

16. Thermal Energy: 2. Bioenergy

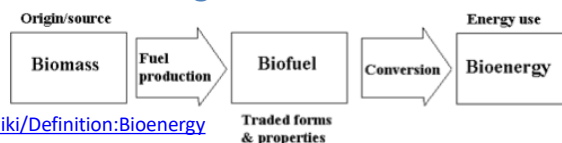
Fathi Anayah, PhD

Lecture 16



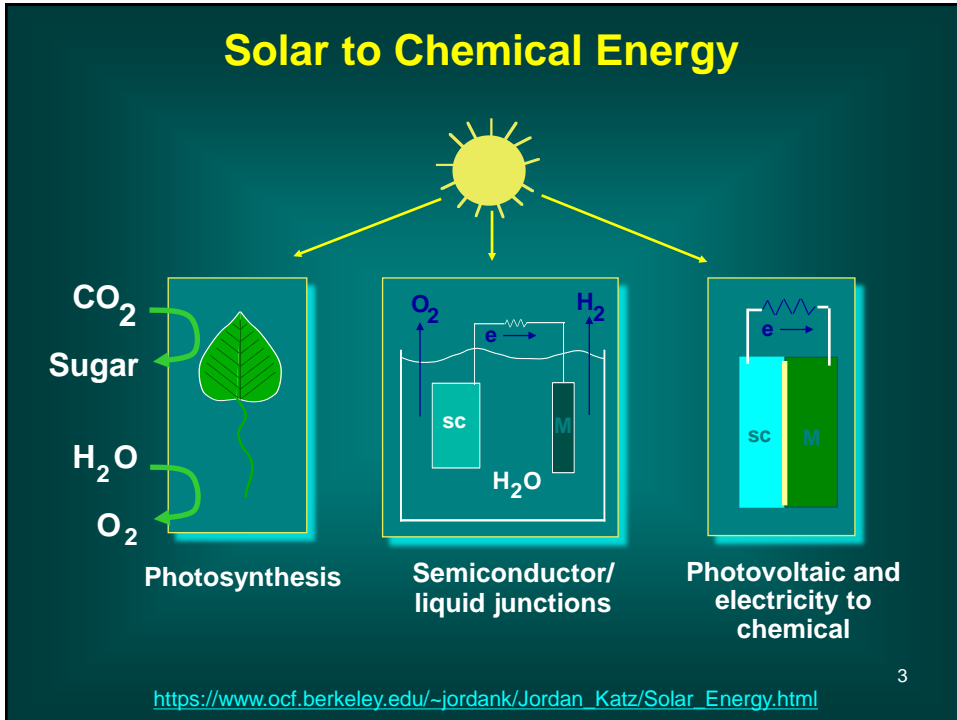
Definitions

- **Bioenergy** is renewable energy made available from materials derived from biological sources.
- **Biomass** is the material derived from recently living organisms, which includes plants, animals and their byproducts.
- **Biomass** is any organic material which has stored sunlight in the form of chemical energy.
- It may include **wood**, **wood waste**, **straw**, **manure**, **sugarcane**, and many other byproducts
- In its most narrow sense it is a synonym to **biofuel**, which is **fuel** derived from **biological sources**.



<https://openei.org/wiki/Definition:Bioenergy>

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Introduction

Biomass is material from living sources. The simplest biomass energy sources are **plants** which can be burnt to produce **steam** to turn a **turbine**.



Traditionally, **wood** is burnt to give **heat** but trees grow slowly and require a lot of land. Other materials such as the **waste** from **chicken farms** can also be burnt.

Biomass fuels are **renewable** as more **plants** can be **grown**, producing yet more biomass.

Biomass fuels do not contribute to **global warming** as the carbon dioxide **released** when they are burnt is **absorbed** by the **plants** grown to **replace** them.

http://bioblocks.weebly.com/uploads/8/7/0/6/8706802/notes_renewable_energy.pdf

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Biofuels - biogas

Some sources of biomass energy are further processed to produce more valuable **biofuels**.

Some **plants** can be **fermented** to give ethanol, a **biofuel**, which can be used instead of petrol or even **aviation fuel**, as in this plane!



Methane is **biogas** which can be used a replacement for **natural gas**. It is produced in **anaerobic digesters** by rotting **animal waste** and often found on **remote farms**, such as this digester on a pig farm.

http://bioblocks.weebly.com/uploads/8/7/0/6/8706802/notes_-_renewable_energy.pdf

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History of Bioenergy

- Historically, **biomass** has been the main source of the world's primary energy supply.
- In 1850, **85%** of the world's total primary energy supply was derived from **biomass** whereas, in 2005, **85%** of the world's supply was from **fossil fuels**.

Why Biomass?

- Biomass is a **flexible** energy source and, unlike some other sources of renewable energy such as wind and solar, can be **stored** and used as a fuel when required.
- Biomass is a **cost effective** way to deliver energy. Biomass is recovered from **negative cost sources**, such as biodegradable municipal waste, which also reduces the amount of waste disposed of in landfill sites.

<https://www.nationalgeographic.org/encyclopedia/biomass-energy/>

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What might the implications of biomass be?

- There is an ongoing **debate** regarding the potential for energy crops to displace food crops which could lead to **food shortages**, **higher prices** and increased levels of **hunger**, particularly in poorer countries and within vulnerable communities.
- This could be alleviated by utilizing marginal and degraded **land unsuitable** for annual food crops.
- Other concerns include the impact of **land use change** on **climate change**, **air quality** and **public health** issues arising from combustion plant emissions, lower energy density and variable quality compared with fossil fuels
- Security and sustainability of **feedstock supplies** is concerning in a globally competitive market, and the amount of **investment** required to alter the **energy infrastructure** to cater for biomass derived fuels.

<http://www.fao.org/3/a-i6583e.pdf>

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Pros and cons of biomass

Pros



- Renewable energy
- Carbon neutrality
- Energy Storing
- Abundant
- Less pollution
- Clean
- Cheap








Cons

- Biofuels controversy
- Storing cost
- Needs safe handling
- Highly inflammable
- Harmful emissions – nitrous oxide (N₂O) and methane (CH₄)

<https://www.energysage.com/about-clean-energy/biomass/pros-and-cons-biomass/>⁸

Differences between biofuel and fossil fuel	
Biofuel	Fossil fuel
Bio-fuel is produced directly from plant matter typically corn, sugar cane, sugar beets, or cellulose transforming it into alcohol.	Fossil fuels are produced by either the decomposition of plant or animal matter over long periods of time under certain conditions such as high temperature and pressure. Fossil fuels are coal, oil, and natural gas.
	
https://www.slideshare.net/smkxlr/biomass-energy-49378928	

Types of Biomass	
Wood remains the largest biomass energy source today; examples include forest residues . burning woods in order to produce electricity or heat energy.	 Wood fuel
Waste energy is the second-largest source of biomass energy. Rotting garbage, and agricultural and human waste, all release methane gas - also called "landfill" or "biogas."	 Rubbish
Crops , such as corn and sugar cane, can be fermented to produce the transportation fuel, ethanol.	 Alcohol fuels
	 Crops
	 Landfill gas
https://pontianakbiomass.wordpress.com/2011/10/17/what-is-biomass/	10

Where can Biomass be used?

1. Heat and Power

- Biomass can be combusted to produce heat (large plants or localized biomass boilers), electricity, or used in combined heat and power (CHP) plants.
- It can also be used in combination with fossil fuels (co-firing) to improve efficiency and reduce the build up of combustion residues.

2. Renewable Gas

- The two main sources of renewable gas are **biogas** and synthetic natural gas derived from biomass (bio-SNG or syngas).

<https://www.man-es.com/discover/decarbonization-glossary---man-energy-solutions/synthetic-natural-gas>¹¹

a. biogas

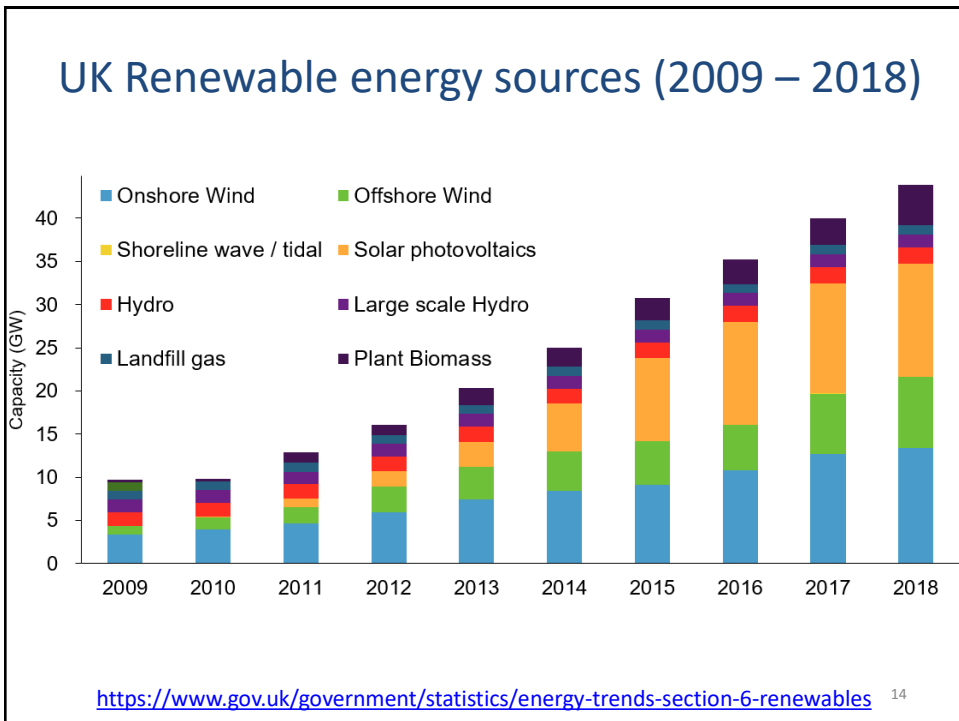
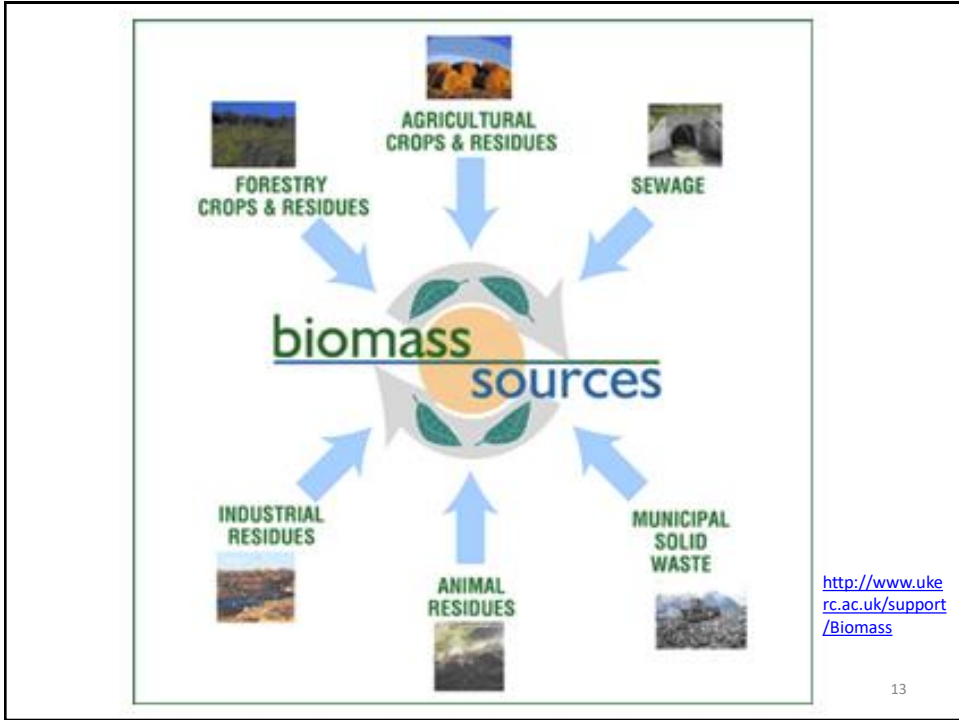
- Biogas is produced through a process of anaerobic digestion (AD), “the bacterial fermentation of organic material in the absence of free oxygen to produce a fuel gas.”
- It can also be produced at landfill sites (landfill gas) and at sewage treatment works (sewage gas).

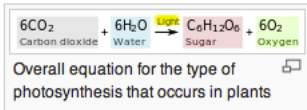
https://www.homebiogas.com/Blog/142/What_is_Biogas%7Cfq%7C_A_Beginners_Guide

b. syngas

- Syngas is the combustible gas created by the thermochemical process of gasification of biomass.
- This involves heating the material to a high temperature and allowing chemical reactions to occur forming a synthesis gas comprising hydrogen (H₂), carbon monoxide (CO), methane (CH₄) and carbon dioxide (CO₂).

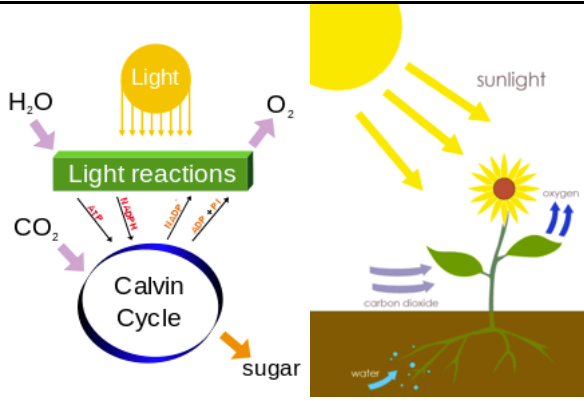
<https://worldbioenergy.org/uploads/Factsheet%20-%20Thermochemical%20gasification%20of%20Biomass.pdf>¹²



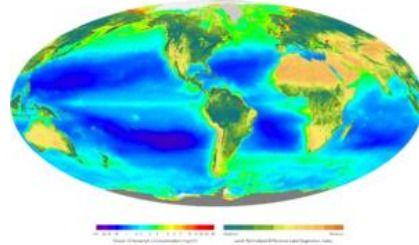


Biomass sources

- cycle of sunlight
 - photosynthesis
 - plant growth
 - absorption of CO₂
 - emission of O₂
- combustion of wood - heat
- some plants - alcohol
- decomposition - methane/landfill gas/fuel for heating

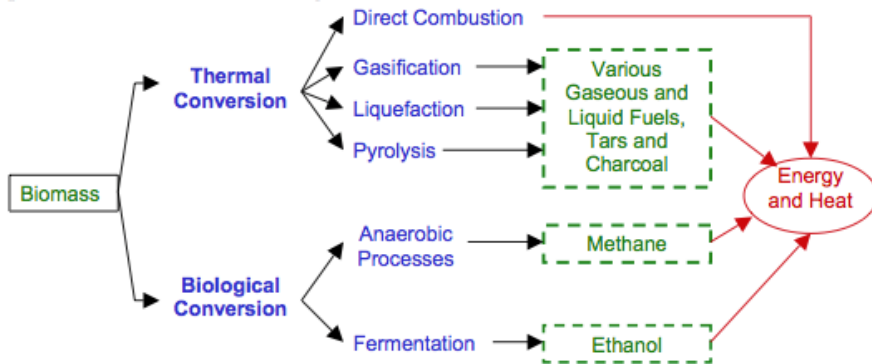


Global distribution of photosynthesis



Source: Renewable Energy PPT by Garth Ratcliffe

Converting biomass into bioenergy



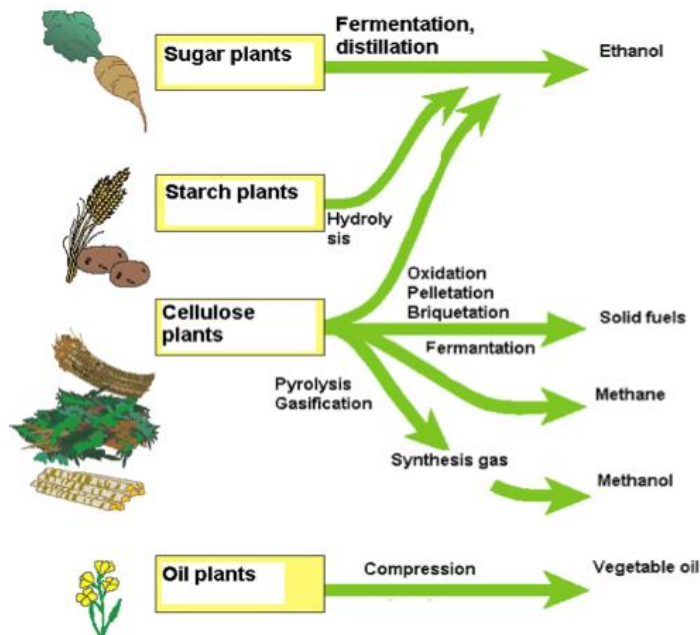
Conversion of Biomass Waste into Useable Fuel

- **Gasification:** Exposing a solid fuel to high temperatures and limited oxygen produces biogas.
- **Pyrolysis:** Heating the biomass can produce pyrolysis oil and phenol oil leaving charcoal.
- **Digestion:** Bacteria, in an oxygen-starved environment can produce *methane*.
- **Fermentation:** Bio-material that is used to manufacture *Ethanol* and Bio-diesel by an anaerobic biological process in which sugars are converted to alcohol by the action of micro-organisms, usually yeast.
- **Solid Fuel Combustion:** Direct combustion of solid matter.



<https://www.slideshare.net/PoonamSarawgi/biomass-updated>

Biomass-based raw material for energy conversion



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1. Biogas (Pyrolysis process)

- Getting energy out of biomass by burning it, turning it into a liquid or by turning it into a gas called bio gas.
- It contains about 65% of methane gas as a major constituents.



<https://www.slideshare.net/smkxlr/biomass-energy-49378928>

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2. Biofuel

- Biofuel (also called agro fuel) is a bioorganic fuel
- It is obtained by the fermentation of biomass
- The process by which micro-organisms break down into a complex organic substances generally in the absence of oxygen to produce alcohol and carbon dioxide is called (Fermentation)

Calorific value: is the amount of heat released by a unit weight or unit volume of a substance during complete combustion.

<https://www.slideshare.net/smkxlr/biomass-energy-49378928>

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Examples of Biofuel

Ethanol

- It is produced from sugarcane .Its CALORIFIC VALUE is less than petrol. It also less heat when compare to petrol.

Methanol

- It is easily obtained from ethanol .Its CALORIFIC VALUE is too low when compared to gasoline and diesel.

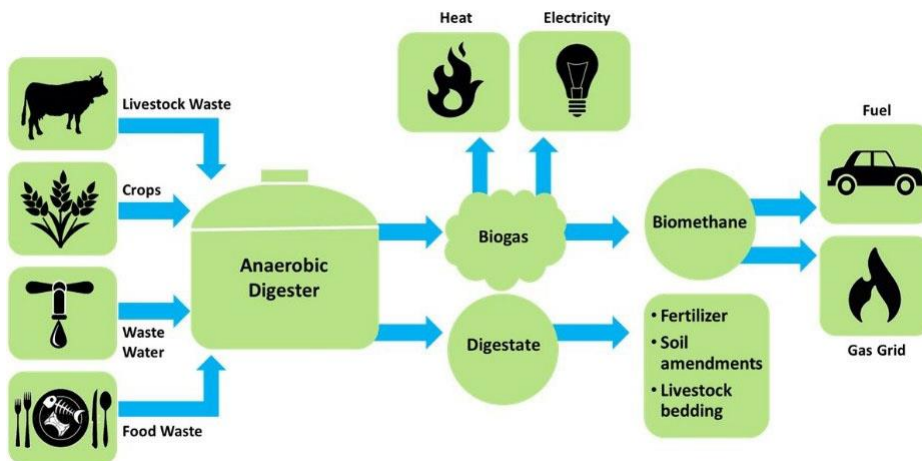
Gasohol

- It is a mixture of ethanol + gasoline .It is used in cars and buses.

<https://www.slideshare.net/smkxlr/biomass-energy-49378928>

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Anaerobic digestion process



<https://www.eesi.org/papers/view/fact-sheet-biogasconverting-waste-to-energy> 22

Woodburning Electricity Generation



ARBRE is the first commercial wood-burning plant of its type in Europe.

It produces enough electricity for 33,000 people from clean and sustainable wood fuel sources.

The plant has a 10MW electricity generating capacity and 8MW is exported to the local grid.

The fuel for the plant is wood chips from forestry and short rotation coppice.

Source: Renewable Energy PPT by Garth Ratcliffe

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Coppice harvesting



First
Renewables
Ltd

Short rotation coppice harvesting for ARBRE wood-fuelled power station. As trees grow they store energy from the sun in their biomass. At ARBRE's power plant the energy stored in the biomass is converted to electricity.

Source: Renewable Energy PPT by Garth Ratcliffe

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Straw Burning Power Plant



Lorry leaving
plant after
delivering straw

Elean Power station near Ely, Cambridgeshire generates 36MW of electricity and is the worlds largest such facility. It supplies 80,000 homes with electricity.

Source: Renewable Energy PPT by Garth Ratcliffe

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Biomass Plant in Fife



Plant burns poultry
litter and produces
10MW of electricity
and fertiliser



Fluidised bed boiler
ensures efficient burning
and low emissions

Source: Renewable Energy PPT by Garth Ratcliffe

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Landfill Gas



1MW generator at
Buckden - Biogas
Association



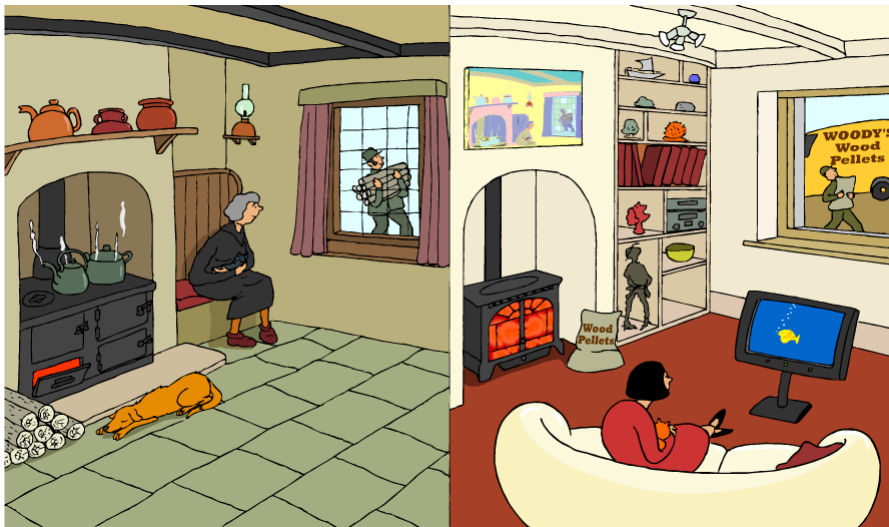
Landfill gas, Dorset

Source: Renewable Energy PPT by Garth Ratcliffe

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The then and now guide to biomass

How has the use of biomass changed over time?



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