Plants species from different Agro-Ecologies and Forestry System for Bioenergy – an Overview

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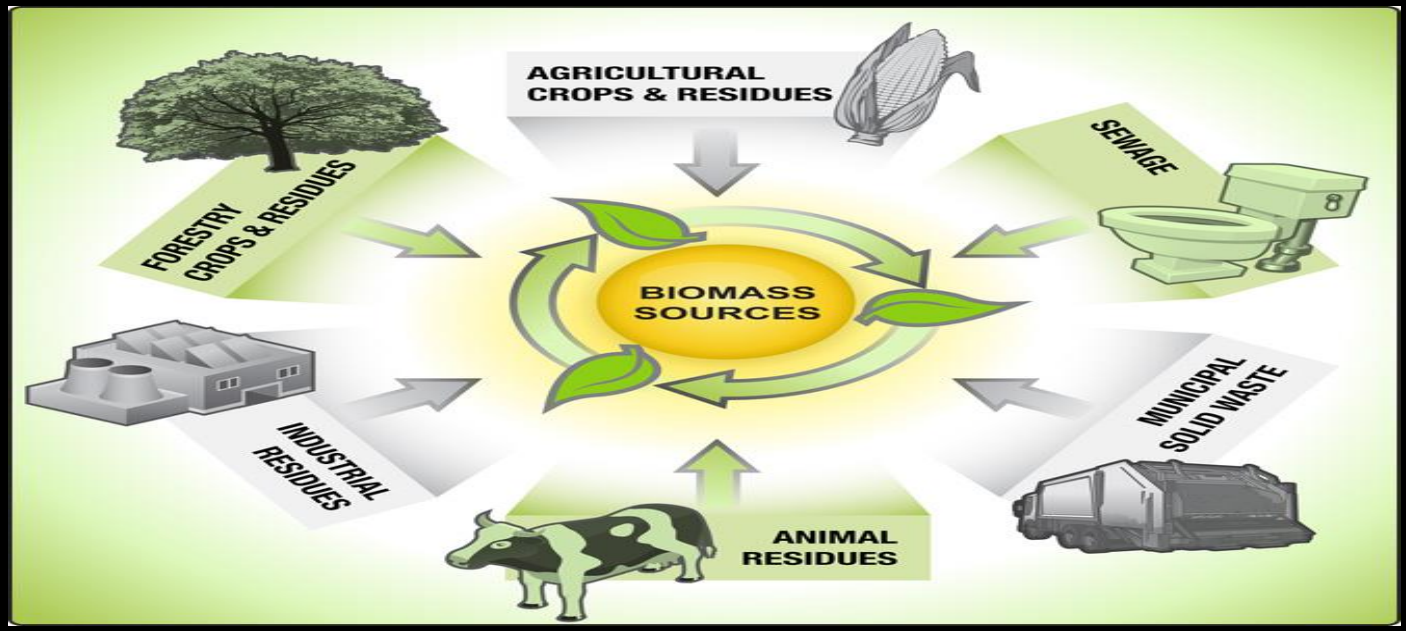
INTRODUCTION

- Energy is a vital element for development.
- Post oil crises shifted the focus of energy planners towards renewable resources and energy conservation.
- Plant biomass account for 75% energy in rural India
- Bioenergy ⟶ Sun ⟶ Photosynthesis
- Biomass energy comes from Photosynthesis that converse sun energy to bioenergy
- Biomass energy can be converted to bio electricity or biofuels.

Bio Energy Sources:

Biomass in a way is a nature's 'solar batteries'.

Bioenergy exemplified by wooden log fire or transform biofuel that can be generated using specific technology. This is an infinite renewable energy that has socioeconomic benefits.

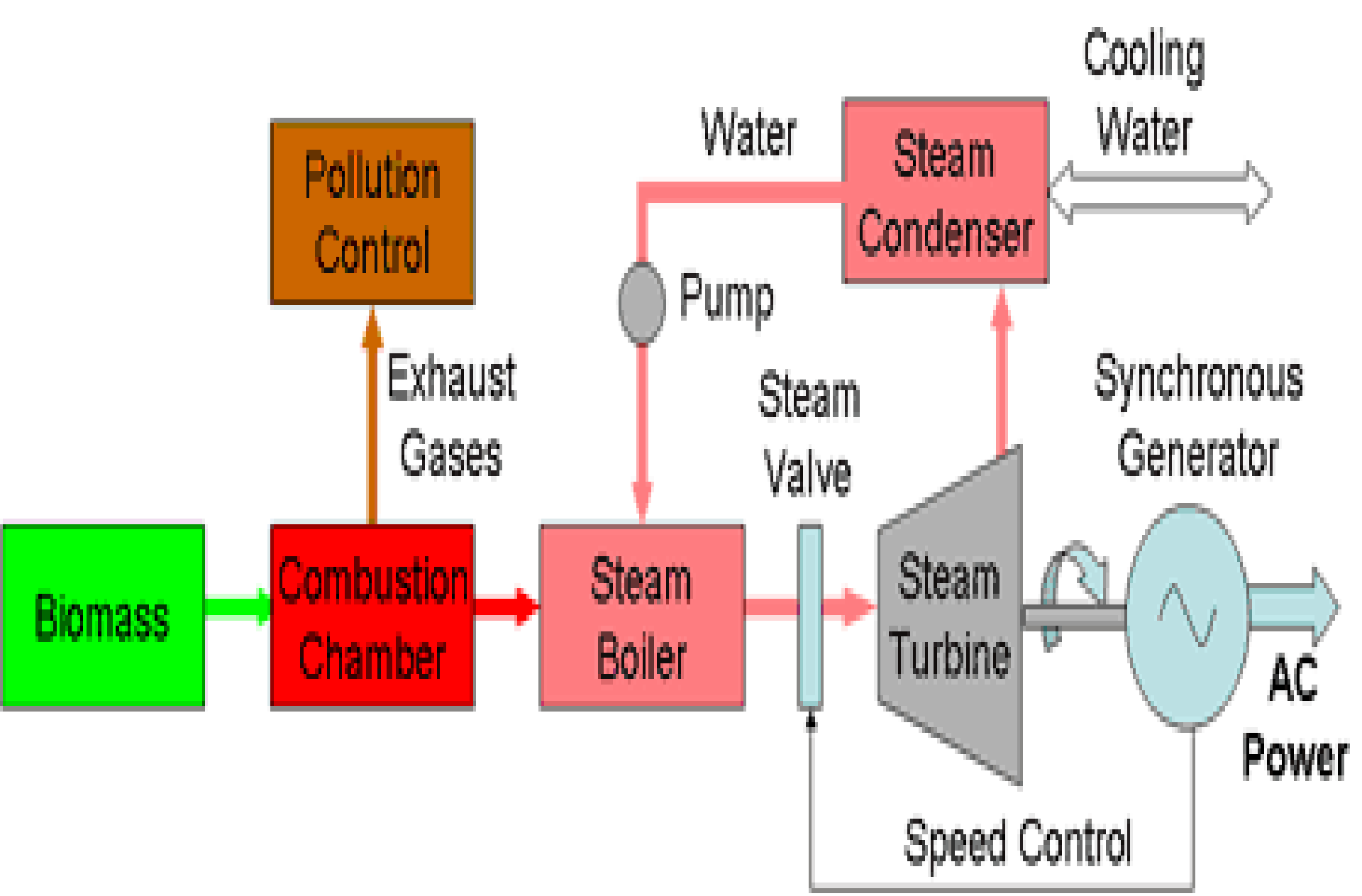


ADVANTAGES OF PLANT BIOMASS

Biomass can be used for fuels, power production and replacing fossil fuels.

Biomass can provide an array of benefits. For example:

- **Reduce GHG** emissions
- Reduced imports of coastally foreign oil
- Reduced GHG emission for CO_2, methane (CH_4), and nitrous oxide (N_2O) help balance life cycle assessment.
- By way of sequestration CO_2 to form biomass.



Electricity Generation Powered by Biomass

Types of plants required to produce bioenergy

- Species that would allow production on a reasonable land footprint.
- Biomass species should produce higher biomass yields with lower inputs and energy uses.
- Globally the common biomass spices are:

- Grass species
- Switch grass
- Miscanthus
- Sugarcane and related species
- Sweet sorghum
- Pearl millet
- Corn (*Zea Mays*)
- Soybean oil
- Bamboo
- Woody biomass species
- Crop residues

General criteria for selecting bioenergy crop species

- high suitability for genetic improvement
- high biomass accumulation
- high water use efficiency and harvest index
- high bulk density and high N use efficiency
- high fraction of biofuel in harvested biomass
- harvested material able to be Stacked and stored in the field
- large-scale potential production
- low cost of harvest
- Amenability for bailing or blocks

BIO-BASED PRODUCTS AS RENEWABLE ENERGY SOURCES

BIOALCOHOLS

- Rotten grains for alcohols production through microorganisms and enzyme mediated bio fermentation products ethanol, propanol and butanol .
- Biobutanol (also called biogasoline) is often claimed to provide a direct replacement for gasoline, because it can be used directly in a gasoline engine (in a similar way to biodiesel in diesel engines).
- Ethanol can be used in petrol engines as a replacement for gasoline; it can be mixed with gasoline to any percentage.

- **Methanol** is currently produced from natural gas a non-renewable fossil fuel. It can also be produced from biomass as biomethanol.
- **Butanol** is formed by ABE fermentation (acetone, butanol, ethanol) and experimental modifications of the process show potentially high net energy gains with butanol as the only liquid product. Butanol will produce more energy and allegedly can be burned "straight" in existing gasoline engines and is less corrosive and less water soluble than ethanol, and could be distributed via existing infrastructures.

BIO-BASED PRODUCTS …..

GREEN DIESEL

- It is also known as renewable diesel and is a form of diesel fuel which is derived from renewable feedstock rather than the fossil feedstock used in most diesel fuels.
- Green diesel feedstock can be sourced from a variety of oils including canola, algae, jatropa and salicornia in addition to tallow.

BIO-BASED PRODUCTS …..

BIODIESEL

- Most common biofuel in Europe. It is produced from oils or fats using transesterification and is a liquid similar in composition to fossil/mineral diesel.
- Feedstocks for biodiesel include animal fats, vegetable oils, soy, rapeseed, jatropa, mahua, mustard, flax, sunflower, palm oil, hemp, field pennycress, pongamia pinnata and algae.
- Pure biodiesel (B100) is the lowest emission diesel fuel. Biodiesel can be used in any diesel engine when mixed with mineral diesel.

BIO-BASED PRODUCTS …..

VEGETABLE OIL

- Straight unmodified edible vegetable oil is generally not used as fuel, but lower quality oil can and has been used for this purpose.
- Used vegetable oil is increasingly being processed into biodiesel, cleaned of water and particulates and used as a fuel.

BIOETHERS

- Bio ethers (also referred to as fuel ethers or oxygenated fuels) are cost-effective compounds that act as octane rating enhancers.
- Greatly reducing the amount of ground-level ozone, they contribute to the quality of the air we breathe. (The Council of the European Communities, 1985; Commission of the European Communities, Brussels, 2007)

BIO-BASED PRODUCTS …..

BIOGAS

- Biogas is methane produced by the process of anaerobic digestion of organic material by anaerobes.
- It can be produced either from biodegradable waste materials or by the use of energy crops fed into anaerobic digesters to supplement gas yields.
- The solid byproduct, digestate, can be used as a biofuel or a fertilizer.
- Biogas can be recovered from mechanical biological treatment waste processing systems. Farmers can produce biogas from manure from their cows by using an anaerobic digester (Farmers Guardian , 2009).

SOLID BIOFUELS

- These include sawdust, grass trimmings, domestic refuse, charcoal, agricultural waste, non-food energy crops and dried manure.

BIOENERGY CROPS

Jatropha (*Jatropha curcus*)

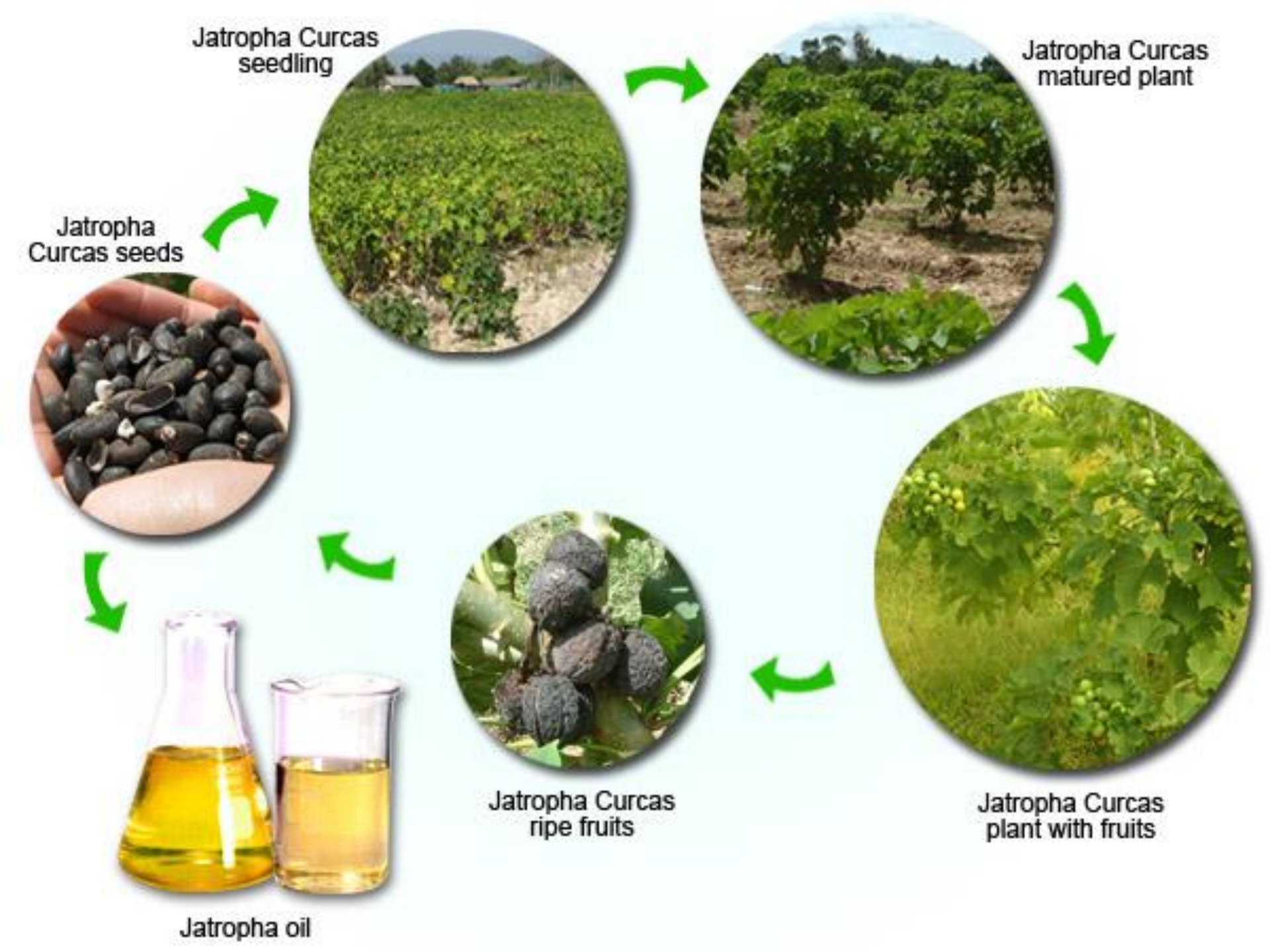
- The genus Jatropha (*Jatropha curcus*) belongs to the tribe Jatropheae in the Euphorbiaceae family and contains approximately 170 known species. It is also known as Physic Nut which can yield up to two tons of biodiesel fuel per year per hectare.
- It can be planted in arid and hot regions such as the desert areas of Egypt, India, and Madagascar, and contribute a reduction of up to 25 t of CO_2 per hectare per year from the atmosphere (over a 20 yr period) (K. Becker et al 2013).
- It requires minimal inputs, stablizes or even reverses desertification, and has use for a variety of products after the biofuel is extracted.

Cont…….

- It is well adapted to arid and semi-arid climates with demonstrated molecular mechanisms for resistance to drought (Zhang et al., 2008). It can also grow on a large range of soils provided they are well drained and aerated (Kumar and Sharma, 2008).
- The utilization of liquid fuels such as biodiesel produced from Jatropha oil by trans-esterification process represents one of the most promising options for the use of conventional fossil fuels.

Cont…….

- The Jatropha oil is converted into jatropha oil methyl ester known as biodiesel, prepared in the presence of homogeneous acid catalyst. The physical properties such as density, flash point, kinematic viscosity, cloud point and pour point of Jatropha oil and Jatropha methyl ester closely matched with the values of conventional diesel and can be used in the existing diesel engine without any modification. The oil is non-edible due to the presence of a toxic substance, ‘curcascine’.
- Different plant part of jetropha produce different biochemical substances which are useful for bio energy


Jatropha Curcas seedling
Jatropha Curcas matured plant
Jatropha Curcas seeds
Jatropha Curcas ripe fruits
Jatropha Curcas plant with fruits
Jatropha oil

Some of the plant species suitable for energy plantation in Arid and Semi-arid zone

- *Acacia arabica*
- *Acacia auriculiformis*
- *Acacia catechu*
- *Acacia senegal*
- *Acacia tortillis*
- *Casaurina equisetifolia*
- *Terminalia arjune*
- *Terminalia tormentosa*
- *Leucaena leucocephala*

Jojoba (*Simmondsia chinensis*)

- Jojoba is a shrub native to southern Arizona, southern California, and northwestern Mexico.
- The plant has also been used to combat and prevent desertification in the Thar Desert in India.
- Its oil is the liquid wax produced in the seed of the plant. The oil makes up approximately 50% of the jojoba seed by weight.
- Unrefined jojoba oil appears as a clear golden liquid at room temperature with a slightly fatty odor. Refined jojoba oil is colorless and odorless.

Cont…….

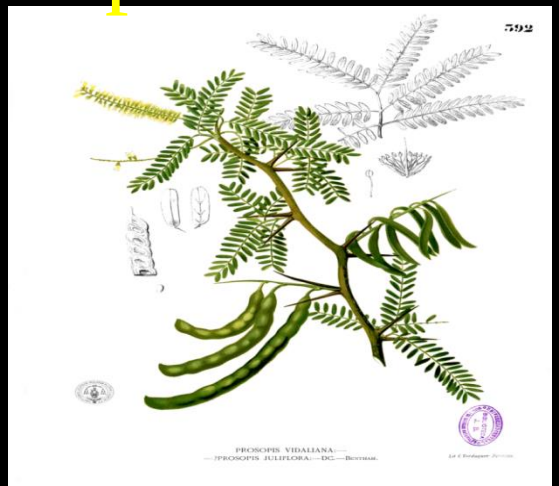
- The melting point of jojoba oil is approximately 10°C and the iodine value is approximately 80.
- Jojoba oil is relatively shelf-stable when compared with other vegetable oils mainly because it does not contain triglycerides, unlike most other vegetable oils such as grape seed oil and coconut oil.
- It has an Oxidative Stability Index of approximately 60, which means that it is more shelf-stable than oils of safflower oil, canola oil, almond oil or squalene but less than castor oil and coconut oil.

Palm (*Phoenix dactylifera* L.)

- Palm oil, like other vegetable oils, can be used to create biodiesel, as either a simply processed palm oil mixed with petrodiesel, or processed through transesterification to create a palm oilmethyl ester blend. Glycerin is a byproduct of transesterification.
- The actual process used to produce biodiesel around the world varies between countries and the requirements of different markets.

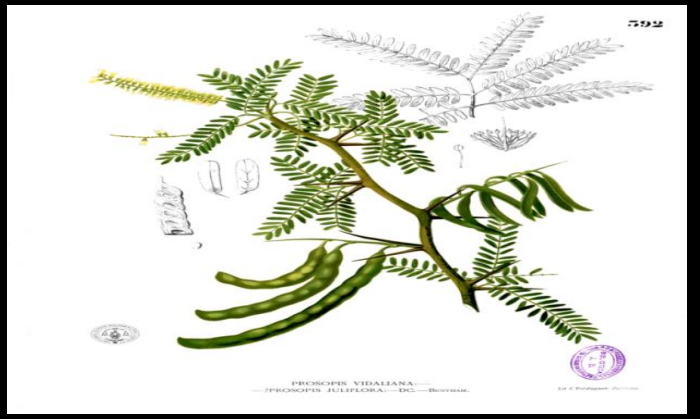
Prosopis juliflora

- *Prosopis juliflora* is a shrub or small tree in the Fabaceae family, a kind of Mesquite.
- It is native to Mexico, South America and the Caribbean. It has become established as an invasive weed in Africa, Asia, Australia and elsewhere.
- It is a fast-growing, drought resistant and a natural fuelwood plant.



Cont…….

- With specific gravity 0.70 or higher, the wood has been termed "wooden anthracite", because of its high heat content, burning slowly and evenly and holding heat well.
- This species provides >90% of the fuelwood in some Indian villages (Sharma, 1981).
- Its wood is a very important source of domestic fuel for millions of people in many arid and semiarid zones of the world.



Panicum virgatum

- Commonly known as switchgrass and is a perennial warm season bunchgrass native to North America, where it occurs naturally from 55°N latitude in Canada southwards into the United States and Mexico.
- Mainly used for soil conservation, forage production, game cover, as an ornamental grass, and more recently as a biomass crop for ethanol and butanol, in phytoremediation projects, fiber, electricity, and heat production and for biosequestration of atmospheric carbon dioxide.

Cont…….

- Switchgrass has the potential to produce up to 380 liters of ethanol per tonne harvested ("Switchgrass: Native American Powerhouse?").

Mahua (*Madhuca indica*)

- *Mahua* is a frost resisting tree of the dry tropics and sub-tropics, common in deciduous forests and dry sal plain forests.
- The tree is culturally most identified with Indian life in the plains being the lifeline of tribal belt in central India.
- It is one of the forest based tree-borne non-edible oils with large production potential of about 60 million tons per annum in India.

Cont…….

- Its flowers are sweet, delicious and are consumed besides tasty fruits and are used to make vinegar. The seeds yield fat known as *Mahua* butter used in cooking, adulteration of *Ghee*, manufacturing chocolates and even soaps, besides treatment of rheumatism and constipation.
- Next to cane molasses; it constitutes the most important raw material for alcohol fermentation. The yield of alcohol is about 405 litres from one tonne of dried flower.
- The kernel of the *Mahua* fruit contains about 50% oil. The oil yield is 34-37% by small expeller.

Karanj *(Derris indica)*

- It is also known as Pongamia pinnata and is a fast-growing evergreen legume tree which reaches 40 feet in height and spread, forming a broad, spreading canopy casting moderate shade.
- Its natural distribution is along coasts and river banks in India and Myanmar. Native to the Asian subcontinent, this species has been introduced to humid tropical lowlands in the Philippines, Malaysia, Australia, the Seychelles, the United States and Indonesia.
- Its seeds contain oils and fatty acids suitable for biodiesel production. Although all parts of the plant are toxic and will induce nausea and vomiting if eaten, the fruits and sprouts, along with the seeds, are used in many traditional remedies.

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- Juices from the plant, as well as the oil, are antiseptic and resistant to pests.
- *Derris indica* is one of the few nitrogen fixing trees (NFTS) used to produce seeds containing 30- 42% oil which is an important asset of this tree having been used as lamp oil, in soap making, and as a lubricant for thousands of years.

Drumstick Tree *(Moringa oleifera)*

- Native of India, occurring wild in the sub-Himalayan regions of Northern India, and now grown world-wide in the tropics and sub-tropics. It is an important crop in India, Ethiopia, the Philippines and the Sudan, and is being grown in West, East and South Africa, tropical Asia, Latin America, the Caribbean, Florida and the Pacific Islands.
- Fast growing tree which commonly reaches four meters in height just 10 months after the seed is planted and can bear fruit within its first year. Its pods are triangular in cross-section (30 to 50 cm long) and legume-like in appearance. These pods have oil rich black and winged seeds, which can be crushed to produce biodiesel.

Cont…….

- *Moringa* could yield +3 ton oil per ha and that it could be used for food in times of shortages. The seeds contain 30 percent to 40 percent oil that is high in oleic acid. The meal yields about 61 percent protein.
- Biodiesel made from *Moringa* has better oxidative stability than biodiesel made with most other feedstocks .
- Other than biodiesel, the pods can also produce edible (in fact, highly nutritious) seeds and leaves.

Cassava (*Manihot esculenta*)

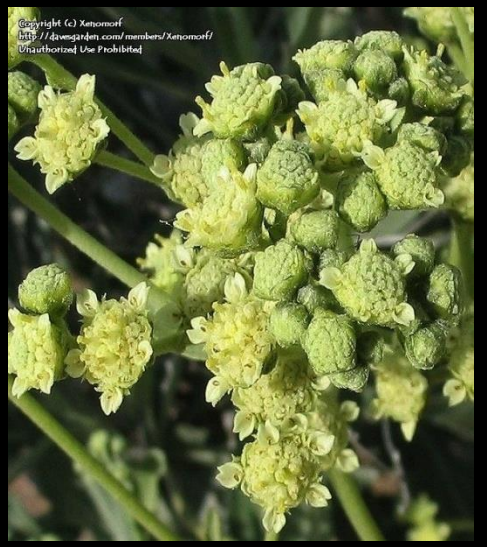
- It is a tuber widely cultivated in tropical and sub-tropical regions, and is currently one of the world's most cost-efficient biofuel feedstocks.
- It is more efficient compared to other energy crops, such as sugar cane, sweet sorghum, corn and wheat.

Cont…….

- One hectare of farm land cultivated with cassava is able to produce on average 6,000 kg of ethanol. (Ghizan and Rajanaidu 2011) Ethanol made from cassava costs more than the molasses-based varieties. In contrast one hectare of corn only produces 2,050 kg of ethanol per year, a little over a third of the same area as cassava. (Dominick, 2012).

Guayule (*Parthenium argentatum*)

- Thrives in hot, dry ecosystems where many other biofuel crops wouldn't grow well.
- The hardy shrub requires less fertilizer than other crops currently produced in the desert Southwest.
- Guayule shrubs can be harvested as early as two years after planting, and are ready to harvest again in about another year and a half.
- It offers many biofuel benefits.



Salicornia

- It is a genus of succulent, halophyte (salt tolerant) plants that grow in salt marshes, on beaches, and among mangroves.
- It is native to North America, Europe, South Africa, and South Asia.
- It is one of the oilseed crops being considered to produce bio-derived jet fuel.

Cont…….

- It is considered as a healthy plant due to its high protein content with around 30% and a variety of healthy salts that can be sundried and used in foods.
- *Salicornia* has been known to have pharmalogical value with special medicinal properties and other plant properties which makes it ideal for other sustainable materials, alternative animal feed and soil remediation projects.

Sweet Sorghum

- It has been shown to require half of what sugar beets need for crop production and one fourth of what sugarcane requires for water usage (Prasad et al 2007).
- Called the sugarcane of the desert, it is one of the most promising crops for biofuel.
- It can be used as a feedstock for ethanol production under hot and dry climatic conditions (Almodares and Hadi , 2009).
- It can be used as a substitute not only to produce food (Anglani, 1998), but also energy (Reddy et al.,2005), feed(Almodares et al.,1999; Fazaeli et al.,2006) and fiber (Murray et al.,2008a,b).

Amaranth (*Amaranthus)*

- With various species and varieties it is a very healthy plant that grows in a variety of climates and conditions.
- The leaves can be consumed by humans or livestock, the plant contains grains that can be converted into a type of bread or also used in fermentation to produce alcohol. The bread made from amaranth is beneficial to people who require gluten free bread with a lot of other health benefits.

Cont…….

- The protein content of amaranth is high for a plant source, being around 15 percent and it also contains amino acids that aren't present in other plant sources.
- Amaranth provides grain meal that can be fermented by a variety of microorganisms, one type named *Rhizopus oryzae* can produce ethanol plus other organic compounds from amaranth (Bramorski et al 1998).
- Certain species of Amaranth are known to grow quite well in dry, arid desert lands such as Palmer Amaranth.

Pencil Tree *(Euphorbia tirucalli)*

- It is a tropical to subtropical plant commonly known as milkbush.
- According to Calvin (1980), as cited by Purdue University, the plant is capable of producing between 10 to 50 barrels of oil (biodiesel) per acre.
- The plant also produces latex, and its wood can be used as framing lumber if the plants are allowed to grow tall enough.

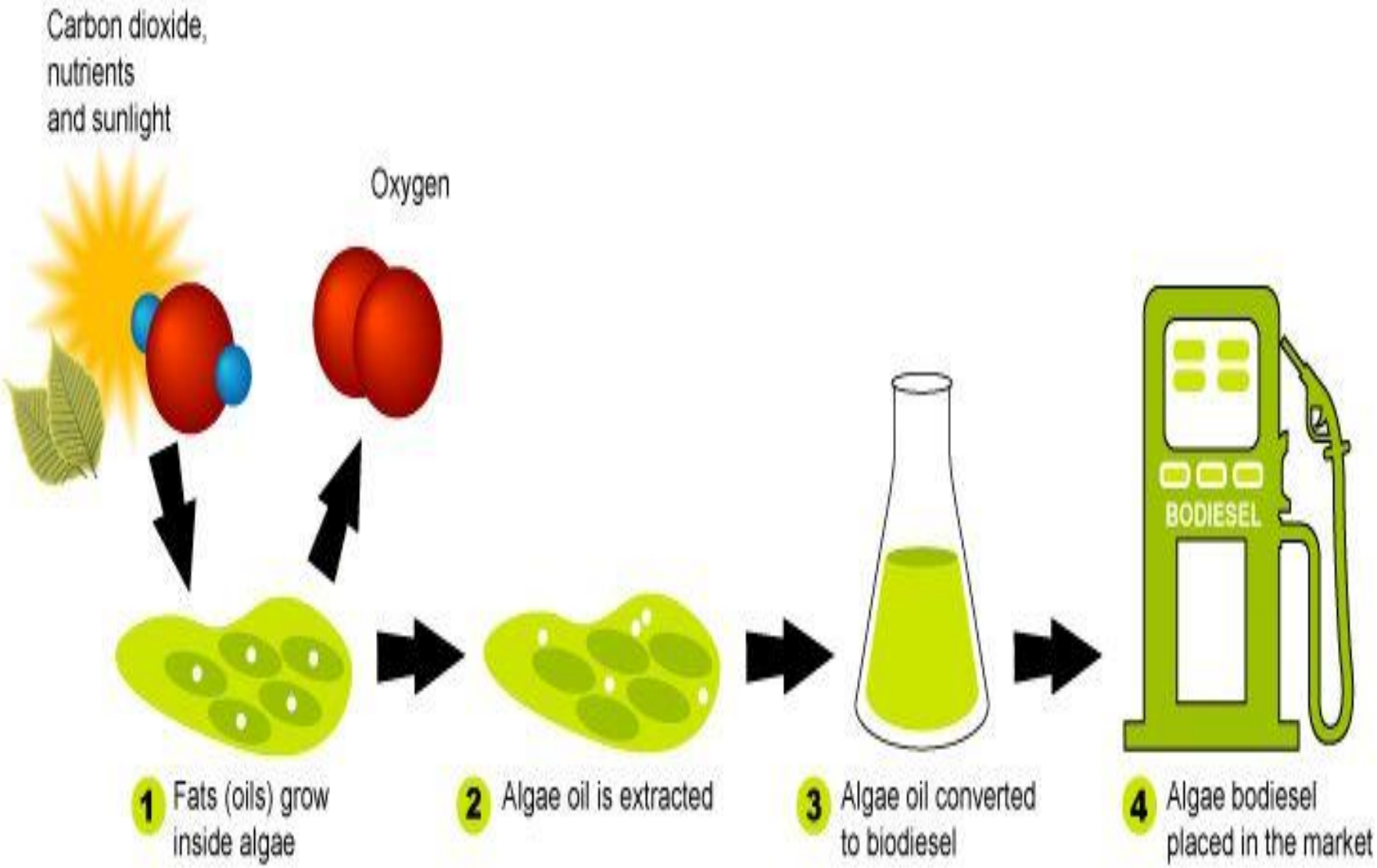
Algae

- Algae are a diverse group of photosynthetic aquatic organisms which includes seaweed (macroalgae) and microscopic floating plants such as phytoplankton (microalgae). Like other plants, algae also make sugar and oil molecules through photosynthesis.
- According to Thomas (2006), microalgae can produce between 5,000 to 15,000 gallons of oil per acre per year.
- In the right conditions some species of microalgae can accumulate oil in quantities up to half their dry cell weight which means they have the potential to provide up to 24 times the amount of oil per acre than palm, the most productive terrestrial crop.

Seaweed being harvested in China

Cont…….

- Algae are also incredibly flexible: they can grow in a wide range of conditions including marine, brackish or nutrient-rich wastewater.
- Microalgal biodiesel has other benefits over traditional land-grown biofuels. It has high levels of polyunsaturated fatty acids so it can remain fluid at low temperatures, which improves the performance of diesel engines in cold conditions.
- Macroalgae could also be fermented to make ethanol.
- Desert land is ideal for the large ponds' space requirement, but one of the major drawbacks is that shallow ponds must be filled in, and the only way this is possible is by piping in water to desert areas.


Carbon dioxide,
nutrients
and sunlight
Oxygen
BODIESEL
1 Fats (oils) grow inside algae
2 Algae oil is extracted
3 Algae oil converted to biodiesel
4 Algae bodiesel placed in the market

Soybean (*Glycine max*)

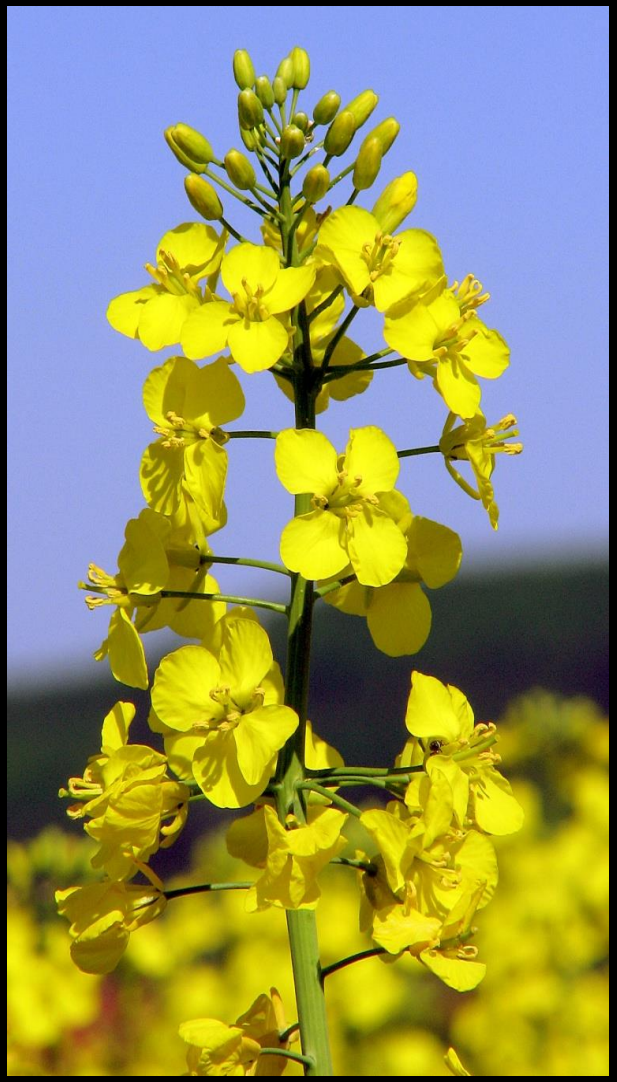
- It is a major crop throughout much of North America, South America and Asia.
- Soybean acreage is much greater than other oilseed crops leading to substantial soybean oil production and its availability as a biofuel feedstock.
- Soybean oil is currently a major feedstock for production of biodiesel.

Cont…….

- The most common method of biodiesel production is a reaction of vegetable oils or animal fats with methanol or ethanol in the presence of sodium hydroxide (which acts as a catalyst).
- The transesterification reaction yields methyl or ethyl esters (biodiesel) and a byproduct of glycerin.

Brassica

- *Brassica* is the most important oilseed crop of semi-arid and arid regions of India spreading over Western Rajasthan, North Gujarat, South-West Haryana and Punjab, some parts of Andhra Pradesh, West Bengal and Karnataka.
- Brassica crops are important sources of animal feed, vegetable oil for human consumption and are increasingly used globally as renewable energy.
- *Brassica* oil is most suitable for transesterification process for bio-diesel production due to its low price compared to other vegetable oils.



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- Due to the high content of oleic acid and low levels of both saturated and polyunsaturated acids, the oil is the ideal raw material for combustion, due to its characteristics (oxidative stability and cold temperature behavior).
- Bio-diesel from *Brassica* oils present comparable characteristics to diesel oil concerning viscosity, setting point, carbon residue and cetane number.
- The calorific value varies according to the species but they are close to the heating value of the diesel. These characteristics made brassica oil as the best renewable energy source to substitute partially or totally for diesel oil.

Castor Bean (*Ricinus Cummunis)*

- It belongs to the Euphorbiaceae family and it is commonly known as castor oil plant, and Palma Christi.
- This plant originates in Africa but it is found in both wild and cultivated states in all the tropical and subtropical countries of the world.
- It is high yielding, yielding as much as 350-650 kg of oil per hectare when no maintenance is applied to the crop i.e. fertilizers etc, to a high end yield where annual rainfalls happen at the right times, (1000 liter per hectare) (Anonymous, 2010). It has a very high oil content of approximately 50%.

Cont…….

- The biodiesel prepared from castor oil has certain properties that are attractive particularly for cold climate.
- It has flash point of 190.70C which is much higher than petro diesel and other vegetable oil biodiesel. The oil is stable at low temperature and makes it an ideal combustible for region of extreme seasonal weather.

Coriander (*Coriandrum sativum* L.)

- It is native to southern Europe and North Africa to southwestern Asia and is an annual herb in the family Apiaceae.
- Coriander (*Coriandrum sativum* L.) seed oil methyl esters (CSME) has been prepared and evaluated as an alternative biodiesel fuel and has been found to have excellent fuel properties as a result of its unique fatty acid composition containing petroselinic (6Z-octadecenoic; 68.5 wt %) acid which is the principle component in biodiesel fuels.

Cont……

- The other properties of coriander oil like its acid value, free and total glycerol content, iodine value, sulphur and phosphorous content are acceptable as per declared biodiesel standards.
- Coriander oil can be a potential source for biodiesel production in future (Moser and Vaughn, 2010).

Crop residues

- Crop residues left in the field after grain harvest has a large potential as a bioenergy feedstock.
- As a byproduct of grain production these residues have been called waste, yet research has shown their nutrient, erosion and soil carbon characteristics have value that must not be overlooked.
- Crop residues of interest for bioenergy include; corn stover, corn cobs, wheat straw, soybean straw and rice hulls.

Woody crops

- These are generally fast-growing plants like grasses or trees, which are cultivated for energy production, but can also be forestry or agricultural residues.
- Short rotation woody crops are fast growing hardwoods, planted at high density and generally harvested two to twelve years after planting.

Cont…….

- In case of arid and semi-arid climates, the rotation period is likely to be closer to the higher end of this range in order to allow for more efficient harvesting.
- The harvested wood is used for various energetic purposes such as direct use as fuel wood for cooking, heating and lighting, co-firing for electricity production, ethanol production via fermentation and biodesel via gasification/ Fischer-Tropsch process.

Bamboo (*Bambusoideae)*

- Bamboo biomass energy has great potential to be an alternative for fossil fuel. Bamboo biomass can be processed in various ways (thermal or biochemical conversion) to produce different energy products (charcoal, syngas and biofuels), which can be substitutions for existing fossil fuel products.
- In Vietnam, energy generation from bamboo is a new concept despite the fact that Vietnam is rank fourth in bamboo production. However, efforts are undergoing to make bamboo biomass energy closer to its potential.

Corn (*Zea mays*)

- The production of ethanol from corn for use as a transportation fuel is mature technology. It was first introduced in the United States in the early 1900s. Today, most fuel ethanol is produced from corn either by the dry grind (67%) or the wet mill (33%) process.
- The wet milling process is more capital and energy intensive, as the grain must first be separated into its components, including starch, fibre, gluten, and germ.

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- The germ is removed from the kernel and corn oil is extracted from the germ. The remaining germ meal is added to fibre and the hull to form corn gluten feed. Gluten is also separated to become corn gluten meal, a high-protein animal feed.
- In the wet milling process, a starch solution is separated from the solids and fermentable sugars are produced from the starch. These sugars are fermented to ethanol.

Pearl millet (*Pennisetum glaucum*)

- Pearl millet crop has been tapped for biofuel production. Pearl millet scores a rich source of carbohydrates namely cellulose and hemicellulose which accounts for 41.6 % and 22.32 %.
- So many technologies are existing for biofuel production from cellulosic ethanol production. Several enzymes can break down the cellulose to glucose.

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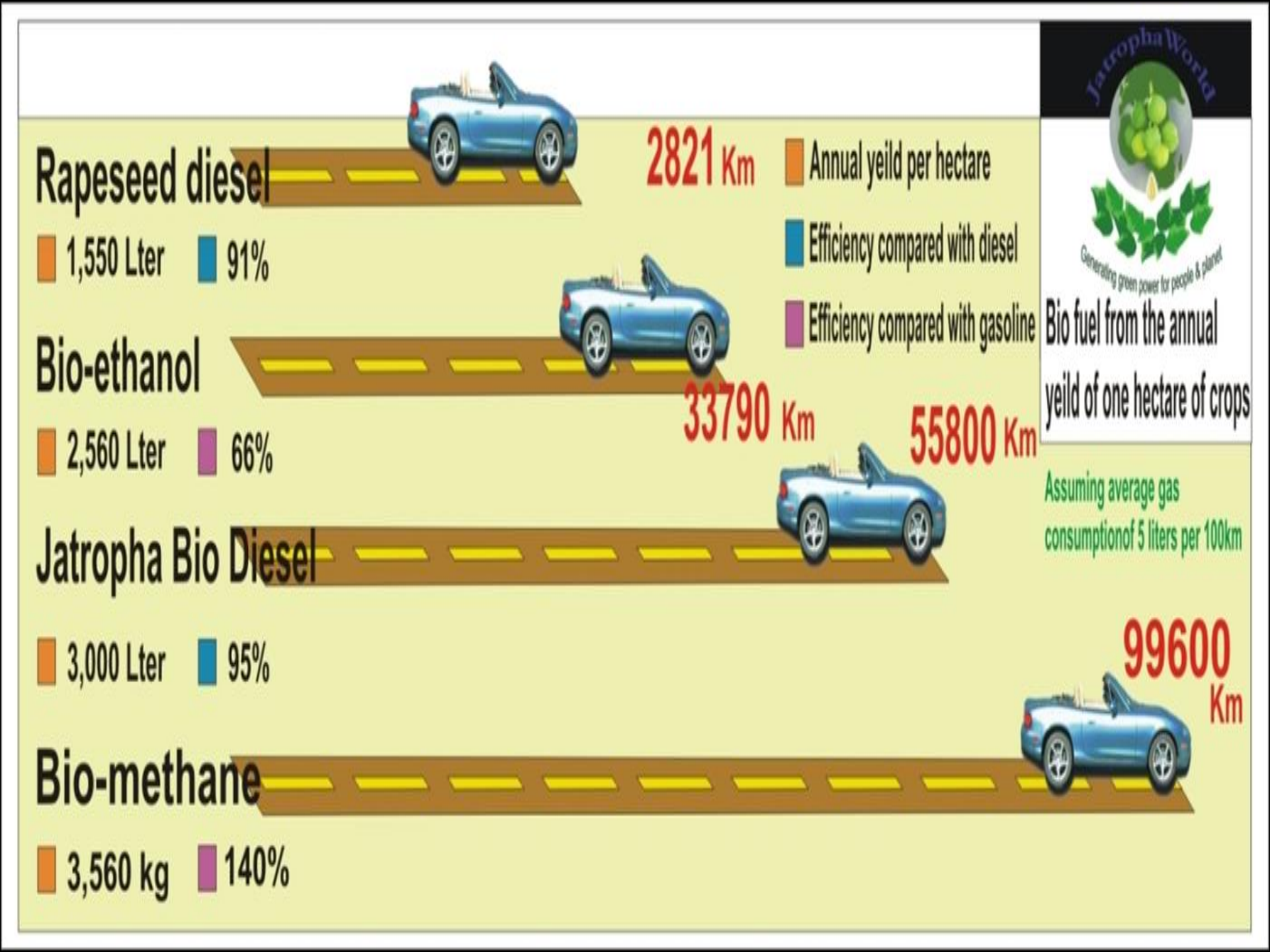
- These fermentable sugars can be further fermented into ethanol by microorganism. Pearl millet biomass may be used as commercial scale-up of ethanol production within a few years due to low cost.


Rapeseed diesel
1,550 Lter
91%
2821 Km
Bio-ethanol
2,560 Lter
66%
33790 Km
Jatropha Bio Diesel
3,000 Lter
95%
55800 Km
Bio-methane
3,560 kg
140%
99600 Km
Annual yeild per hectare
Efficiency compared with diesel
Efficiency compared with gasoline
Jatropha World
Generating green power for people & planet
Bio fuel from the annual yeild of one hectare of crops
Assuming average gas consumptionof 5 liters per 100km

Countrywide biomass generation from crop residues and corresponding power potential for the year 2004
Source: Indian Institute of Science, Bangalore. 2005

Crop	Area MHa	Biomass Surplus MT/Year	Power Potential MWe
Wheat	43.8	23.9	3190.5
Maize	12.5	6.0	800.6
Sorghum	27.8	4.0	529.5
Soyabean	6.0	3.2	423.4
Pearl Millet	244.9	3.1	402.0
Mustard	3.9	2.9	388.2
Ground nut	13.0	2.7	345.5
Tapioca	0.2	2.3	309.1
Sugarcane	2.7	1.5	212.5

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Source: Indian Institute of Science, Bangalore. 2005

Crop	Area MHa	Biomass Surplus MT/Year	Power Potential MWe
Castor seed	1.0	0.7	96.5
Sesame	1.2	0.64	83.6
Safflower	0.3	0.4	48.9
Green gram	2.6	0.3	42.3
Black Gram	2.9	0.3	35.2
Finger Millet	1.4	0.2	23.6
Casuarina	0.02	0.1 8	24.9
Cluster Bean	0.26	0.16	22.7
Eucalyptus	0.016	0.13	19.1
Sun flower	1.3	0.12	16.2
Pulses	1.87	0.11	14.9
Oilseeds	0.34	0.096	11.5

CONCLUSION

- The sustainable production and use of energy in the form of biofuels can offer significant benefits to both the urban and rural sectors.
- Bioenergy produced from non conventional energy sources such as desert plants is the future power of automobiles, homes, industries and agriculture.
- Using deserts for bioenergy production would definitely help to alleviate the problems associated with land-use and biodiversity as far as biofuel production is concerned.

Cont…….

- The projects undertaken to produce biofuels from desert plants would definitely help to improve the economy and environment at local and global levels.
- However numerous questions remain unanswered as far as the best suited plant for biofuel production is concerned.
- Lot of research needs to be done in search of bioeconomic prosperity and sustainability.