

Biomass / Biodiesel / Ethanol

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BIO / EES 105 – Energy in
Our World



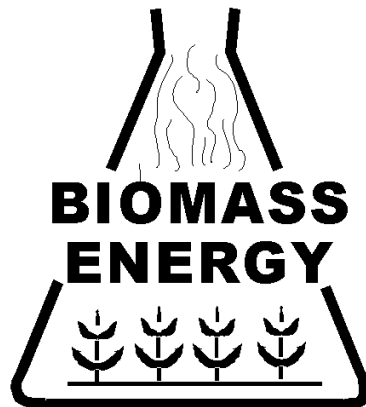
Overview

- All utilize energy fixed by photosynthetic reactions
 - $\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + \text{O}_2$
 - Sugar is an energy-rich molecule
 - Can be converted into starch, lignin, lipids, ethanol
 - Combustion releases energy for heating, electricity, transportation fuel



Attractive as an energy source

- Based on recent (not ancient) photosynthesis
- Combustion does not contribute net addition to atmospheric CO₂
- Supplies will not run out – thus sustainable



Topics to be discussed

- Presentation I: Biomass
 - Forms
 - Utilization
 - Benefits and drawbacks
- Presentation II: Biodiesel
 - What is it?
 - How made
 - Utilization
 - Benefits and drawbacks
- Presentation III: Ethanol
 - What is it?
 - Grain vs cellulosic
 - Utilization
 - Benefits and drawbacks



Biomass energy

- Direct use of organic material
 - Harvested plant material
 - Waste material
 - Pulp manufacturing
 - Municipal waste
 - Animal wastes
- Combustion for heat
 - Dried solids
 - Gasses



Plant derived biomass

- Material derived from woody or herbaceous plants
- Typically requires physical conversion
 - Cutting
 - Drying
 - Compressing
- Chemical conversion is minimal
- Used for millennia through burning wood
- Current techniques involve compressing herbaceous material

Wood as biomass

- Derived from trees and other long-lived plants



<http://www.calmexfireplaces.com/images/logs-without-flame.jpg>

Wood as biomass

- Processing involves timbering, drying, cutting into logs, and perhaps chipping
 - Thus, often easier to transport and use than herbaceous plant matter



<http://thetyee.cachefly.net/Opinion/2009/07/15/loggingtruck.jpg>



http://www.lanl.gov/orgs/pa/newsbulletin/images/Firewood_Giveaway.jpg

Wood as biomass

- Not all trees are equal
 - Growth rate
 - Wood density
 - Additional compounds in wood



Each species has unique geographic distribution



Baobob Tree in Hawaii



Spruce Trees in Maine

Some areas (tundra, grasslands, desert) not forested



Once cut, trees take a long time to regrow.



<http://pubs.usgs.gov/sir/2007/5011/images/coverphoto.jpg>

Tree species often used for biomass



Eucalyptus



Willow



Poplar

Herbaceous plants as biomass

- Based mainly on stems and leaves
- Derived from grasses and herbs



Herbaceous plants as biomass

- Processing involves cutting, drying, and perhaps pelletizing
 - Not as convenient to transport as wood



<http://www.abe.msstate.edu/Biomass/images/gasifierpics/Chips&Pellets.jpg>

Herbaceous plants as biomass

- Look for rapid growth and high density foliage



<http://www.ncagr.gov/Research/images/switchgrass.jpg>

Herbaceous plants as biomass



<http://www.oh.nrcs.usda.gov/>



<http://www.sbp.de/de/html/>

- Grow best in grasslands
 - Need ecosystem disturbance to grow in otherwise forested areas
 - Need irrigation to grow in deserts, scrublands
 - Amenable to cultivation in greenhouses

Herbaceous species used in biomass

Miscanthus



<http://www.michelleworld.com/images/plants/Miscanthus%20sinensis%20%27Giganteus%27.jpg>

Switchgrass



[http://nybiofuels.info/generalInformation/biomass/PublishingImages/switchgrass%20\(Small\).JPG](http://nybiofuels.info/generalInformation/biomass/PublishingImages/switchgrass%20(Small).JPG)

Additional considerations



- Ability to accumulate biomass amenable to breeding
- Biomass cultivation viewed as beneficial use of severely disturbed lands

Other forms of biomass

- Waste from pulp manufacturing
 - High in cellulose
 - Used to make electricity through steam production



Other forms of biomass

- Municipal waste
 - Contains paper, wood, food waste, other organics
 - Incineration yields energy
 - Landfill waste yields natural gas.



Other forms of biomass

- Agricultural waste
- Methane from farm animals
 - 280 L / cow / day (http://www.riverdeep.net/current/2002/03/032502t_cowpower.jhtml)

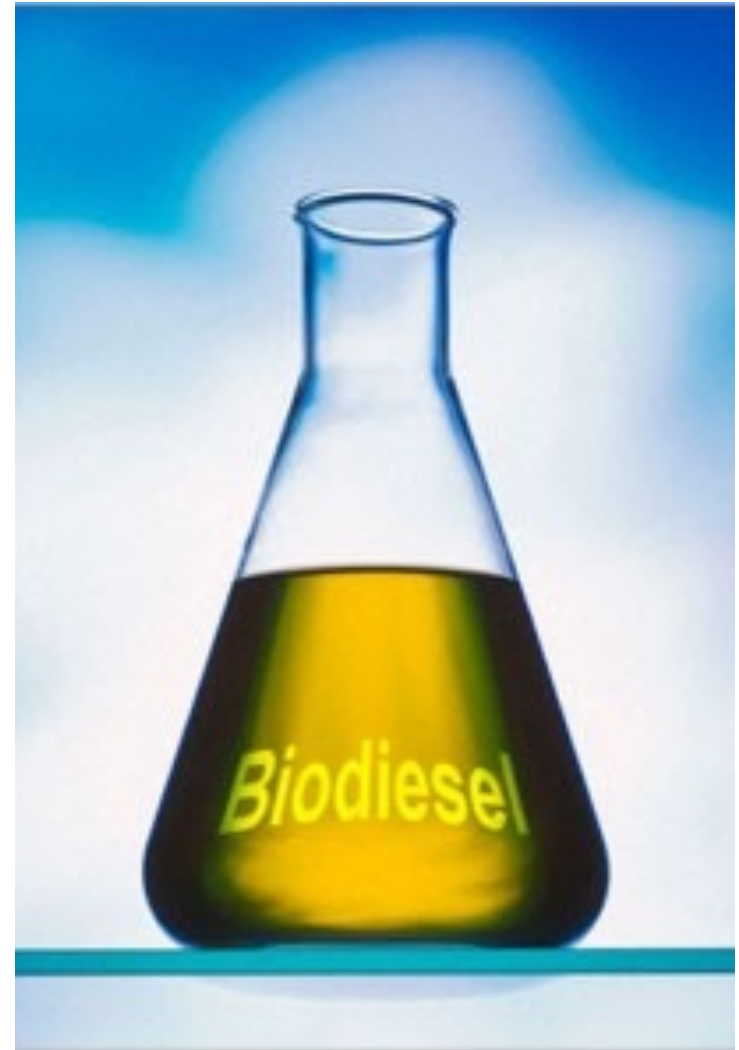


Biodiesel



What is Biodiesel?

- Liquid fuel used to power diesel engines and electrical generation equipment
- Produced by chemically combining a lipid with an alcohol (transesterification reaction)
 - Byproduct is glycerin, used to make soaps, cosmetics, medicines
- Often blended with petroleum-based diesel
 - B30 is 30% diesel



Source material for biodiesel

- Fats of biological origin
 - Plants (mainly seeds)
 - Animal tallow
 - Algae (maybe)
- Can be created by processing food wastes
- How to make



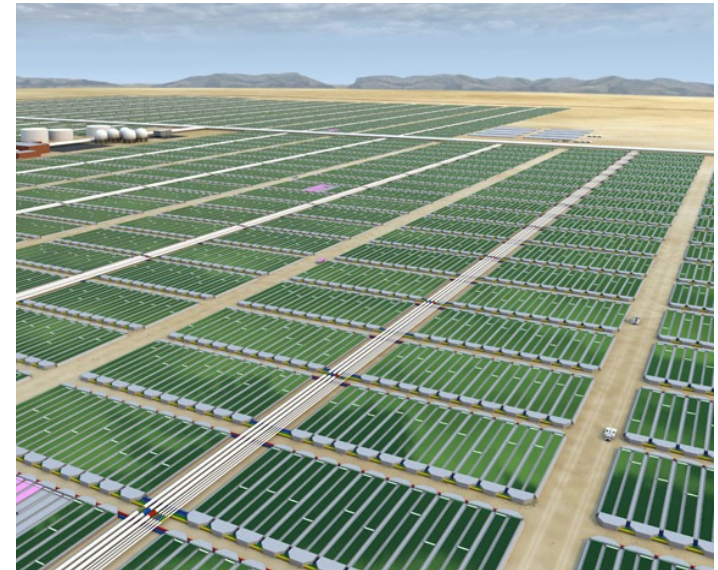
http://blogs.seattleweekly.com/dailyweekly/biodiesel_flowers_websize.jpg

Energy from Algae

- Algae are diverse producers
 - Some freshwater, others saltwater
 - Some microscopic, others large
- Can be cultivated
- Produce oils and other chemicals for fuels

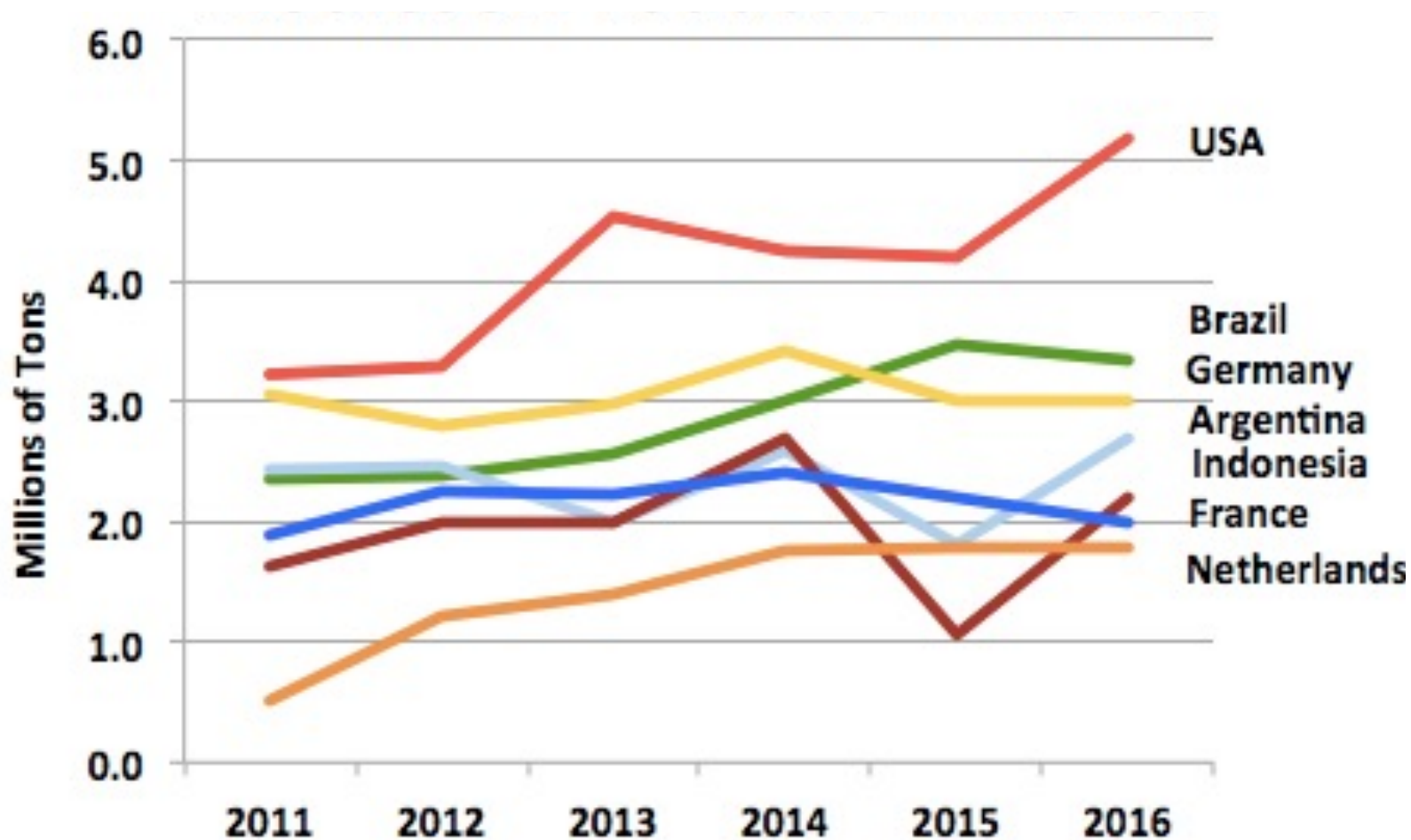


<https://energyeducation.ca/encyclopedia/Algae>



<https://www.lowtechmagazine.com/2008/04/algae-fuel-biof.html>

Biodiesel Production Trends



Advantages of using biodiesel

http://www.biodiesel.org/resources/Biodiesel_basics/

- Not based on fossil fuels
- Lower emissions
- Non-toxic
- Safe to handle
- Useful for all diesel engines
- Biodegrades readily



<http://cdn-www.greencar.com/images/biodiesel-facts/biodiesel-station.jpg>

Disadvantages of using biodiesel

<http://www.fueleconomy.gov/FEG/biodiesel.shtml>

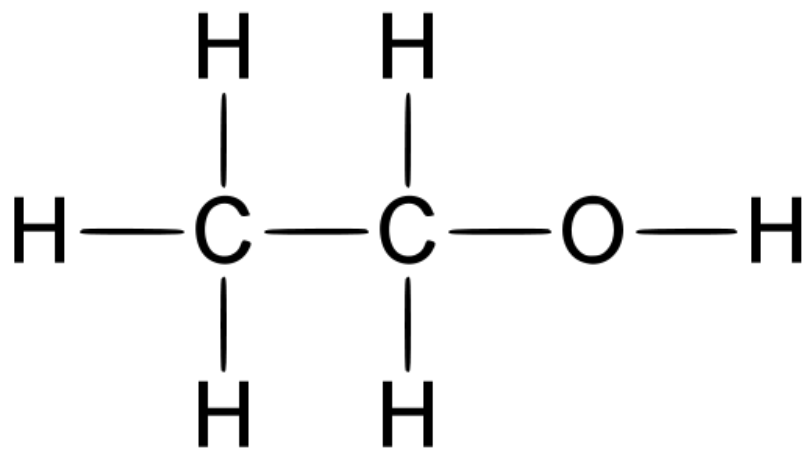
- Use of blends above B5 not yet warrantied by auto makers
- Lower fuel economy and power (10% lower for B100, 2% for B20)
- Currently more expensive
- More nitrogen oxide emissions
- B100 generally not suitable for use in low temperatures
- Concerns about B100's impact on engine durability

Ethanol



Ethanol

- Relatively small organic molecule
 - $\text{C}_2\text{H}_5\text{OH}$
 - Liquid at normal temperatures and pressures



Producing ethanol

- Produced by processing sugars
 - Anaerobic conditions
 - Fermentation
 - Distillation
- Distillation requires heating fluid, which requires energy



Ethanol can be used to power internal combustion engines

- Most gasoline engines will run on ethanol, though less efficiently
- Easily run on blends (E20 is common)
- E85 used by Flex-Fuel vehicles, with sensors that detect alcohol content.



Ethanol is derived from three starting materials



Simple sugars (beets, cane)



Starch (grains, tubers)



Cellulose (leaves, stems)

Where does ethanol come from?

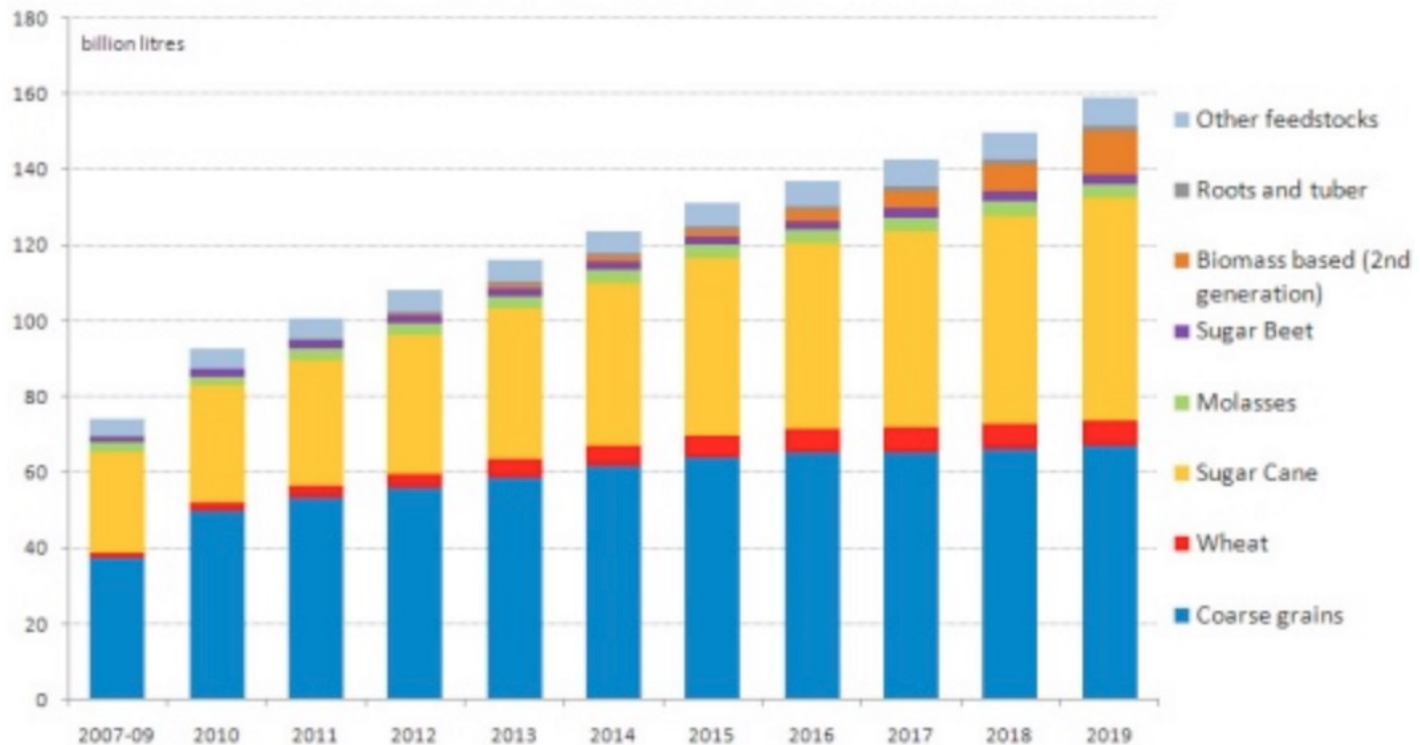


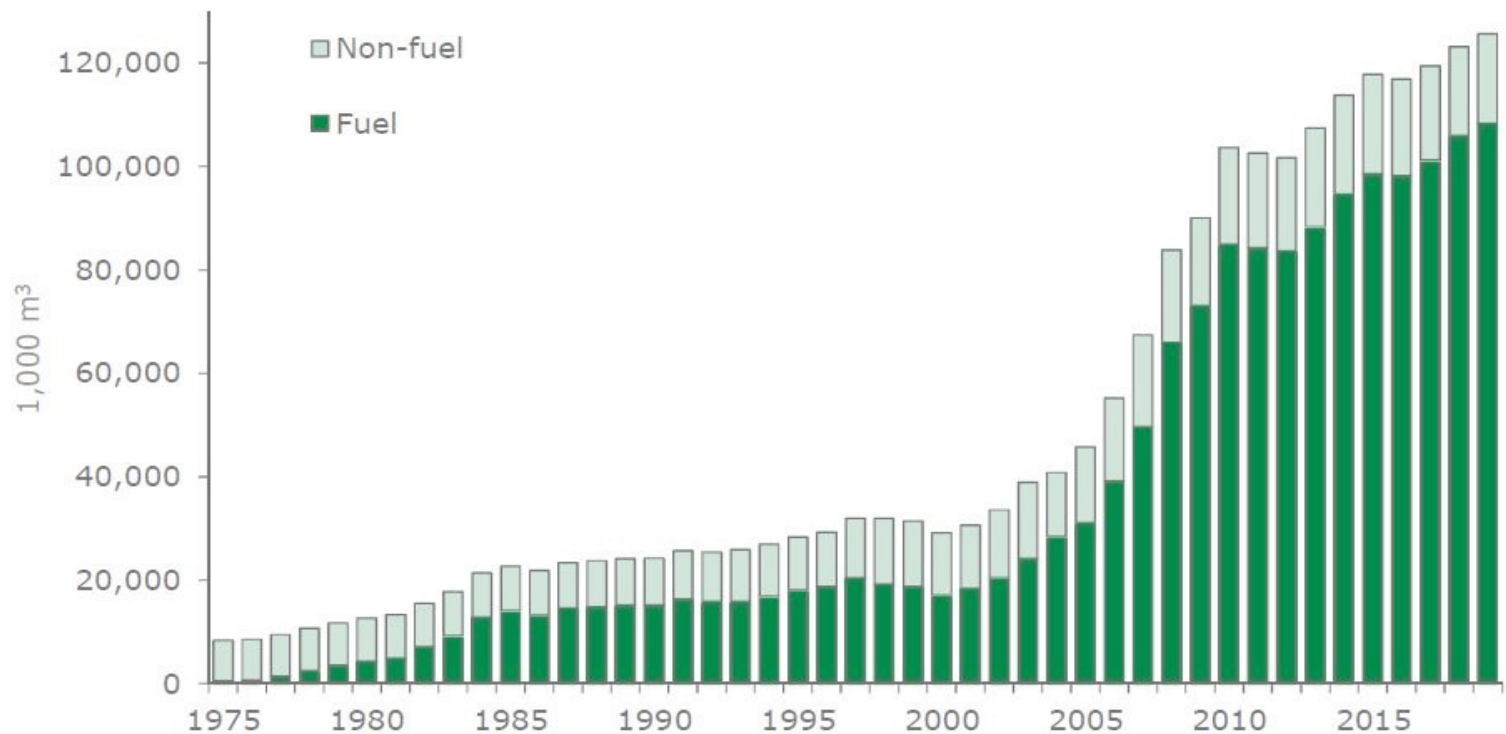
Figure 11.1: Global ethanol production by feedstock from 2007-2019.

Source: [The Crop Site](#)

World Ethanol Production (1975-2019)

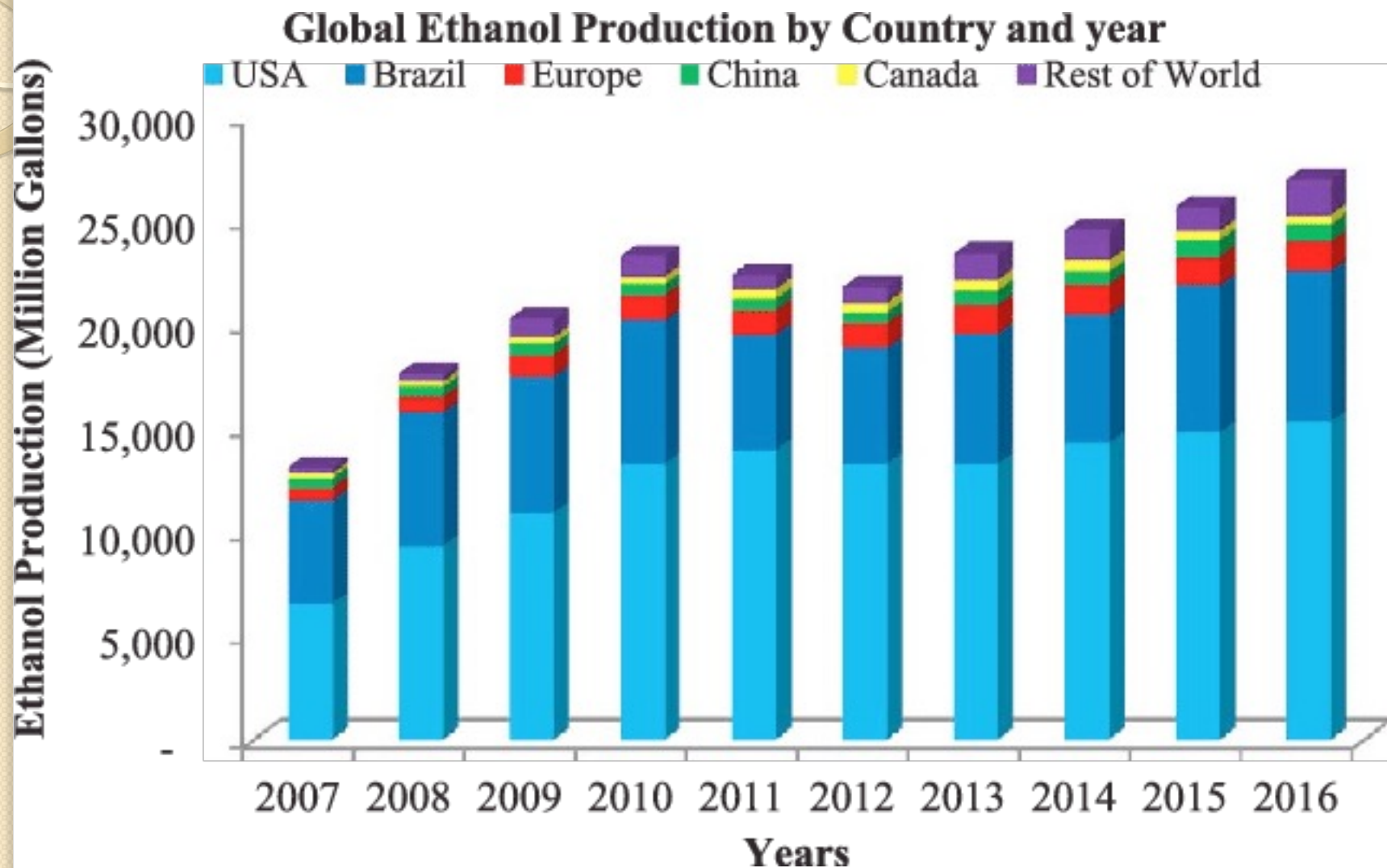
Million Liters

World Ethanol Production



Licht Interactive Data

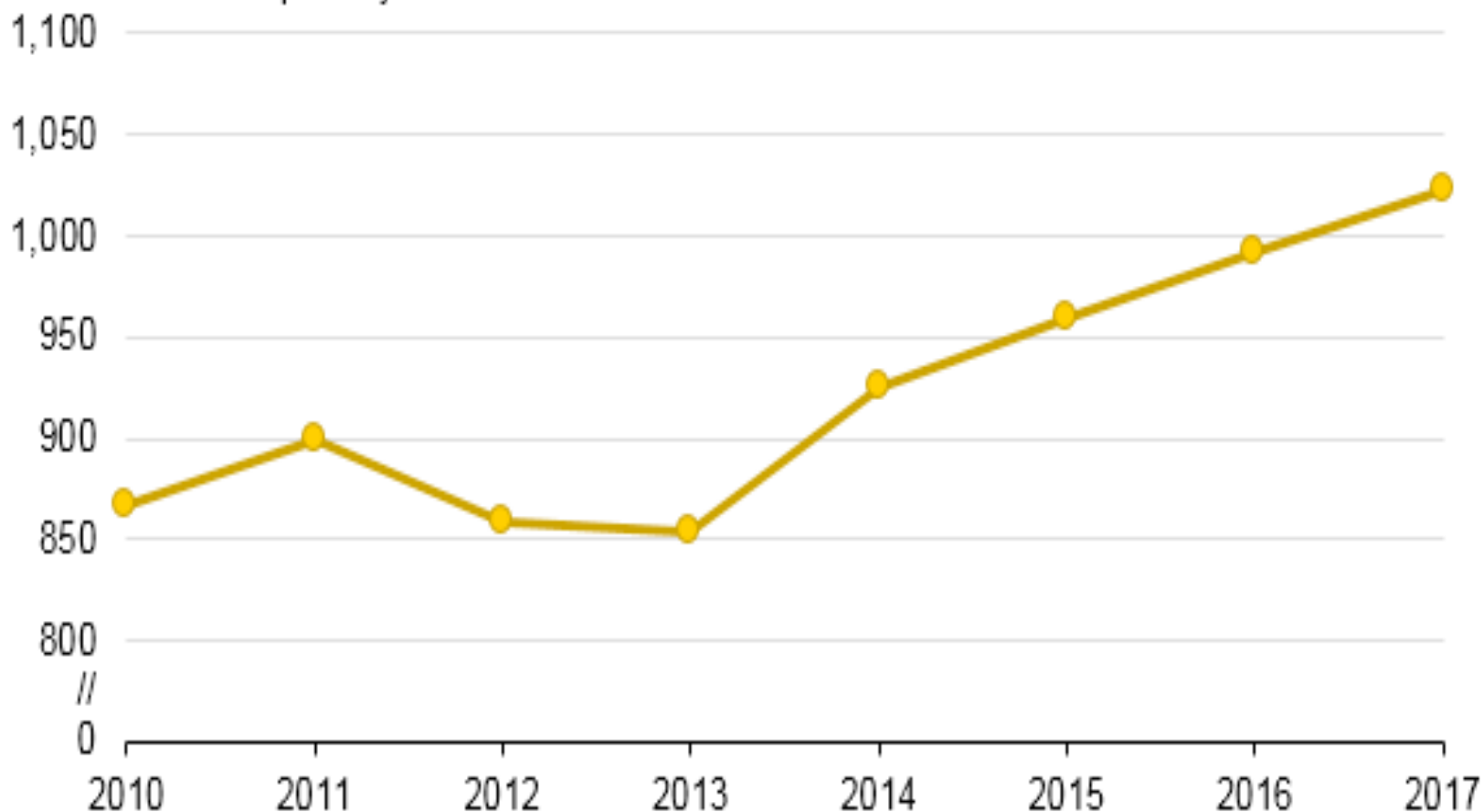
Global leaders in ethanol production



US Ethanol production (2010-2017)

U.S. ethanol production (2010-2017)

thousand barrels per day



Where would cellulosic ethanol come from?



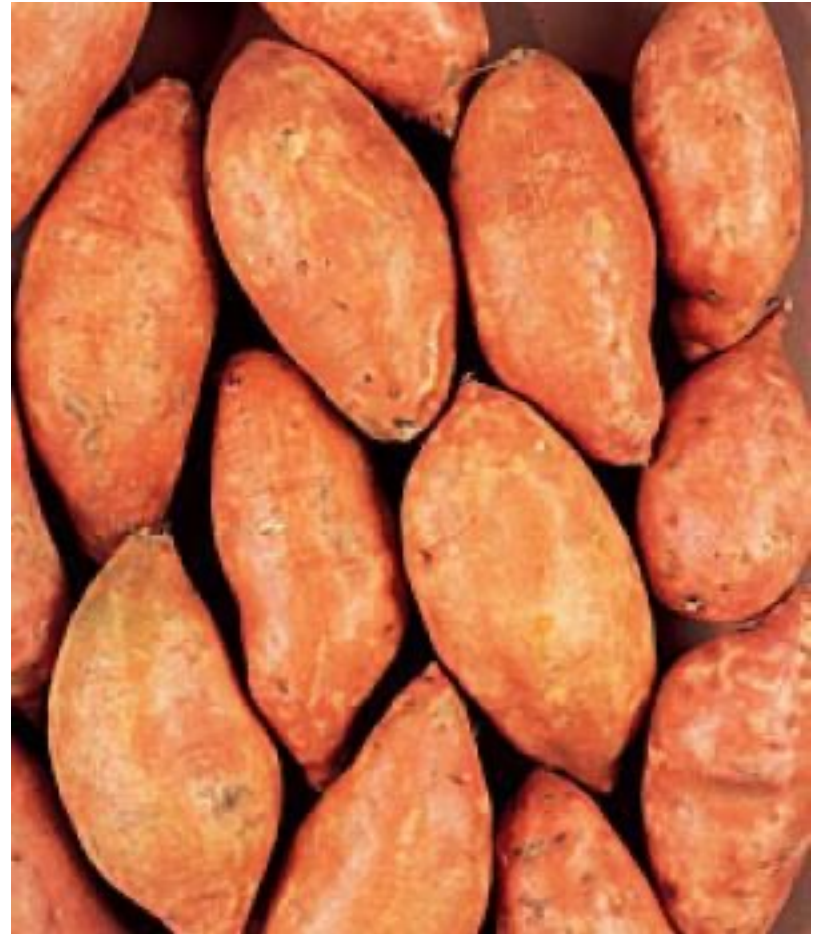
Issues relating to use of simple sugars

- Relatively little post-extraction processing needed
- Production best in tropical countries
 - Brazil nearly energy independent



Issues relating to use of starches

- Post-extraction processing simple
 - Need amylase
- Depends on materials normally used as food
 - Amenable to cultivation
 - Concern over diverting resource from food supply to energy supply
 - Concern over energy yield



Issues relating to use of cellulose

- Any plant material is potential source
- Creating source sugar more challenging
 - Macerate harvested material
 - Treat material with cellulase enzyme
 - Not really proven



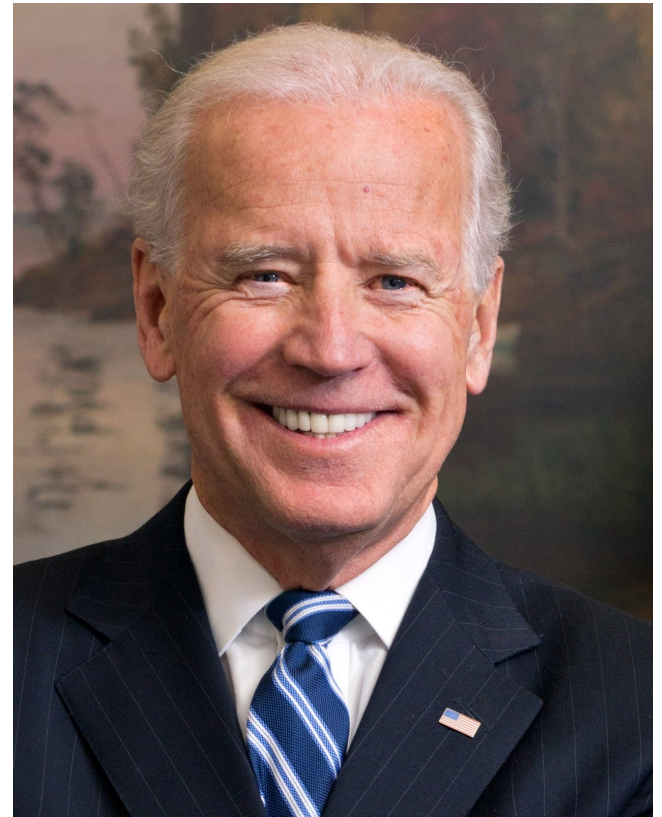
Benefits of biomass / ethanol.

- Not fossil fuels
- No radioactivity
- More reliable than wind or solar

Drawbacks of biomass / ethanol.

- Low energy yield compared to inputs
- Extensive land use
- Fertilizers energy expensive, environmentally damaging

Trump vs Biden on Biomass



Did their policies differ?
Was it an issue?