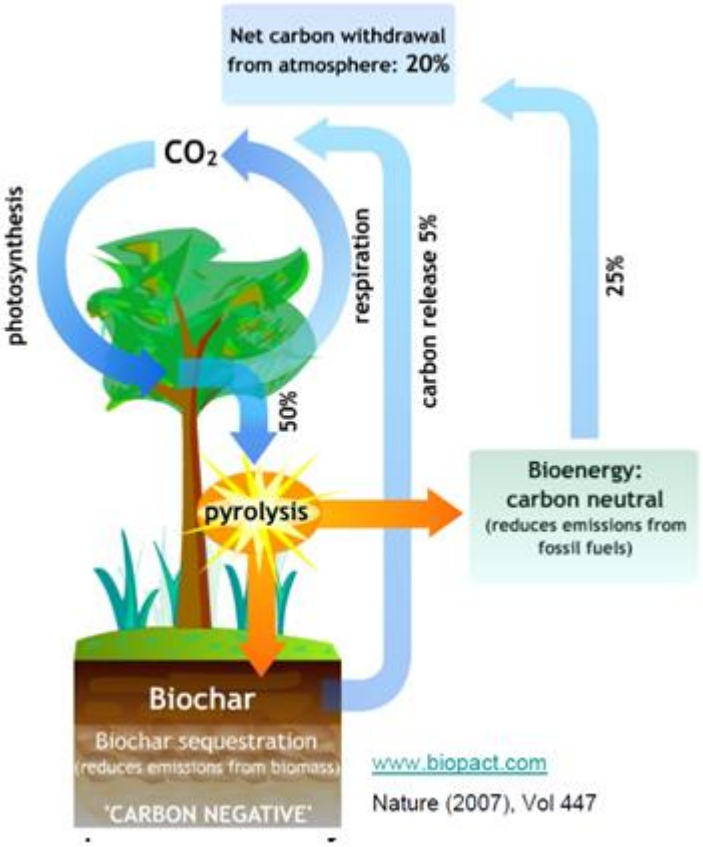
Negative carbon cycle

When biochar is stored in soils to make them more fertile, the biofuels carbon cycle is negative.

Application to the soil, in conjunction with bioenergy generation, can result in carbon sequestration.

Biochar is relatively stable that can be used to increase the soil organic contents of eroded areas.

Adding these materials may make a longer term impact on the soil productivity.



Ref: Alberta Biochar WorkshopOverview

FUTURE

Pyrolysis is considered to be one of the sustainable solution that may be economically profitable in large scales and minimise environmental concerns especially in terms of

Waste minimization

Carbon sequestration

Soil amendment

Energy/heat supply

Value added chemicals

Development of rural areas

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