# BIOMASS CONVERSION COURSE

Doctoral School
EPFL

# Bioethanol

# Bioethanol

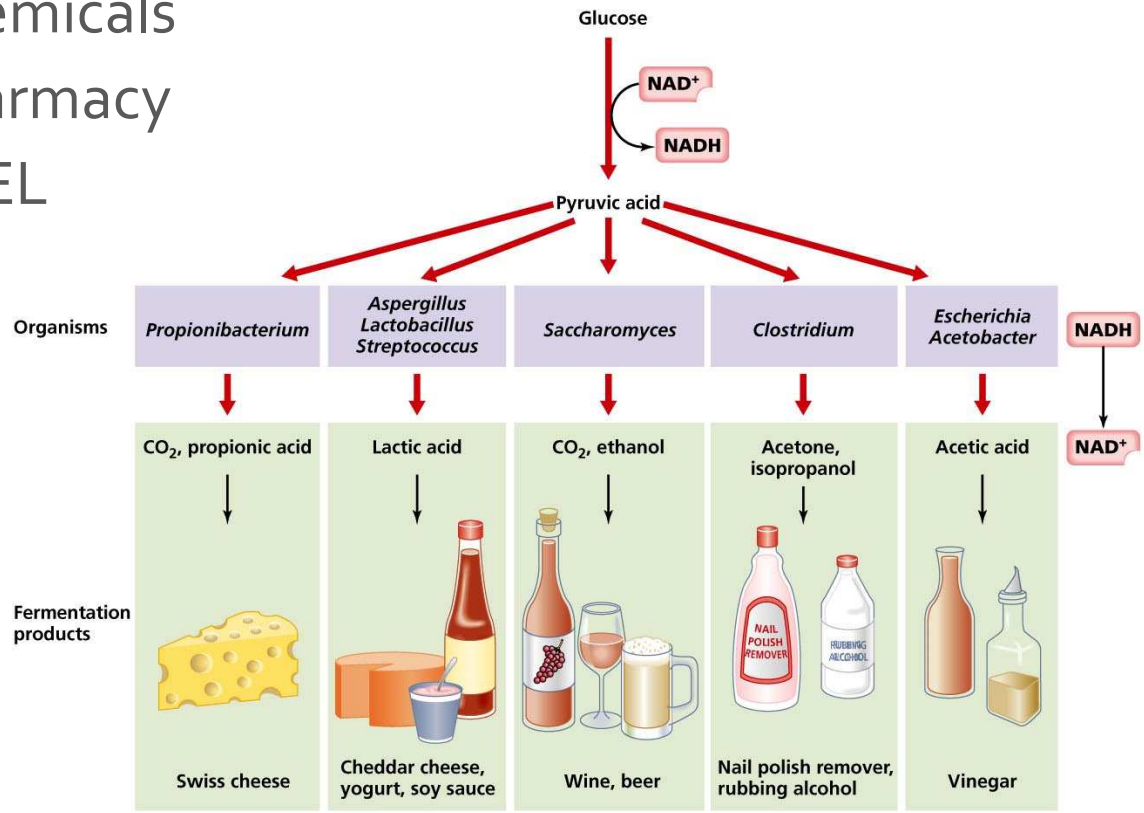
- Obtained with fermentation of sugars
- $C_2H_5OH$
- Current applications:

Food

Chemicals

Pharmacy

FUEL








Source:http://academic.pgcc.edu/~kroberts/Lecture/Chapter%205/fermentation.html

# Bioethanol

Compared to gasoline

## Advantages

- higher octane number
- broader flammability limits
- higher flame speeds
- higher heats of vaporization
- higher compression ratio
- shorter burn time

## Disadvantages

- lower energy density
- its corrosiveness
- low flame luminosity
- lower vapour pressure (difficult for cold starts)
- miscibility with water
- toxicity to ecosystems

# Bioethanol

Properties of ethanol, compared to other alcohol fuels (source: Balat, 2007)

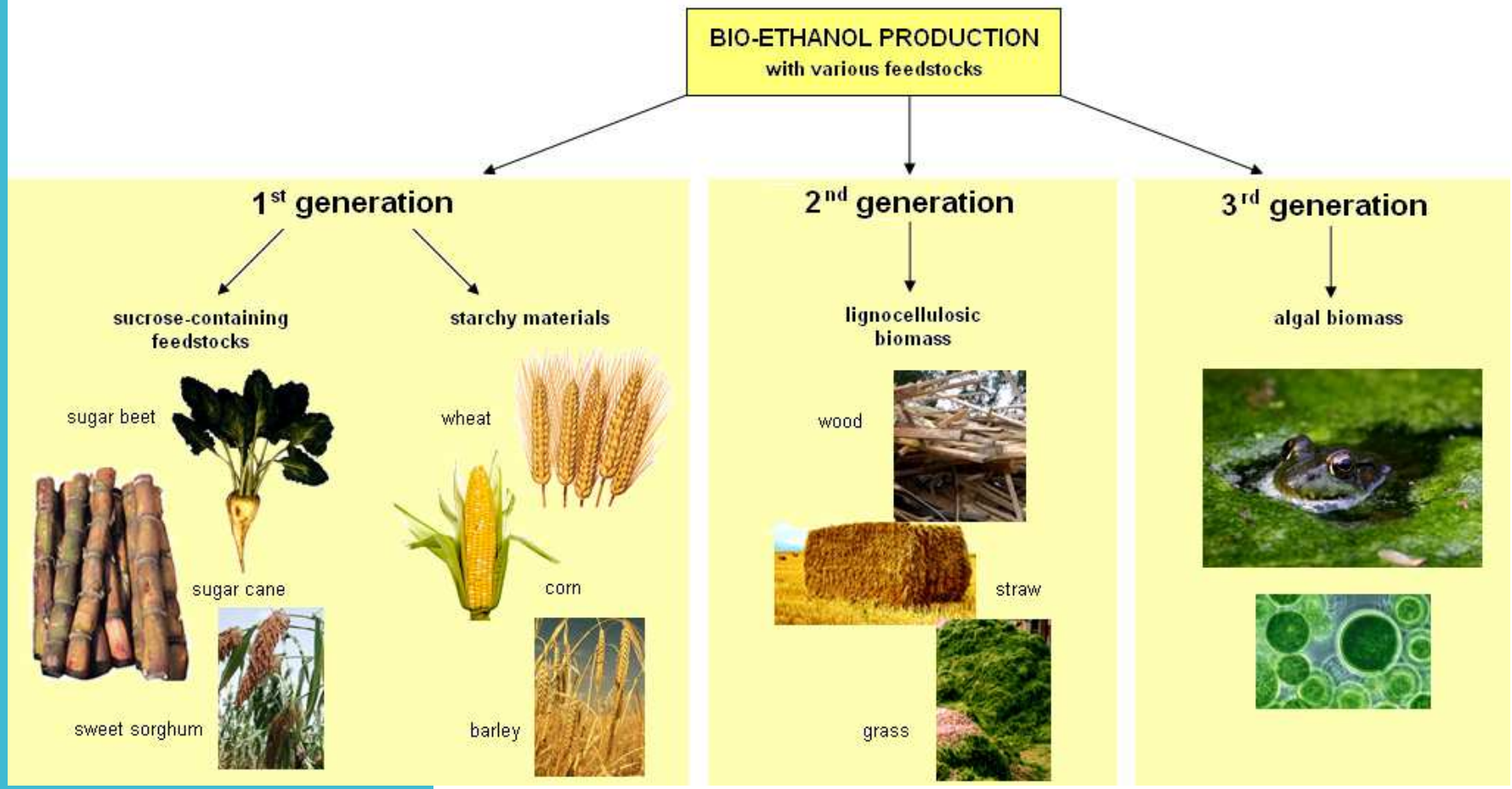
| Fuel property | Isoctane | Methanol | Ethanol |
|---|---|---|---|
| Cetane number | - | 5 | 8 |
| Octane number | 100 | 112 | 107 |
| Auto-ignitation temperature (K) | 530 | 737 | 606 |
| Latent heat of vaporization (MJ/Kg) | 0.26 | 1.18 | 0.91 |
| Lower heating value (MJ/Kg) | 44.4 | 19.9 | 26.7 |

# Bioethanol

- Hydrated form: 92.6 – 93.8 wt% – direct use as fuel
- Anhydrous form: 99.3 wt% – blended with gasoline

- Boiling point: 78.4°C
- Density: 0.789 g/cm$^3$

- Azeotropic point with water: 95 wt% at 1 atm (constant boiling point)




Source:http://www.responsiblebusiness.eu/display/rebwp7/Technology

# Bioethanol

| Feedstock | Bioethanol production potential (L/ton) |
|---|---|
| Sugar cane | 70 |
| Sugar beet | 110 |
| Sweet potato | 125 |
| Sweet sorghum | 60 |
| Potato | 110 |
| Cassava | 180 |
| Maize | 360 |
| Rice | 430 |
| Barley | 250 |
| Wheat | 340 |
| Cellulosic biomass | 280 |



Source:http://www.responsiblebusiness.eu/display/rebwp7/Technology

# Alcoholic Fermentation

- Anaerobic process that occurs in the cytoplasm of cells.
- One molecule of glucose is broken down into pyruvate

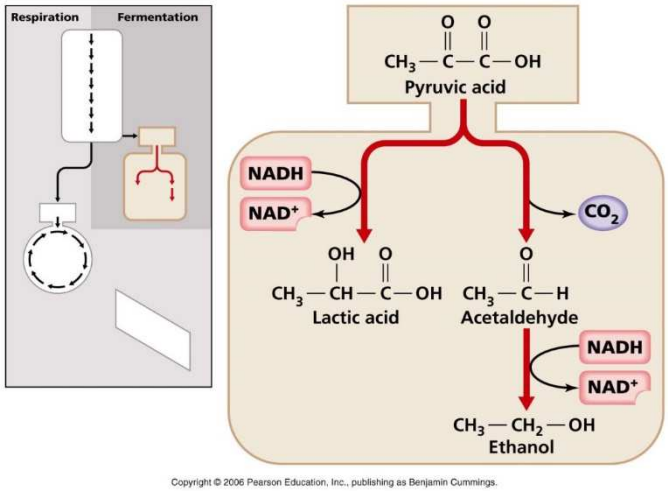
$$C_6H_{12}O_6 \rightarrow 2\ CH_3COCOO^- + 2\ H^+$$

…which is then convert
into acetaldehyde and
carbon dioxide

$$CH_3COCOO^- + H^+ \rightarrow CH_3CHO + CO_2$$

Subsequently, the acetaldehyde
is reduced to ethanol

$$CH_3CHO + NADH \rightarrow C_2H_5OH + NAD^+$$





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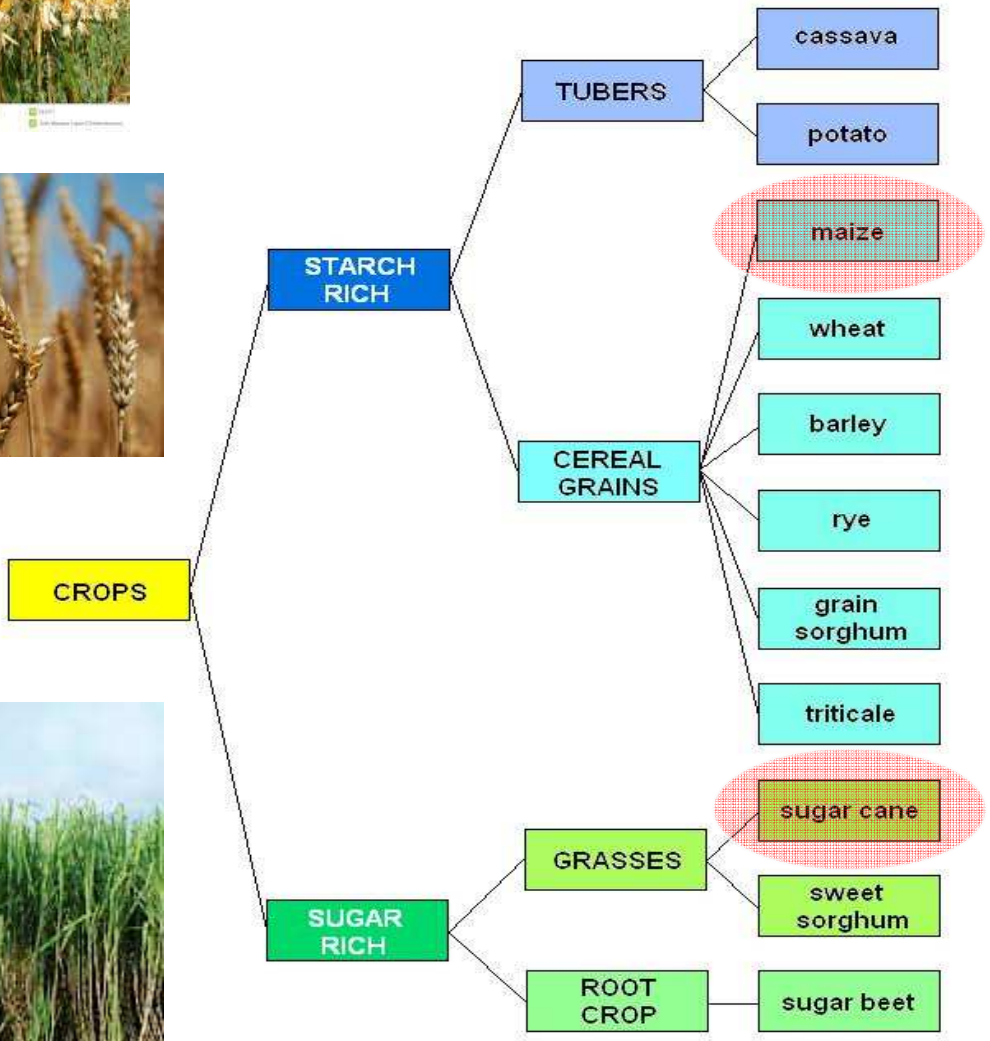
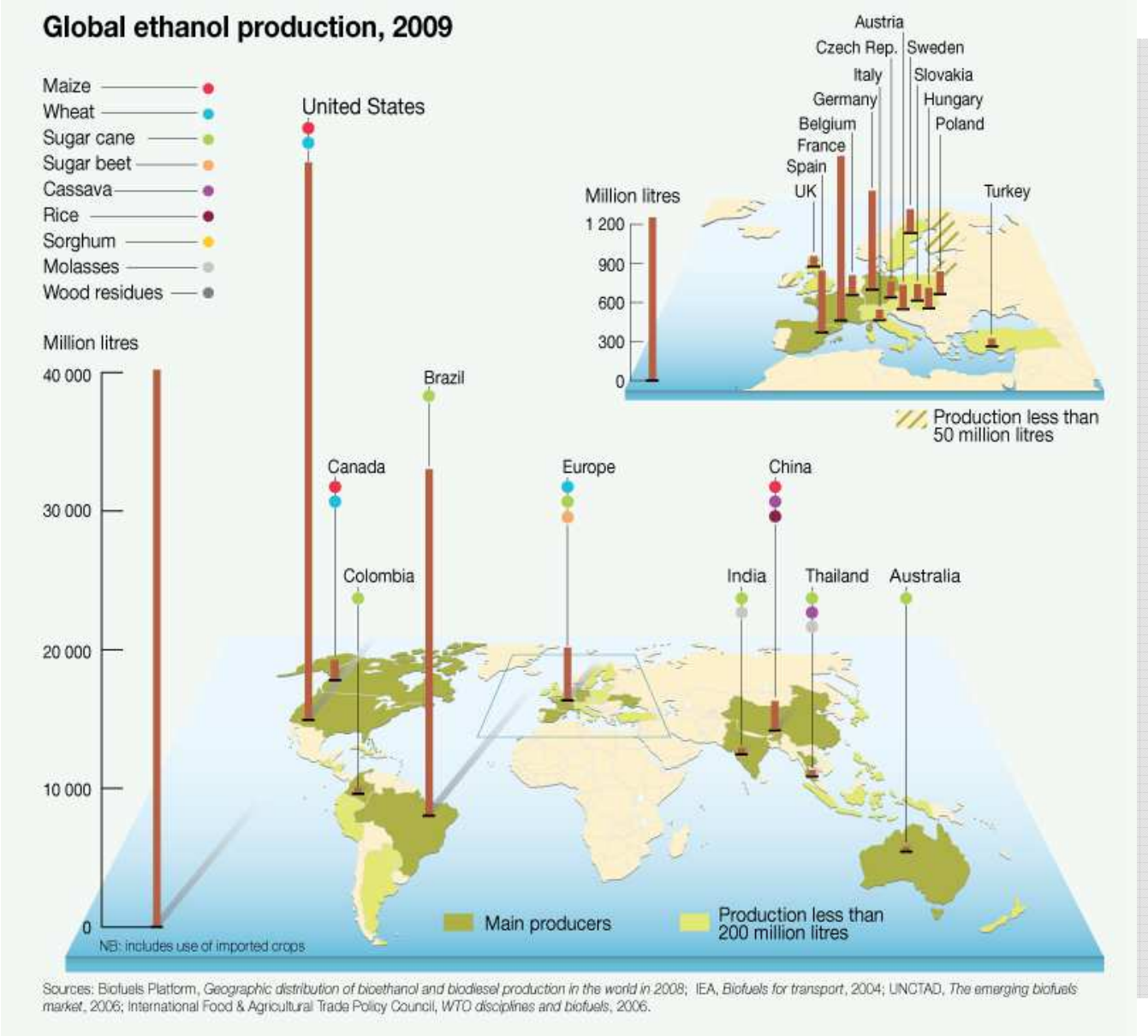
# Bioethanol

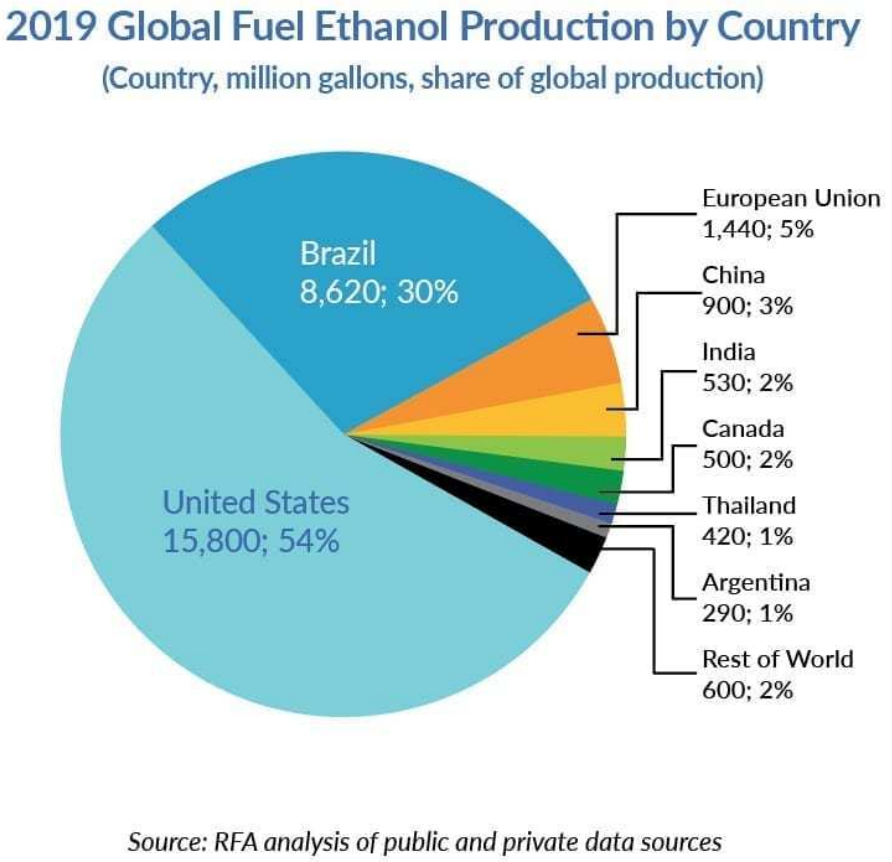
## Major feedstocks



# Bioethanol

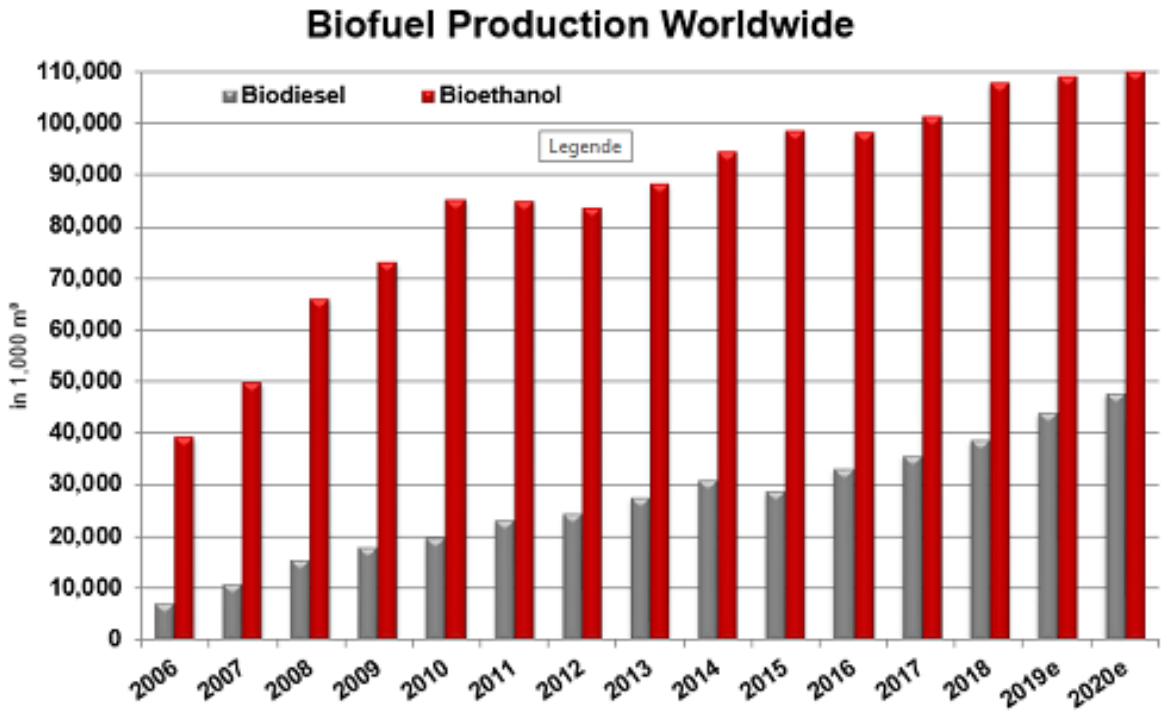

Global ethanol production, 2009
Maize
Wheat
Sugar cane
Sugar beet
Cassava
Rice
Sorghum
Molasses
Wood residues
Million litres
40 000
30 000
20 000
10 000
0
NB: includes use of imported crops
United States
Brazil
Canada
Colombia
Europe
China
India
Thailand
Australia
Austria
Czech Rep.
Sweden
Italy
Slovakia
Germany
Hungary
Belgium
Poland
France
Spain
UK
Turkey
Million litres
1 200
900
600
300
0
Production less than 50 million litres
Main producers
Production less than 200 million litres
Sources: Biofuels Platform, Geographic distribution of bioethanol and biodiesel production in the world in 2008; IEA, Biofuels for transport, 2004; UNCTAD, The emerging biofuels market, 2006; International Food & Agricultural Trade Policy Council, WTO disciplines and biofuels, 2006.

# Bioethanol




Source: https://ethanolrfa.org/exports-and-trade/

# Bioethanol


Biofuel Production Worldwide
Biodiesel
Bioethanol
Legende
in 1,000 m³
110,000
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019e
2020e

## Hypothetical potential for ethanol from principal cereal and sugar crops

| CROP | GLOBAL AREA | GLOBAL PRODUCTION | BIOFUEL YIELD | MAXIMUM ETHANOL | PETROL EQUIVALENT | SUPPLY AS SHARE OF 2003 GLOBAL PETROL USE[1] |
|---|---|---|---|---|---|---|
| | *(Million ha)* | *(Million tonnes)* | *(Litres/ha)* | *(Billion litres)* | *(Billion litres)* | *(Percentage)* |
| Wheat | 215 | 602 | 952 | 205 | 137 | 12 |
| Rice | 150 | 630 | 1 806 | 271 | 182 | 16 |
| Maize | 145 | 711 | 1 960 | 284 | 190 | 17 |
| Sorghum | 45 | 59 | 494 | 22 | 15 | 1 |
| Sugar cane | 20 | 1 300 | 4 550 | 91 | 61 | 6 |
| Cassava | 19 | 219 | 2 070 | 39 | 26 | 2 |
| Sugar beet | 5.4 | 248 | 5 060 | 27 | 18 | 2 |
| Total | 599 | ... | ... | 940 | 630 | 57 |

*Note:* ... = not applicable. Data presented are subject to rounding.
[1] Global petrol use in 2003 = 1 100 billion litres (Kim and Dale, 2004).
*Source:* Rajapogal *et al.*, 2007.

Source: FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2008 The state of food and agriculture, 2008 **BIOFUELS: prospects, risks and opportunities.**

# Bioethanol

USA : bioethanol is mainly used as a 10% petrol additive (E10).
Introduction of E15 in January 2011.

Brazil : offered both as a pure fuel (E100) and is blended with conventional petrol with a content of 20 to 25 vol.-%.

Roughly 90% of the new vehicle registrations in Brazil are Flexible Fuel Vehicles (FFVs) which can run on regular petrol, bioethanol or a mixture of both.

Europe : Biofuels directive of 2003 (both the use and the production of bioethanol have been rising steadily in the EU).

"Renewable Energies Directive" (blending rate of 10% in the transport sector by 2020).

About 15 million $m^3$ are expected for 2020.



Source: http://www.cropenergies.com