BIOMASS ENERGY

"Biomass" means any plant-derived organic matter available on a renewable basis, including dedicated energy crops and trees, agricultural food and feed crops, agricultural crop wastes and residues, wood wastes and residues, aquatic plants, animal wastes and municipal wastes. **Biomass is stored solar energy.**

Topics - Biomass Energy

- What is Biomass?
- Biomass Resources
- Biomass Technologies (Bio-Power, Bio-Fuels)
- Examples of Bio-Fuels & Biomass Technologies
- Global Carbon Cycle
- Bio-Power Technologies (Direct Combustion, Co-firing, Pyrolysis, Anaerobic Digestion, CHP)
- Cost of Biomass Fuel, Liquid Bio-Fuels & Power
- Benefits from Biomass & Wastes
- Environmental Impact & Risks

Biomass Resources

- **Herbaceous energy crops –**harvested annually 1-3 years after planting: switchgrass, miscanthus (elephant grass), bamboo, sweet sorghum, kochia, wheatgrass, cogon, etc.
- **Woody energy crops –**fast growing hardwood trees harvested 5-8 years after planting: hybridpoplar, hybrid willow, silver maple, eastern cottonwood, green ash, black walnut, sweetgum, sycamore and ipil-ipil.
- **Industrial crops –** grown to produce specific chemicals and materials: kenaf and straws for fiber, castor for ricinoleic acid, transgenic crops to produce desired chemicals.
- **Agricultural crops –** commodity products like corn starch, corn oil, soybean, wheat starch and vegetable oils (coconut).
- **Aquatic crops -** aquatic biomass: algae, giant kelp, seaweed, marine microflora that find commercial use.

Biomass Resources (2)

- **Agriculture crop residues –** residues after harvesting main crop: corn stover (stalks, leaves, cobs), wheat and rice straw, sugar cane bagasse.
- **Forestry residues –** biomass not removed from logging sites and materials from forests like dead and dying trees.
- **Municipal waste –** residential, commercial and institutional post-consumer wastes with plant-derived organic material: waste paper, cardboard, wood and yard waste.
- **Biomass processing residues –** processing of biomass yields by-products and waste streams called residues: sawdust, bark, branches, leaves, needles and wood/pulp wastes.
- **Animal wastes –** farms and animal processing wastes that contain organic materials with environmental consequences: cow, pig, chicken and fowl manure.

Biomass Technologies

- **Bio-power –** proven generation technology, with 18 GW of installed global capacity [1995] based on mature direct-combustion technology.
- **Bio-fuels –** fuels made from biomass resources: ethanol, methanol, bio-diesel (coconut oil-diesel blend, CME or coconut methyl ester), and gaseous fuels like hydrogen and methane.
- **DME** or dimethyl ether produced from methanol can be used as ultra-clean fuel for gas turbines and diesel-fed automotive engines.
- Annual global production is over 10 million MT/year of bio-fuels

Biomass Technologies (2)

- **Bio-based Chemicals and Materials –** green chemicals, renewable plastics, natural fibers and natural structural materials (particle boards).
- **Integrated Bio-energy Systems –** a biomass-based system that makes use of the infinite carbon cycle (combustion and photosynthesis). With this system powered by solar energy, the world would have an inexhaustible supply of carbon fuel. It also mitigates global warming by grabbing CO_2 from atmosphere during photosynthesis.

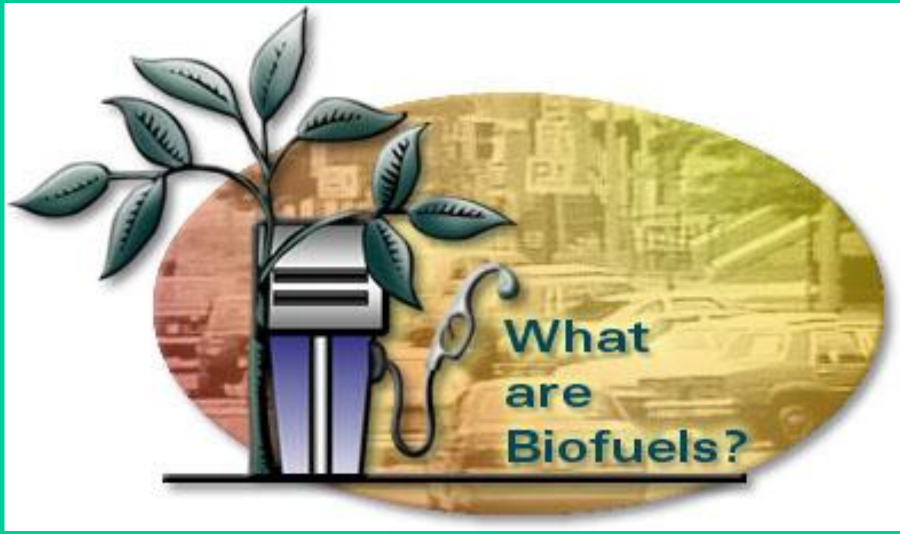
combustion

C (biomass) + O_2 (air) ➔ CO_2 + energy (heat)

photosynthesis

CO_2 (air) + energy (sunlight) + plant life (leaves) ➔ C + O_2

Examples of Bio-Fuels



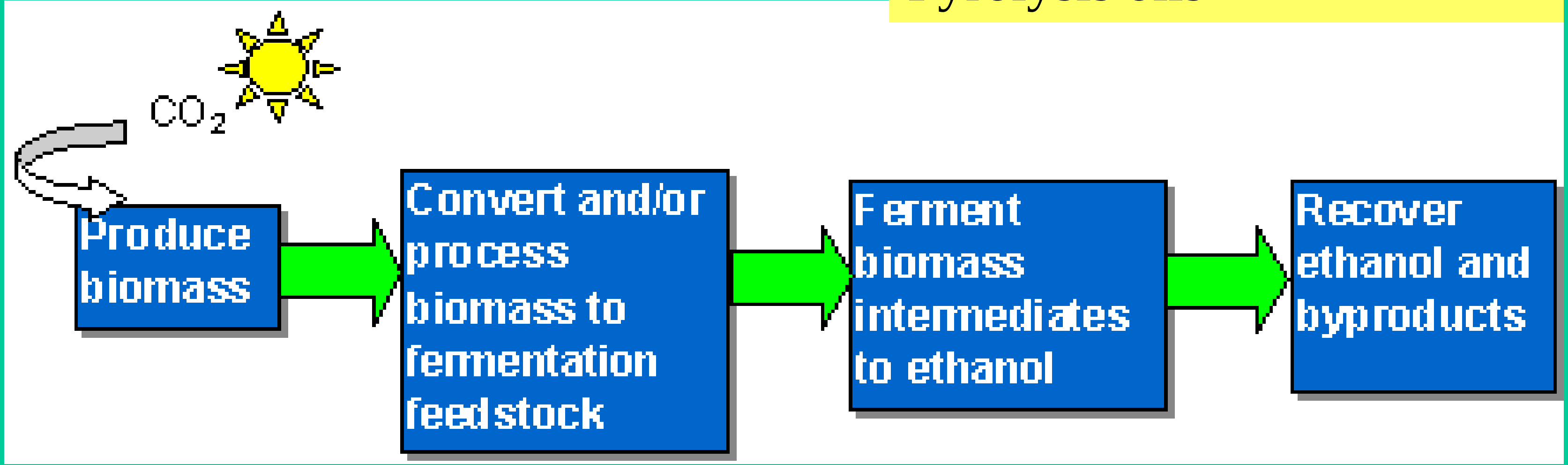
Alcohols (bio-methanol, bio-ethanol)

Ethers

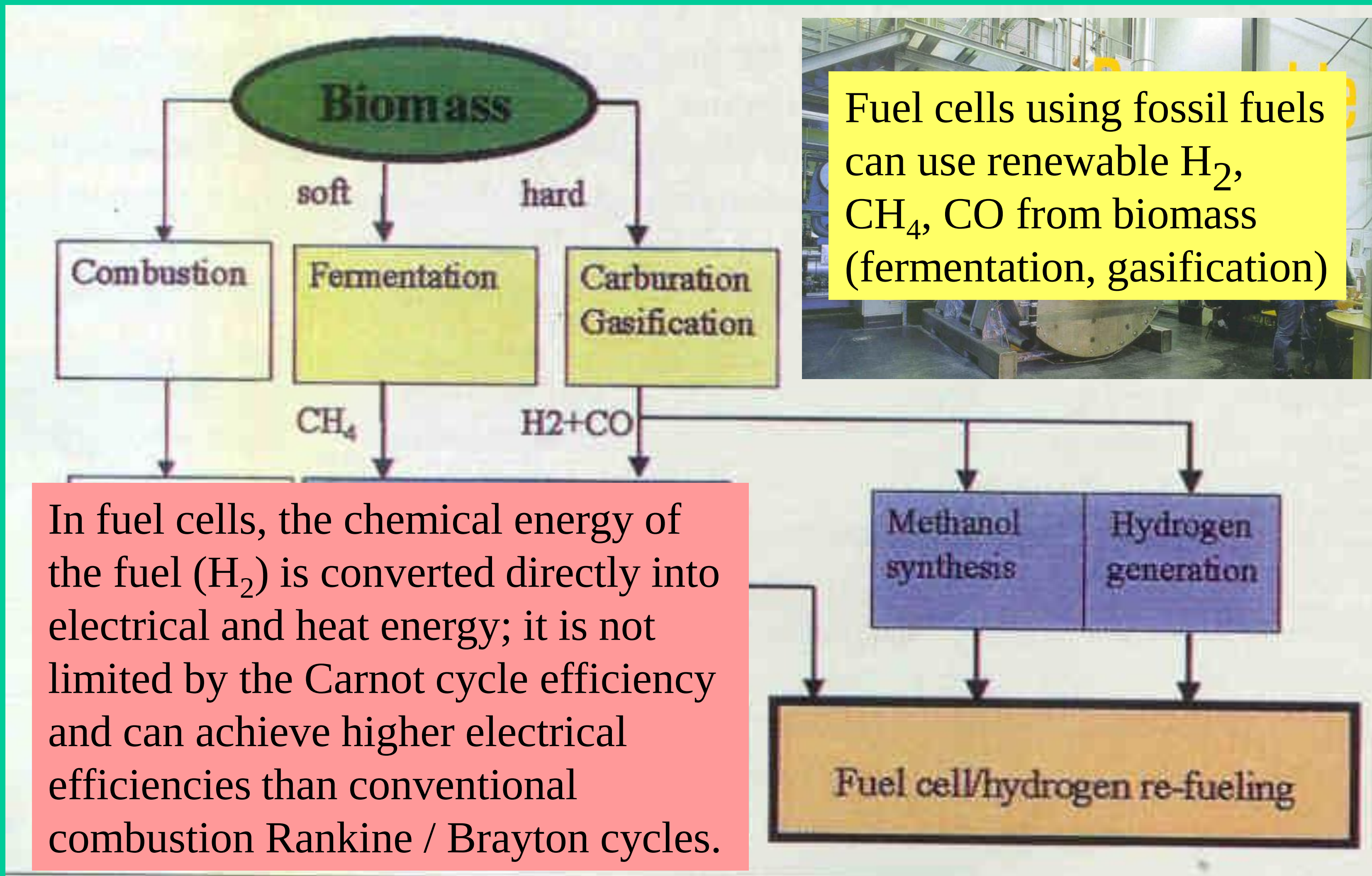
Esters (ethyl, methyl)

Bio-diesels (coconut, CME)

Pyrolysis oils



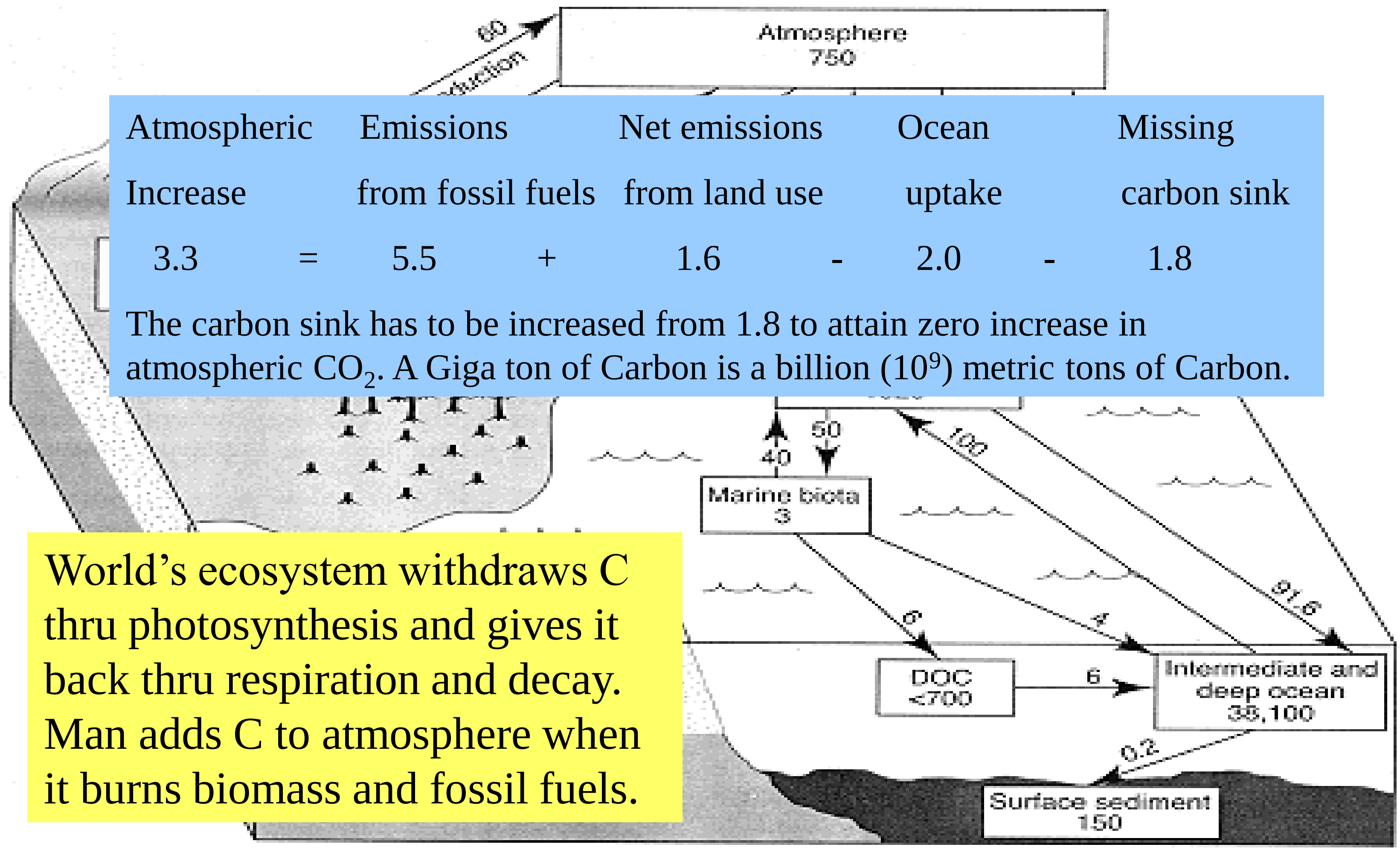
Renewable Fuel Cell Power from Biogas



Fuel cells using fossil fuels can use renewable H_2, CH_4, CO from biomass (fermentation, gasification)

In fuel cells, the chemical energy of the fuel (H_2) is converted directly into electrical and heat energy; it is not limited by the Carnot cycle efficiency and can achieve higher electrical efficiencies than conventional combustion Rankine / Brayton cycles.

Global Carbon Cycle



Atmospheric Increase		Emissions from fossil fuels		Net emissions from land use		Ocean uptake		Missing carbon sink
3.3	=	5.5	+	1.6	-	2.0	-	1.8

The carbon sink has to be increased from 1.8 to attain zero increase in atmospheric CO_2. A Giga ton of Carbon is a billion (10^9) metric tons of Carbon.

World's ecosystem withdraws C thru photosynthesis and gives it back thru respiration and decay. Man adds C to atmosphere when it burns biomass and fossil fuels.

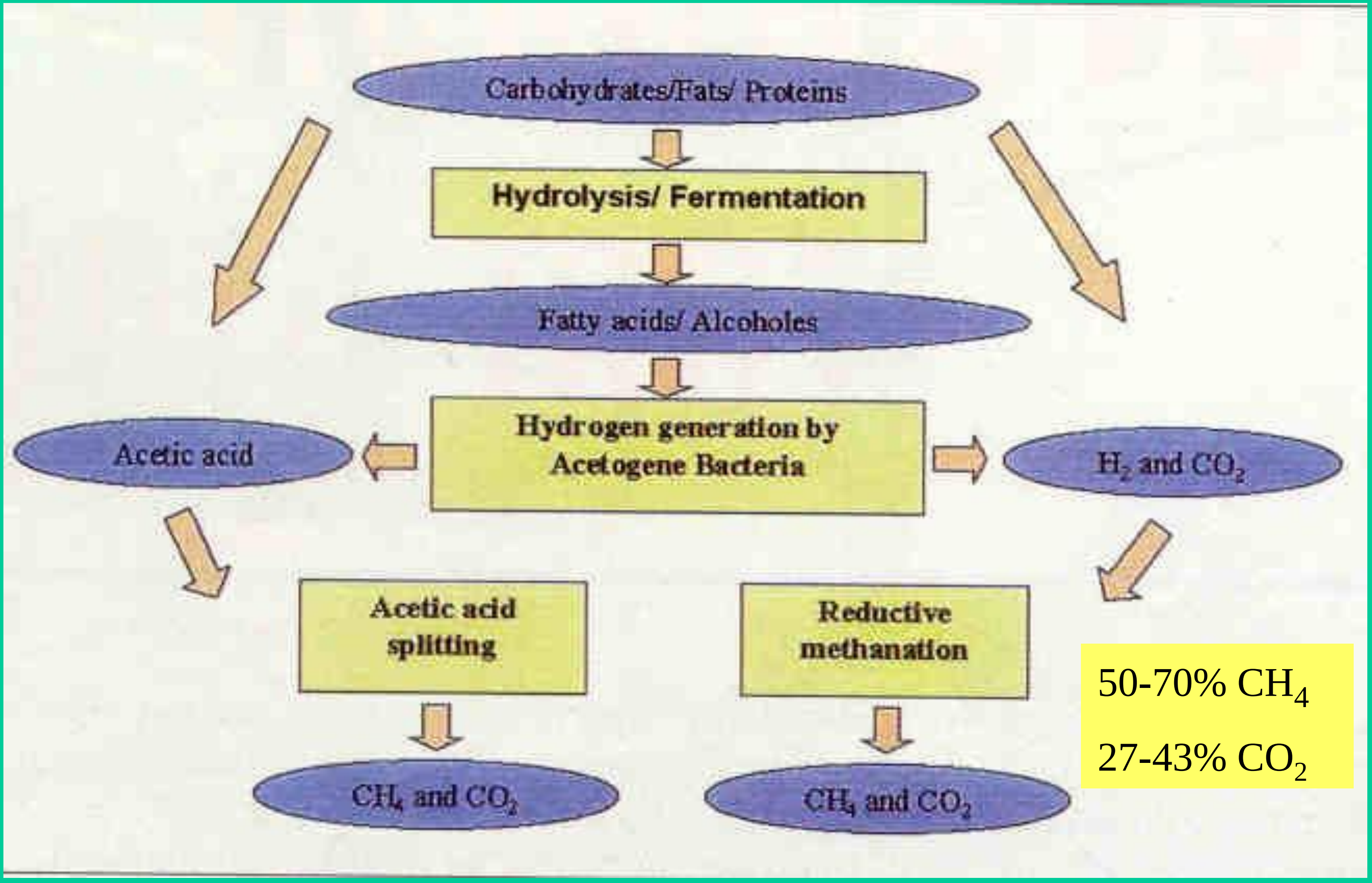
Bio-Power Technologies

- **Direct combustion –** burning of biomass in excess air, producing hot flue gases that are used to produce steam in a boiler, steam drives turbine generators to produce electricity
- **Co-firing –** practice of introducing biomass in high-efficiency coal fired boilers as a supplementary energy source; been evaluated for pulverized coal, fluidized bed and spreader stokers
- **Renewable fuel cells –** hydrogen may be obtained from biomass and fed to fuel cells to produce power, heat and water
- **Gasification –** biomass gasification for power production involves heating biomass under oxygen-deficient conditions to produce a medium or low calorific gas. The “biogas” is then used as fuel in a combined cycle power plant with gas turbine and steam turbine cycles.

Bio-Power Technologies (2)

- **Pyrolysis –** process where biomass is exposed to high temperatures in the absence of air/oxygen, causing the biomass to decompose into combustible end-products: liquids (oxygenated oils), gases (CH_4, CO, CO_2) and solids (char)
- **Anaerobic digestion –** organic matter is decomposed by bacteria in the absence of oxygen to produce CH_4 and other by-products
- **Combined heat and power (CHP) –** much of today's bio-power is provided by CHP, also called cogeneration, which achieves high efficiencies by generating power and excess heat from the burning of biomass for other uses like district heating and industrial processes of pulp and paper plants

Anaerobic Fermentation



50-70% CH_4

27-43% CO_2

Cost of Biomass Fuel

- Economics of using biomass for electricity generation depends much on the delivered cost of biomass feedstock from a plantation developed to grow fuel.

Source Country	Cost $/GJ	GHV btu/lb	GHV GJ/MT	Moisture %	Cost $/MT
Brazil (north-west)	0.97 - 4.6	4299	10	55.0	9.7 - 46
China (south-west)	0.60	4299	10	55.0	6
Hawaii	2.06 - 3.2	4299	10	55.0	20.6 - 32
Philippines	1.25	3439	8	50.0	10
Portugal	2.30	4299	10	55.0	23
Sweden	4.00	4299	10	55.0	40
US	1.9 - 2.8	4299	10	55.0	19 - 28
Coal	2.00	11608	27	7.9	54.0
BTU/LB = MJ/KG * 1000 / (1.05506 * 2.2046) =				429.9253	
MJ/KG = BTU/LB * (1.05506 * 2.2046) / 1000 =				0.002322	
$/MT = $/GJ * GJ/MT =					

Cost of Liquid Bio-Fuels

- Biomass is also used to produce liquid fuels, primarily for use in piston engines. Ethanol may be produced by fermentation of either grain or sugar. In US, 5% of grain crop (corn) is converted into ethanol and used as fuel additive to raise octane. Vegetable oils may be blended or further processed to produce bio-diesel for transport and power generation.

Fuel	Production 10^9 liters/yr	Capital Cost $/liter	Delivered cost, $/liter
ethanol	81	0.06 - 0.13	0.24 - 0.37
bio-diesel (canola, soy)		0.07 - 0.10	0.40 - 0.52
methanol			
coco diesel			
CME			
DME			

Cost of Bio-Power

- Bio-power plants tend to be smaller than coal-fired power stations with boiler sizes around 50 MW, since it would be economic to transport the fuel over short distances only.

Plant Type	Biomass Portion, %	Capacity MW	Capital Cost $/kW	Fixed O&M $/kW/yr	Variable O&M $/kWh	Efficiency %	Fuel Cost $/GJ	Levelized $/kWh
Biomass in general			1,476	43.0	0.520			0.058 to 0.116
Direct Combustion		50	1,900			23	1.00	0.05
Co-firing with coal	10% straw	150						
Biomass gasification		100 kW 30 MW	1,300			35	2.80	0.05
Pyrolysis								
Combined Heat & Power								

Cost of Waste-Power

- Amount of wastes produced in developed countries was estimated by IEA to be 426 million MT/yr, a potential output of 191 TWh/year.
- Landfill gas leaks out an equal mixture of CH_4 and CO_2. Global potential is 13,000 MWh in 1995.

Plant Type	Economic Lifetime, yrs	Fuel Composition	Capacity MW	Capital Cost $/kW	Fixed O&M $/kW/yr	Variable O&M $/kWh	Efficiency %	Levelized $/kWh
Municipal Waste				5,289	0.0	0.540		
Landfill gas	10 - 20	40-60% CH4		630 1,170			26 GT 42 CI	0.04 - 0.06
Anaerobic digestion		65% CH4 35% CO2	100 kW 1 MW CI					0.02 - 0.14
Sewage digestion				5,600				
MSW combustion			50 MW 100 MW	5,000 10,000				0.02 - 0.14
Refuse-Derived Fuel								

Benefits from Biomass & Wastes

- **Biomass is a renewable fuel and is environmentally benign - ** carbon burnt did not come from fossil fuels but from atmospheric CO_2 during photosynthesis; mitigates global warming.
- **Gasifier-fuel cell -** results in net CO_2 reduction because of the higher efficiency of fuel cell and being CO_2-neutral; can be the carbon sink needed to avoid global warming
- **Solves waste disposal problem –** burning of agricultural and municipal solid wastes reduces the garbage dumped into sanitary landfill
- **Perennial plants will stabilize land –** reduce soil erosion when planted in barren lands dedicated to energy plantations
- **Mitigates acid rain -** biomass does not contain sulfur unlike fossil fuels; does not emit SO_2; minimize respiratory illness and corrosion in buildings.

Environmental Impact

- Combustion of waste **kills pathogenic organisms** and **reduces the volume of garbage** to be dumped into the sanitary landfill.
- **Trace quantities of organic chemicals** and **toxic substances** may be released by the flue gas into the atmosphere like **dioxin and heavy metals** during combustion.
- Waste segregation and recycling is needed to reduce by 30-40% the waste volume. Removing **plastics and PVCs** before combustion also avoids dioxin emissions.
- After combustion, only ash (about 10% of original waste) would be disposed in the smaller **sanitary landfill**
- The inert ash dumped into the sea has **reclaimed valuable land** for future public use in Tokyo and New York. However, about 20 years is needed to stabilize the land for safe use.

Risks with Biomass Energy

- **Landfill gas -** power from landfill gas represents the *lowest political risk*. CH_4 is a potent greenhouse gas and its combustion is an environmentally positive procedure; main risk is associated with the **lifetime of the landfill gas supply** since it depends on the organic quality of the waste.
- **Anaerobic fermentation** - of municipal sewage and farmyard wastes has *low risk* and a positive disposal strategy since it treats the pathogenic wastes and derives "biogas" or CH_4 fuel for power generation and heat.
- **Direct combustion of biomass fuels –** the logistics of gathering biomass in a *rate sufficient for steady plant operation is a risk*; co-firing biomass in efficient coal-fired power station so that proper blending of biomass and coal will result in uniform heating value conducive to stable plant operation.