BIOENERGY

Chapter 1. Photosynthesis. Process description.

Chapter 2. Biomass. Definition, biomass composition, biomass as a carbon dioxide storage, types of biomass.

Chapter 3. Biofuels. Introduction. Definition, classification. World markets, production, basic technologies for biofuel production. Relative production efficiency. Energy balance. Biofuels from the environmental point of view.

Chapter 4. Definition and composition of bioethanol, prime materials, production technologies, industrial processes, applications.

Chapter 5. Biodiesel. Definition, the transesterification process. Prime materials. Industrial production. Uses and applications.

Chapter 6. Definition and composition of biogas. Sources, process of biodegradation, production technologies, applications.

Chapter 7. Thermochemical technologies for solid biomass processing.

1. INTRODUCTION

Biofuels have recently entered into the production, private investments and state politics of developed countries.

To be able to describe the importance of such production there are several facts that need to be taken into account:

- **The need to find new alternative energy sources** in order to decrease the dependence on fossil fuels.
- **The effect of the raise in petroleum prices** on importing countries to lessen their dependence
- **The effect on the environment,** emissions of gases that affect global warming and the international conventions to lesser these effects.

2. BIOFUELS. DEFINITION

Biofuels: Solid, liquid or gaseous fuels obtained from renewable biological material.

3. BIOFUEL CLASSIFICATION

3.1 Classification depending on the physical state

- Solid state

- Wood, kindle,...
- Cereal straw, dry grass,...
- Densified solid biofuels: pellets and briquettes
- Vegetable coal

- Liquid state

- Liquid hydrolisis products
- Bioethanol and bioalcohols
- Oxygenated additives
- Vegetable oils
- Biodiesel (methyl esters)

- Gas state

- Biogas from various sources

3. BIOFUEL CLASSIFICATION

3.2. Classification depending on the generation

- First generation biofuels
- Second generation biofuels
- Third *(and consecutive)* generation biofuels

3.2.1 First generation biofuels

CHARACTERISTICS

1. They are obtained from various existing primary sources and until now their main use was for animal or human food.

Basic primary sources are: sugars, starch or vegetable oils, seeds and other grains, such as: corn, wheat, soya, sugar cane, …





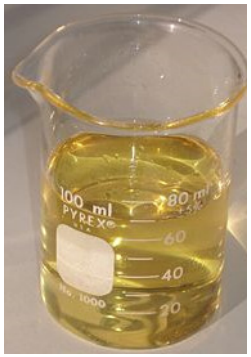
3.2.1 First generation Biofuels

2. They are being **currenly produced** and commercialized using **classical technologies** typical of the chemical and food industry. They are part of established production chains and they go into direct competition with food production.

3. In some cases, they are by-products of the main production-chain.

Example: Biofuel obatined from soya oil. Main product: soya flour.





3.2.1 First generation Biofuels

4. They **already** have a **place in the market**, even if they take just a small percentage of the agricultural business.

5. **Private investments** on biofuel production will depend on the highs and lows of **petroleum and agricultural prices.**

6. They move in **strictly regulated markets.** Industrialized countries give out **finantial help** and **apply strict border taxes to promote production.**

7. They are necessary to develop next generation biofuels.

3.2. Second generation biofuels

CHARACTERISTICS

1. Lignocellulosic biomass is used (wheat straw, corn stubble, pasture, wood, cellulosic plants, energy crops, special crops)

2. Production processes are quite complex: Biomass to Liquid (BtL) Technologies are used in order to obtain cellulosic ethanol (*via* fermentation) or biodiesel (*via* thermochemical process).

3. Most biofuels in this category are in a development stage: biohydrogen, biomethanol, Fischer-Tropsch diesel, or biohydrogen diesel.

3.2. Second generation biofuels

- **Applied Technology:**

2nd generation biofuel production can follow three diferent paths:

- **Transformation of biomass** into ethanol, butanol, and other possible biofuels using **biochemical processes, especially enzymatic hydrolisis.**

- **Photosynthetic conversion through the use of microorganisms (**algae or bacteria) . It could also be possible to obtain conversion using yeasts.

- **Transformation of biomass** into natural gas, diesel or any other liquid fuel using a **thermochemical path.**

Specific technologies have been identified for each of these different paths and each different raw material/fuel combination

3.2.4 Third generation biofuels

- In this classification the biofuels obtained from algae is included.

-**To obtain biofuels from algae, appropriate algae especies and technologies are required:**

- There are different methods to obtain oil from algae: solvents, pressing or enzymes.
- The oil is then processed through transesterification.

- Inside this cathegory, we find **biopropanol or bio-butanol** PRODUCTION (which is not expected to be economically viable before 2050). Raw materials to obtain these biofuels would be the same ones as the 1st generation biofuels but using more sophisticated technologies (UNEP, 2009, OECD-IEA, 2010).



4. BIOFUELS IN THE WORLD MARKET

World production today

- Mostly based on **first generation biofuels**.
- They have shown an important growth in the last years.
- Main product: **Bioethanol**
- Second product: **Biodiesel**

Main productors

- **EEUU**: Bioethanol 55% of the world prod., mainly from corn
- **Brazil:** Bioethanol. 34% of the world prod., mainly from sugarcane
- **EU**: Biodiesel. 60% of the world prod., mainly from rapeseed
  - Germany: 33%
  - France: 25%
  - Italy and Spain: 10%
- Other Bioethanol producing countries: **Australia, Canada, China** , …
- Other Biodiesel producing countries : **South-east Asia** (Malasia, Indonesia, Singapur and China), **Latin America**(Brazil and Argentina) and **Eastern Europe** (Rumania and Serbia).

4. BIOFUELS IN THE WORLD MARKET

Bioethanol. World markets (production in million gallons)

Country / Region	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
USA (Corn)	3.904	4.884	6.521	9.309	10.699	13.720	14.401	13.768	13.300	14.300	14.806
Brazil (Sugar cane)	4.163	4.531	5.524	6.547	6.915	6.922	5.573	5.577	6.267	6.190	7.093
Canada (Wheat, corn)	76	99	187	237	279	357	462	449	523	510	436
China (Wheat, corn)	301	425	448	516	542	542	555	555	696	635	813
EU (Sugar c., wheat, corn)	-	432	486	703	803	1.208	1.167	1.139	1.371	1.746	1.387
India (Sugar cane)	336	504	577	443	298	-	-	-	545	155	211
TOTAL WORLD	**8.780**	**10.873**	**13.742**	**17.754**	**19.536**	**23.540**	**22.802**	**21.488**	**22.702**	**24.570**	**25.680**

SOURCE: Renewable Fuel Association. www.ethanolrfa.org/resources/industry/statistics/.
1 gallon = 3.78 L

4. BIOFUELS IN THE WORLD MARKET

Bioethanol. World markets (production in million gallons)

Country / Region	2016	2017	2018
USA (Corn)	15.250	15.936	16.061
Brazil (Sugar cane)	7.295	6.860	7.920
Canada (Wheat, corn)	436	470	480
China (Wheat, corn)	845	860	1.050
EU (Sugar c., wheat, corn)	1.377	1.400	1.430
India (Sugar cane)	225	210	400
TOTAL WORLD	**26.504**	**26.810**	**28.570**

SOURCE: Renewable Fuel Association. www.ethanolrfa.org/resources/industry/statistics/.
1 gallon = 3.78 L

4. BIOFUELS IN THE WORLD MARKET

Biodiesel. World markets (production in million gallons)

Country / Region	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
EU (Canola y soya)	888	1.416	1.783	1.812	2.477	3.091	3.235	3.177	3.233	3.265	3.422
USA (Soya)	91	250	490	678	516	348	967	991	1.359	1.269	1.263
Brazil (Soya)	0	18	107	308	406	647	692	722	742	756	753
Argentina (Soya)	5	5	54	222	76	555	610	646	670	685	865
Indonesia (Palma)	-	-	35	55	76	84	172	192	206	217	224
Malaysia (Palma)	2	21	30	27	24	25	27	30	33	37	26
TOTAL WORLD	**1.003**	**1.720**	**2.508**	**3.101**	**3.886**	**4.905**	**5.510**	**5.603**	**5.643**	**5.730**	**6.655**

Source: www.oecd-ilibrary.org/agriculture-and-food/data/oecd-agriculture-statistics_agr-data-en.
1 gallon = 3.78 L

4. BIOFUELS IN THE WORLD MARKET

Biodiesel. World markets (production in million gallons)

Country / Region	2016	2017	2018	2019	2020
EU (Canola y soya)	3.354	5.375	5.750		
USA (Soya)	1.569	1.600	1.800	2.600	
Brazil (Soya)	755				
Argentina (Soya)	880				
Indonesia (Palma)	229				
Malaysia (Palma)	30				
TOTAL WORLD	**6.540**	8.375	8.750		

Source: www.oecd-ilibrary.org/agriculture-and-food/data/oecd-agriculture-statistics_agr-data-en.
1 gallon = 3.78 L

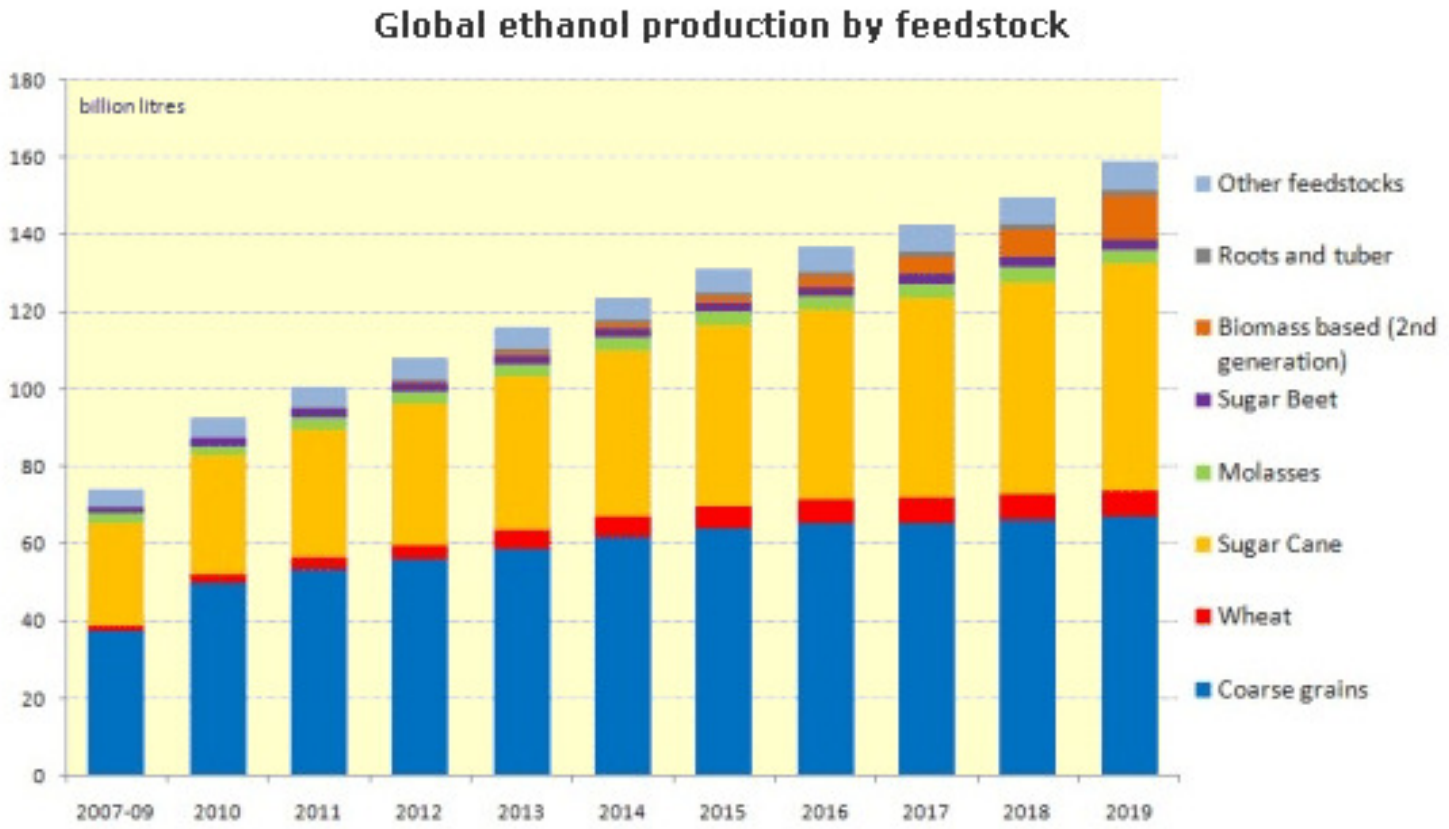
5. BASIC PRODUCTION TECHNOLOGIES FOR BIOFUEL PRODUCTION

Biofuel	BasicTechnology	Main Raw Material	By-products
1st Generation Biofuels			
Bioethanol	Fermentation (sugar) hydrolisis (starch) + Fermentation	**Sugar-rich food crops** - U.S.A.: corn - Brazil-South America: sugar cane - Europe: cereal, sugar beet - Canada: corn and cereal	Animal feed corn, cereal cane chaff to obtain energy.
Biodiesel	Transesterification (Oils and Fats)	Oil from oleaginous crops - U.S.A.: soya, sunflower - Brazil-South America: soya - Europe: rapeseed - Canada: soya, rapeseed - Indonesia and Malasya: Palm Food Applicationof reutilized oil	Glycerin
Biofuels from non eadible raw materials			
Bioethanol	Fermentation (sugar) Fermentation + hydrolisis (starch)	Non-food vegetable Raw Material Cotton, peanuts	Animal feed corn, cereal cane chaff to obtain energy.
Biodiesel	Transesterification Oils and Fats	Oil from oleaginous crops ricino, jatropa, lesquerella, lupino, jojoba, sesame	Glycerin

5. BASIC PRODUCTION TECHNOLOGIES FOR BIOFUEL PRODUCTION

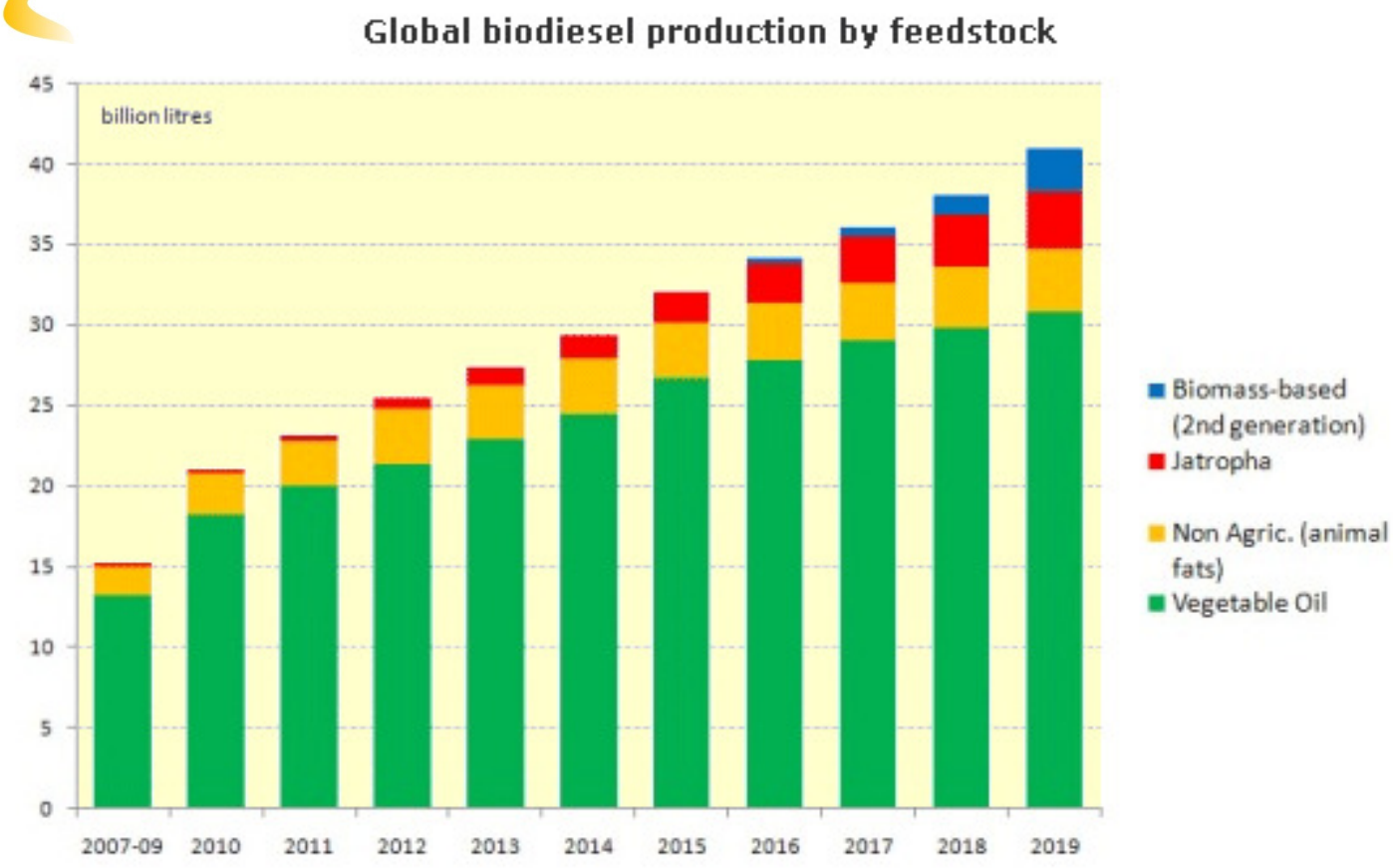
Biofuel	BasicTechnology	Main Raw Material	By-products
2nd Generation Biofuels			
Bioethanol	Separation of Lignocellulosic biomass in different stages, including hydrolisis and Fermentation .	**Lignocellulosic biomass**: -Agricultural and forest residues - Yearly plants, fast growing plantations, - Especial crops: Miscanthus, switchgrass	Lignine
Biodiesel **Biohydrogen** **Biomethane**	Gasification of low humidity biomass.	**Lignocellulosic biomass:** -Agricultural and forest residues	Fuels Plastics
Other Biofuels			
Bioethanol **Biobutanol** **Biodiesel** **Avionic Fuels**	Bioreactors for bioethanol Transesterification for biodiesel. Other developing techniques	Microalgae (sea and still pond)	Animal feed Biopolymers Agricultural fertilizers

Chapter 3. Biofuels.



Edible vegetable oil is expected to remain the major feedstock used to produce biodiesel. However, its share in total biodiesel production should decrease from almost 90% over the base to about 75% by 2019. This is due to the development of the production of biodiesel based on jatropha mainly in India, to the increasing use of animal fats to produce biodiesel in the US and to the availability of biomass based second generation biodiesel in the latter years of the projection period. Biomass based biodiesel should represent almost 6.5% of total biodiesel production by 2019.

Chapter 3. Biofuels.



Biofuel use represents an important share of global cereal, sugar and vegetable oil production. By 2019, about 13% of the global production of coarse grains will be used to produce ethanol compared to 9% over the base. 16% of the global production of vegetable oil will be used to produce biodiesel compared to 9% over the base.

The share of sugar cane to be used for ethanol production at the worldwide level is expected to reach almost 35% in 2019.

6. RELATIVE PRODUCTION EFFICIENCY

Productivity: Liter of biofuel obtained for each acre of plantation.
When evaluating different raw materials for the production of certain biofuel, this is an important factor.

BIODIESEL PRODUCTION

Nowadays:

Soya → small productivities, between 300 and 600 liter per acre
Rapeseed → 1.000 liter per acre or more.
Palm → maximum productivity.

Future:

Algae crops → Highest productivity, up to 20.000 liter per acre.





6. RELATIVE PRODUCTION EFFICIENCY

Bioethanol PRODUCTION

Nowadays:

1st generation Biofuels:

Corn: small productivity , up to 6.000 liter per acre

Sugar cane: maximum productivity, up to 10.000 liter per acre

Future:

2nd generation Biofuels:

Switchgrass is an energy crop that produces high amounts of biomass. It has yields similar to the ones for the cane but the technology to convert it into bioethanol is much more complex.

7. ENERGY BALANCE

It is the relationship between the amount of energy a biofuel can produce and the energy necessary to produce the biofuel.

$$\text{Energy Balance} \rightarrow \text{E.B.} = \frac{\text{Energy produced}}{\text{Fossil Fuel used}}$$

For a certain amount of energy produced, the smaller the divider the higher the outcome (**ENERGY BALANCE).**

Factors that affect the ENERGY BALANCE

1. Raw Materials used
2. Production-Technology
3. Relative distances for the transportation of Raw Materials
4. Fertility of the land

7. ENERGY BALANCE

ENERGY BALANCE FOR BIODIESEL

First Generation Biodiesel

- **Palm Oil : the most favourable** ENERGY BALANCE.
- **Soya Oil: It gives three times the amount of energy necessary to produce.**
- **Reutilized oil:** positive ENERGY BALANCE. **Why?** Usually they are small factories directed to autoconsumption. This translates into a very small energy expenditure.

Second Generation Biodiesel:

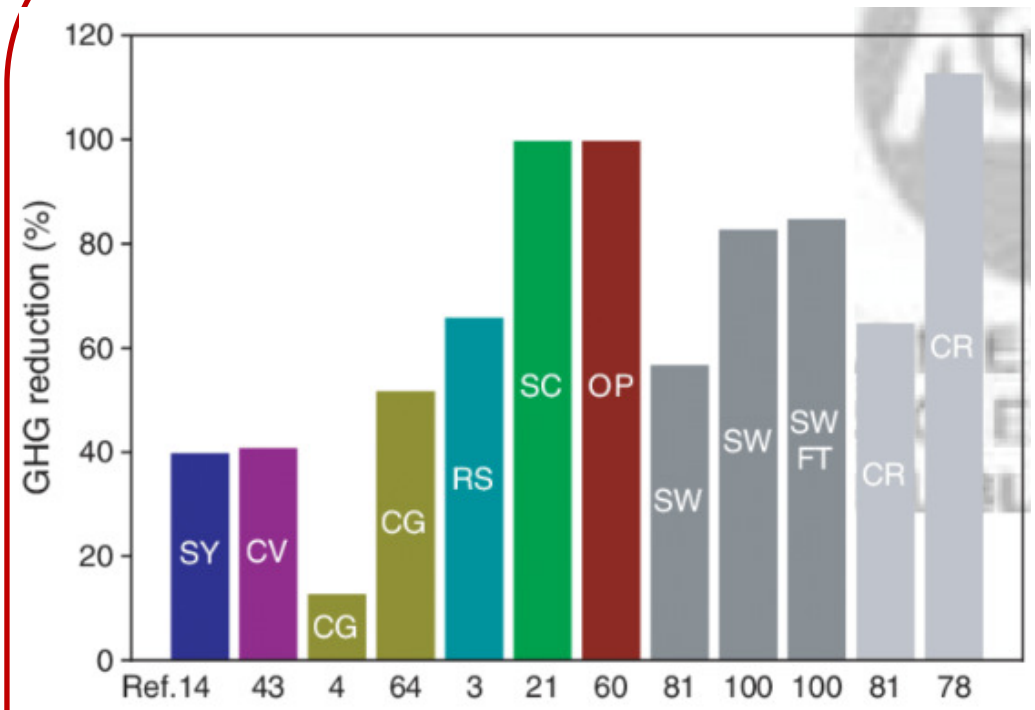
- Very little research has been done
- **Jatropa:** obtains 4 to 6 times the amount of energy necessary to produce it.
- **Microalgae: it doubles the positive balance of soya crops.**

8. OTHER FACTORS TO TAKE INTO ACCOUNT

- **Raw materials availability**
- **Know-how/technologic advances**
- **Development of the industial technologies**
- **Economic viability**
- **Competition for the use of the soil:** production from plantations located in marginal sites when the land is reserved for foold crops.
- **Oportunity costs:** When the raw material can be transformed into a better valued product, opportunity costs will be high. For instance, in the case of oleaginous seeds, if the seed oil can be sold for a better price than biodiesel.

9. BIOFUELS FROM THE ENVIRONMENTAL POINT OF VIEW

Greenhouse gas (GHG) emissions



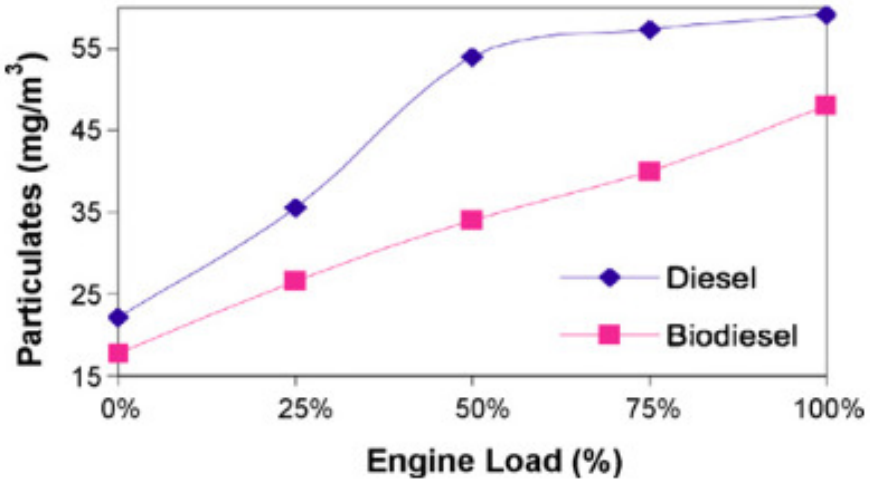
SY: soybean-biodiesel;
CV: cassava-ethanol;
CG: corn grain-ethanol;
RS: rapeseed-biodiesel;
SC: sugarcane-ethanol;
OP: oil palm-biodiesel;
SW: switchgrass cellulosic-ethanol;
SWFT: switchgrass Fischer-Tropsch biofuel;
CR: corn residue-cellulosic ethanol.

- Greenhouse gas (GHG) emissions reduction from biofuel systems compared to gasoline based on estimates published in the literature.
- Different values for the same biofuel crop reflect differences in energy efficiency parameters used in various components of the LCA.

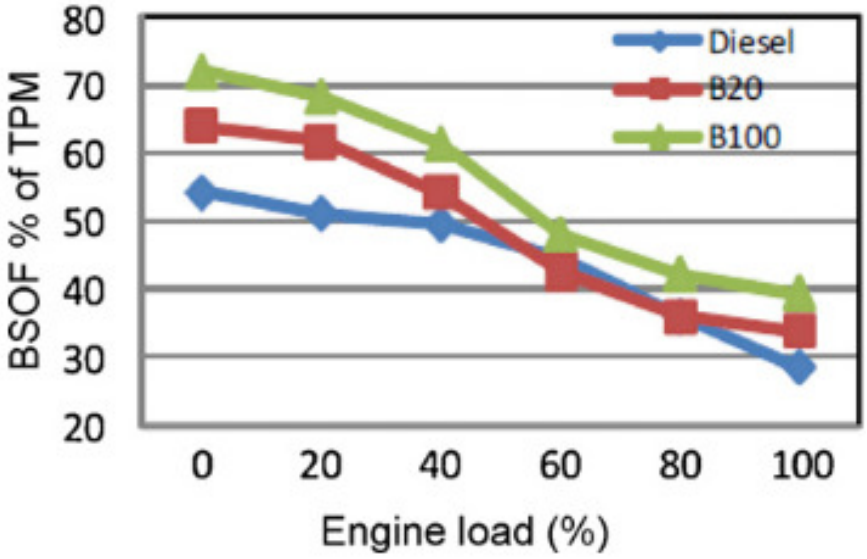
9. BIOFUELS FROM THE ENVIRONMENTAL POINT OF VIEW

Biodiesel

Particulates



Benzene soluble organic fraction (BSOF)

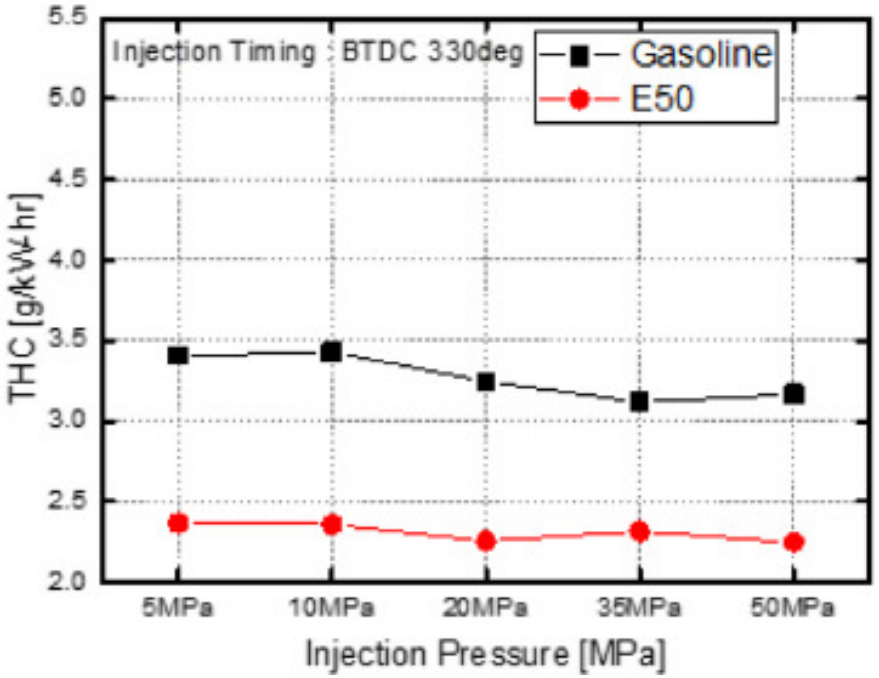


Represent the toxic organic compounds in the particulate

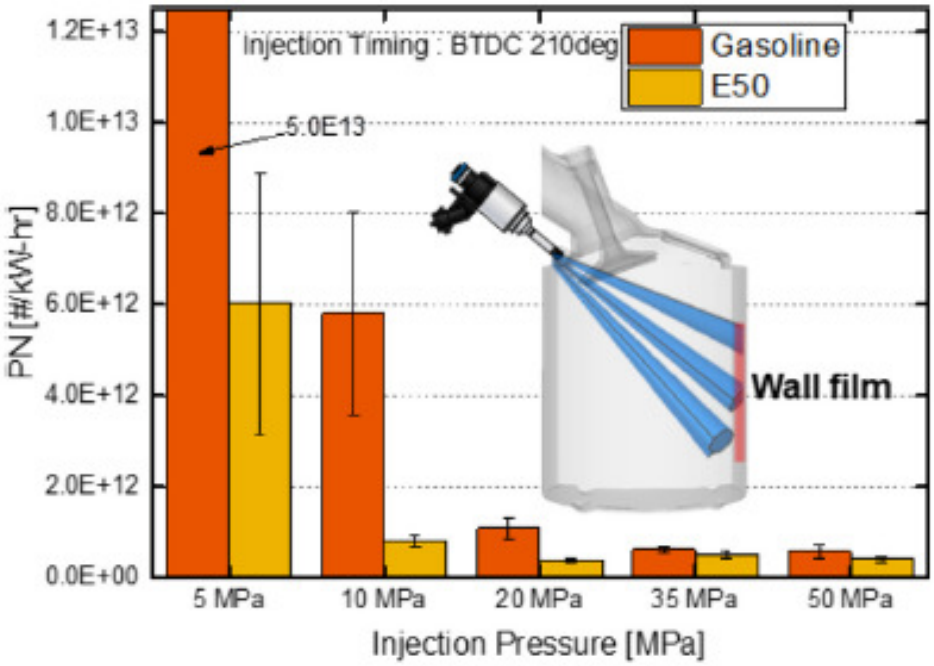
Renewable and Sustainable Energy Reviews 15 (2011) 3278– 3300

9. BIOFUELS FROM THE ENVIRONMENTAL POINT OF VIEW

Bioethanol



THC: Total HydroCarbons



PN: Particle Number

Renewable Energy 149 (2020) 80-90