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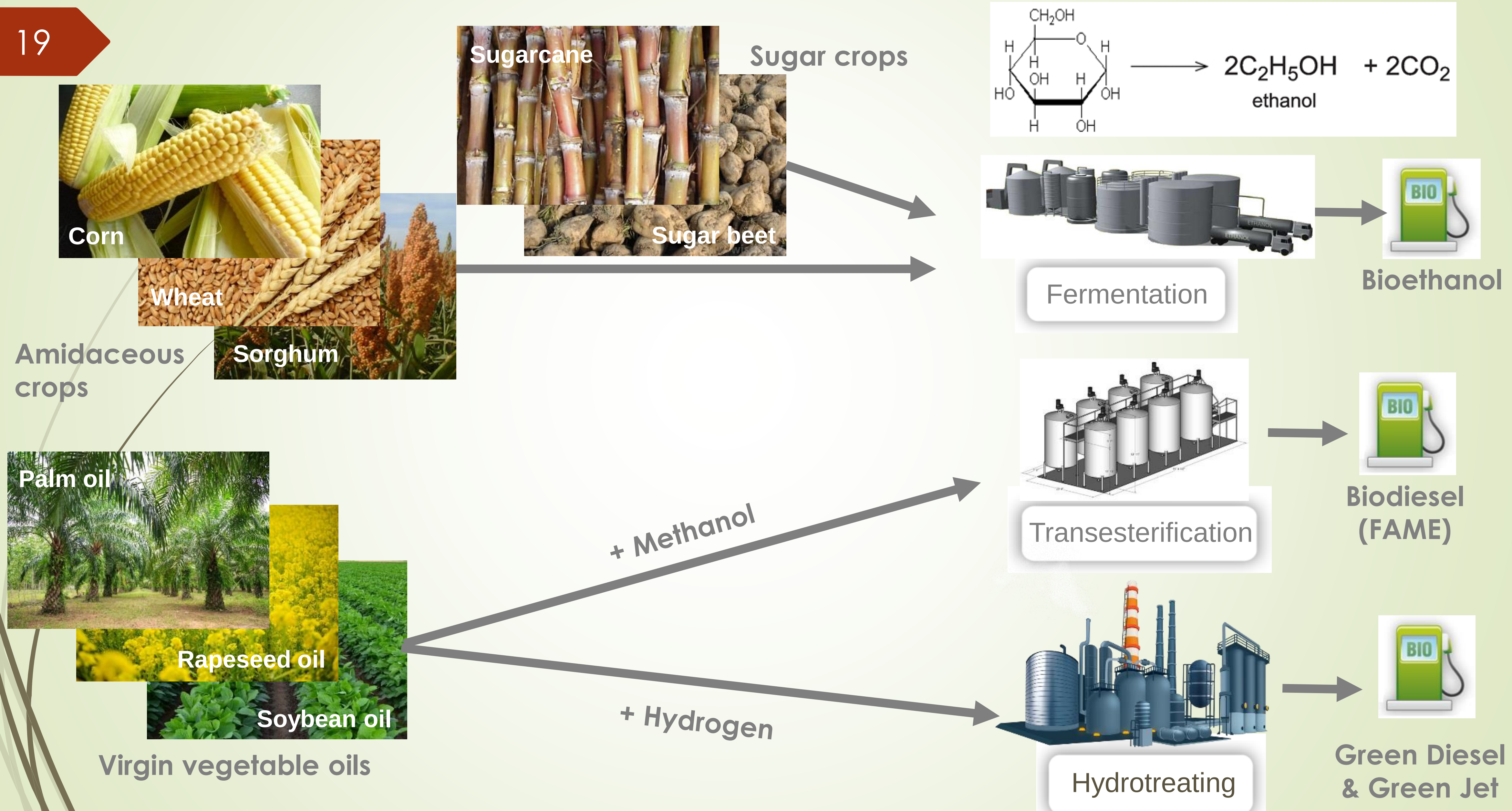
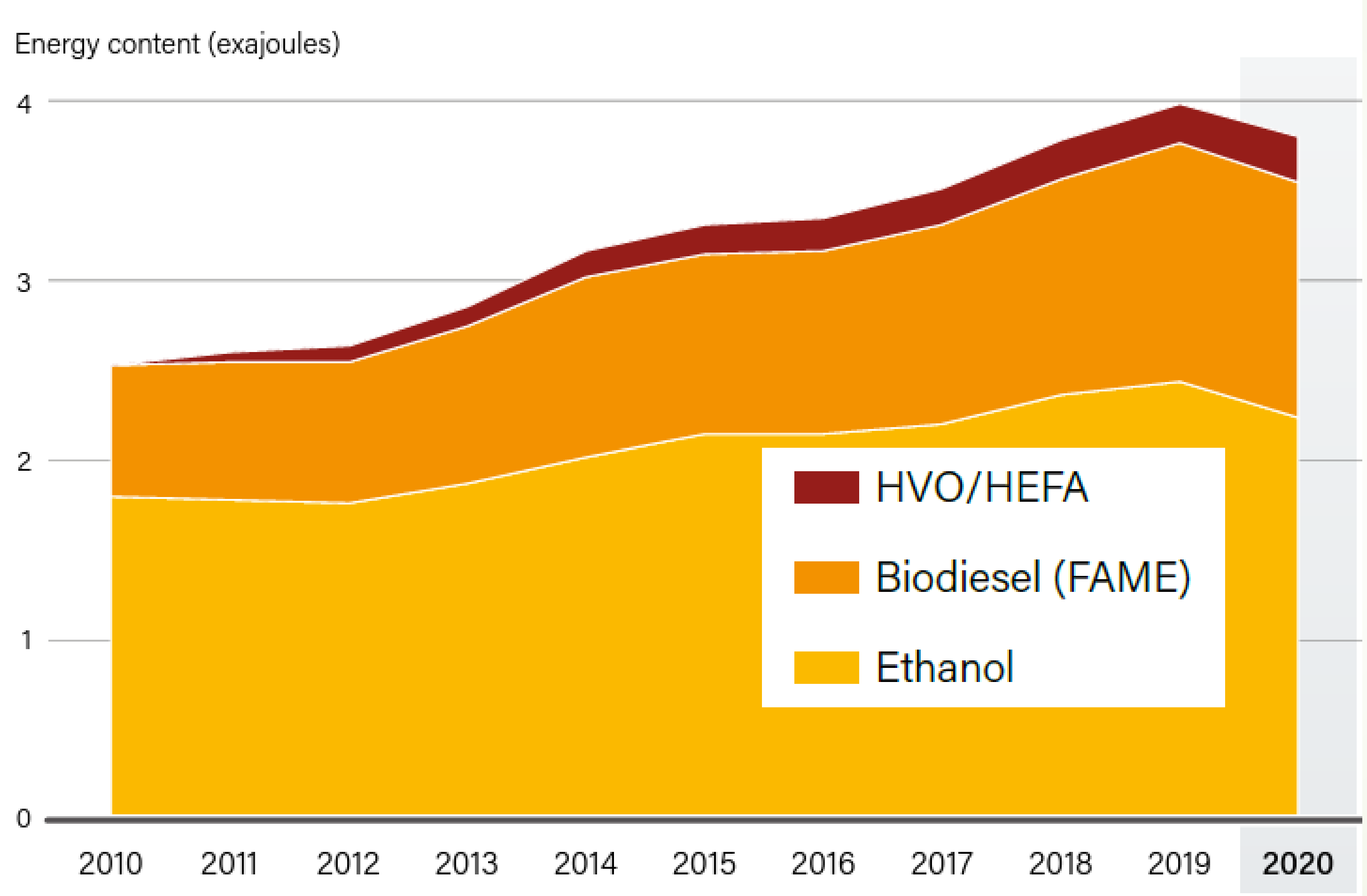
First generation biofuels



Available biofuels

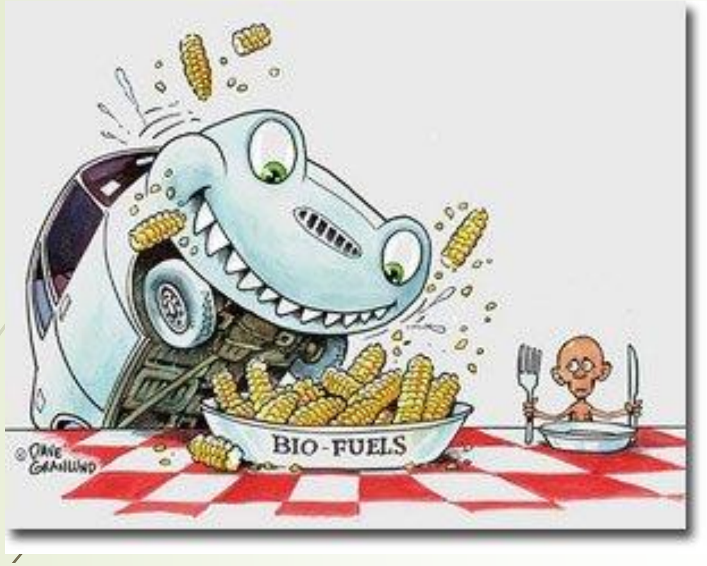


Source: REN21 Renewables 2021 Global Status Report

3,8 EJ = 152 billion litres

- Biomethane and advanced biofuels are only 1% of biofuels production.
- 3,7 % of overall transport fuel
- Biofuels production and is geographically concentrated in United States (53 billion litres of EtOH) and Brazil (34 billion litres of EtOH)
- Biodiesel is manly concentrated in Europe
- Most of them are 1st generation biofuels produced from:
  - corn
  - sugarcane
  - rapeseed oil
  - palm oil

Biofuels vs Food – The Ethical Dilemma?



- With over 7 billion mouths to feed in this world, is it right to be redirecting farmland from growing food to supplying feedstock for biofuels?
- The dilemma is exacerbated by the fact that the most highly impacted are the people of poor third world countries.
- But not everywhere the problem has the same impact.

'Diesel vs doughnuts': new biofuel refineries squeeze US food industry (Financial Times, September 8, 2021)

- "We support renewable fuels and the green agenda, but soyabean oil [prices] have tripled. Our members are worried that they may not be able to buy any oil," said Robb MacKie, chief executive of the American Bakers Association.

Biofuels and geopolitics

Ethanol: The Fuel That Powers Putin

Ending America's foolish subsidies for ethanol could aid Ukraine.

By David Frum

The Atlantic, March 14, 2022

The United States is supporting Ukraine with aid and weapons and punishing Russian aggression with financial and economic sanctions. But the United States can do more to resolve the global crisis caused by the Russian invasion of Ukraine: It can end the ethanol program.

https://www.theatlantic.com/ideas/archive/2022/03/gas-prices-ethanol-subsidies-putin/627053/

Biofuels and geopolitics

23

Food vs fuel: Ukraine war sharpens crop use debate (Financial Times, 12 June 2022)

Between them, Russia and Ukraine produce nearly a fifth of the world's corn and more than half its sunflower oil, but crop exports from the countries are at a fraction of prewar levels. Hundreds of millions of people are at risk of "hunger and destitution" because of food shortages caused by the war, the UN's secretary-general warned last week.

The total amount of crops used annually for biofuels is equal to the calorie consumption of 1.9bn people, according to data firm Gro Intelligence, highlighting the volume of agricultural commodities that could be diverted from energy use if the food security crisis worsened.

In the EU, Belgium and Germany are considering easing biofuel blending mandates to address food security.

The International Energy Agency cut its biofuels growth forecast for this year by 20 per cent, forecasting global demand to increase 5 per cent from 2021 to 8.5bn litres.

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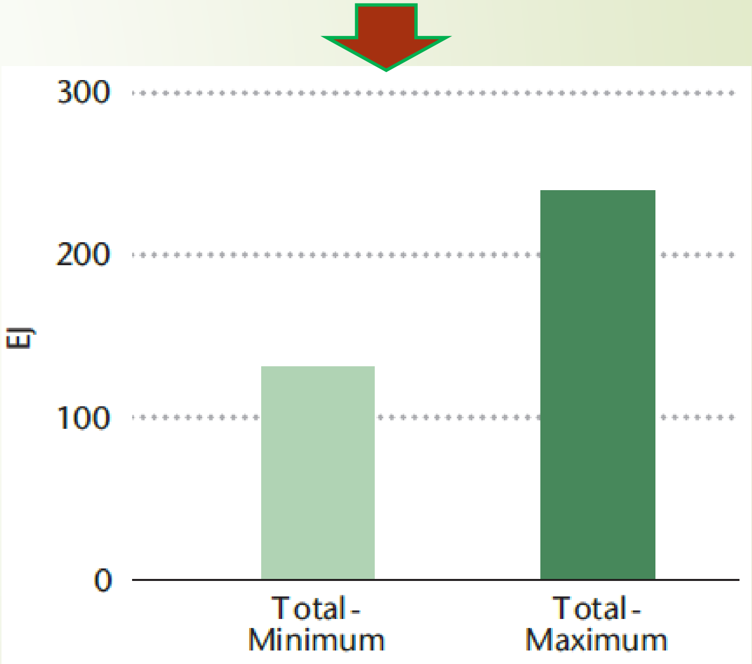
Waste and low-ILUC biomass

Summary of sustainable biomass availability

Bioenergy resource	*Conditions for sustainability*	*Potential (EJ)*
Agricultural wastes, residues and processing residues from wood and agro-industry	Respecting the need to reserve some of the available resource for animal feed and to leave sufficient residues in the field for soil protection, and consistent with other uses.	46-95
Wood harvesting residues co-products	Used within the context of a sustainable forestry plan, which takes carbon aspects fully into account, along with measures to maintain other forest characteristics including biodiversity.	15-30
Agriculture (**Low-ILUC**)	Produced on land in ways which do not threaten food availability and whose use leads to low land use change emissions, and subject to a positive assessment on other sustainability indicators such as biodiversity and water availability and quality. Crop or forestry production on degraded and derelict land linked to attempts to afforest, reforest or otherwise improve the quality of these areas.	60- 100
Municipal wastes	Taking account of the waste management hierarchy, which favours waste prevention and minimisation and recycling, and evolution of waste management systems in economies as they develop.	10-15

Recent assessments indicate that at least 100 EJ could be available in 2050 or 2060, and that potentials within the 130-240 EJ range may still be considered reasonable, although the risks of delivery of sustainable feedstock increase as the estimate rises

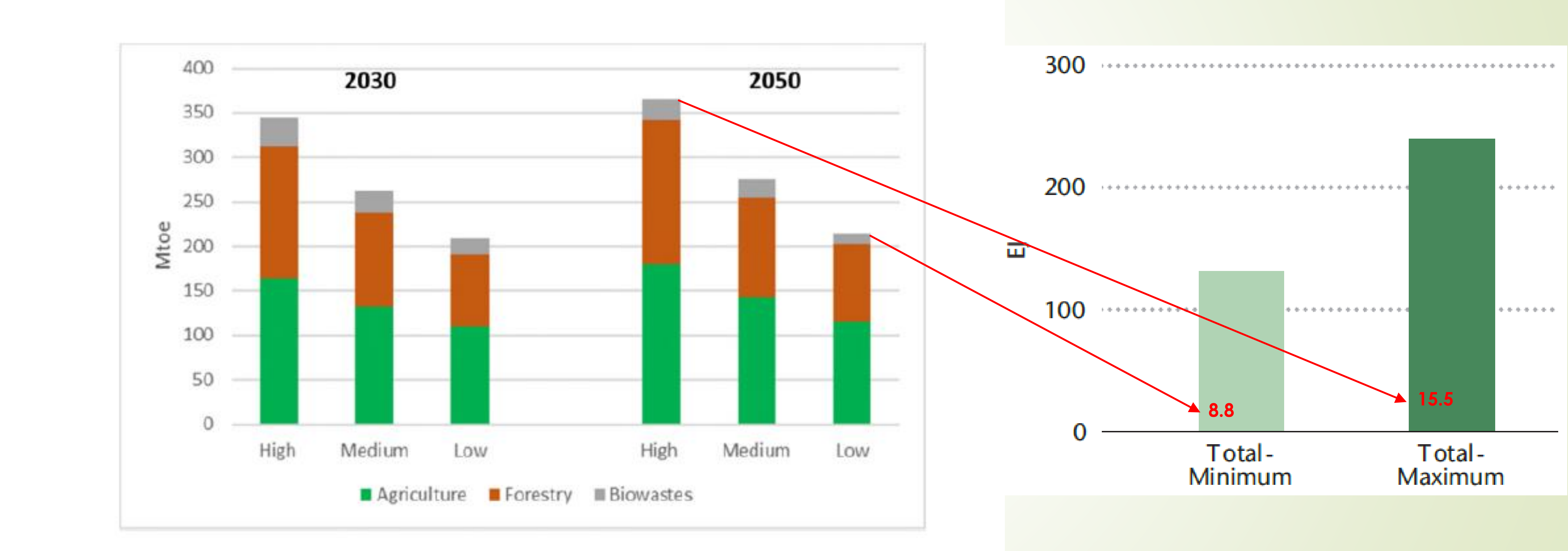


Source: **IEA** -Technology Roadmap - Delivering Sustainable Bioenergy Report 2017

Sustainable biomass availability in EU 27 (+UK)

Feedstocks as mentioned in RED II Annex IX Part A and B) for bioenergy

Summary of world of sustainable biomass availability

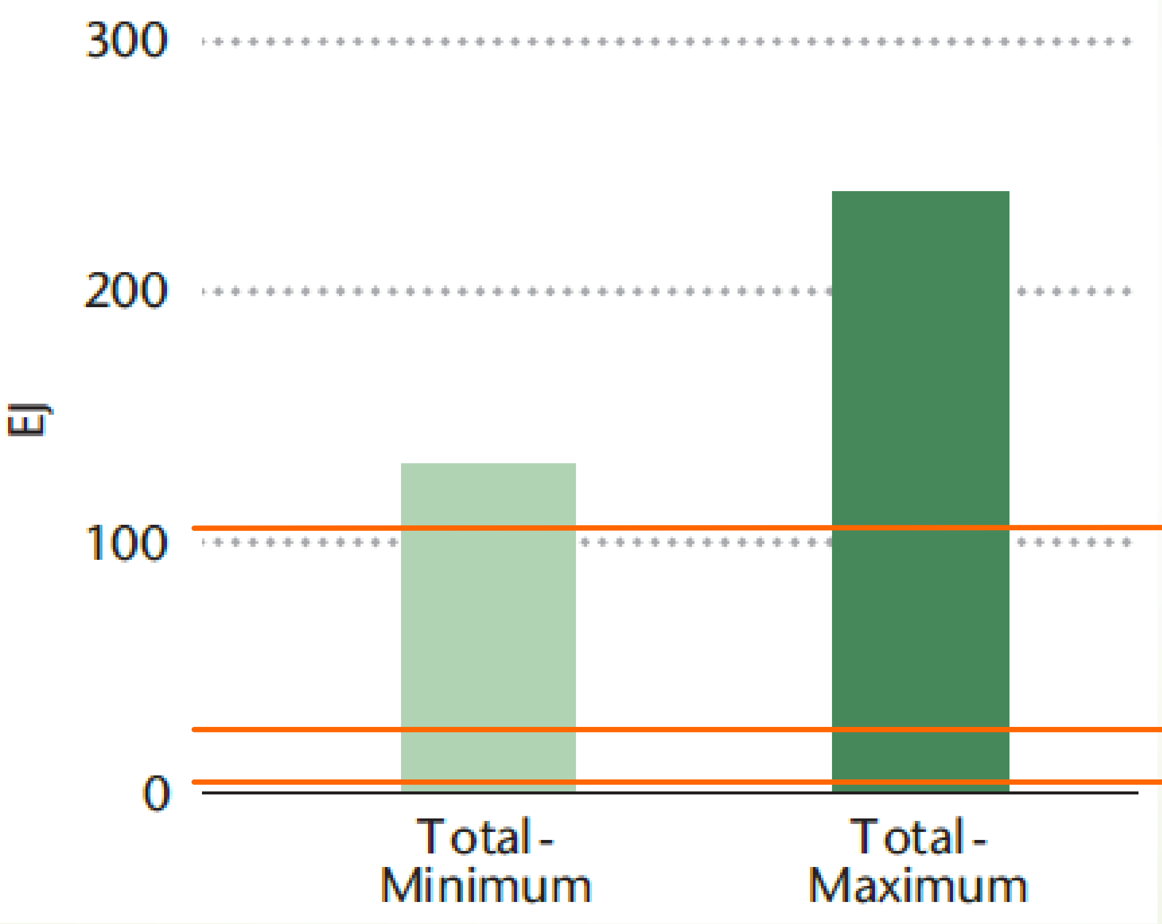


Source: Imperial College London, Sustainable biomass availability in the EU, to 2050, Concawe, August 24, 2021.

Source: IEA -Technology Roadmap - Delivering Sustainable Bioenergy Report 2017

Waste and low-ILUC biomass

Summary of sustainable biomass availability



~587 EJ
2020 World primary energy supply

102 EJ
2050 bioenergy contribution according to Net Zero by 2050 - IEA 2021

23 EJ
2050 biofuel contribution according to Net Zero by 2050 - IEA 2021

3.8 EJ
2020 biofuel contribution to transport sector (*)

(*) WEO IEA 2021

Source: **IEA** -Technology Roadmap - Delivering Sustainable Bioenergy Report 2017

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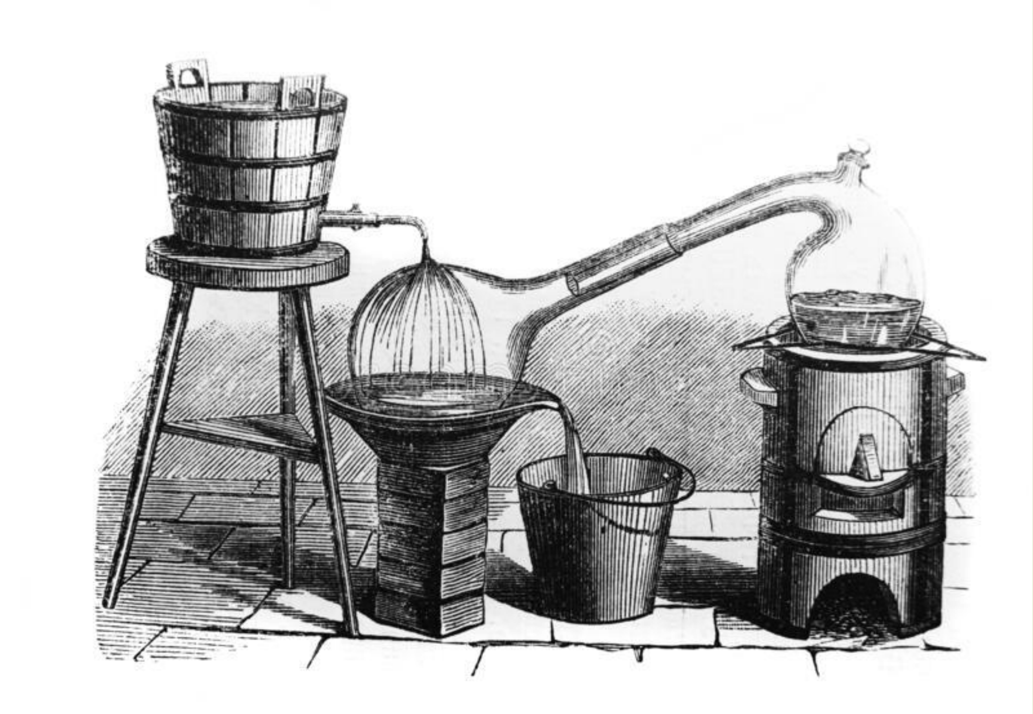
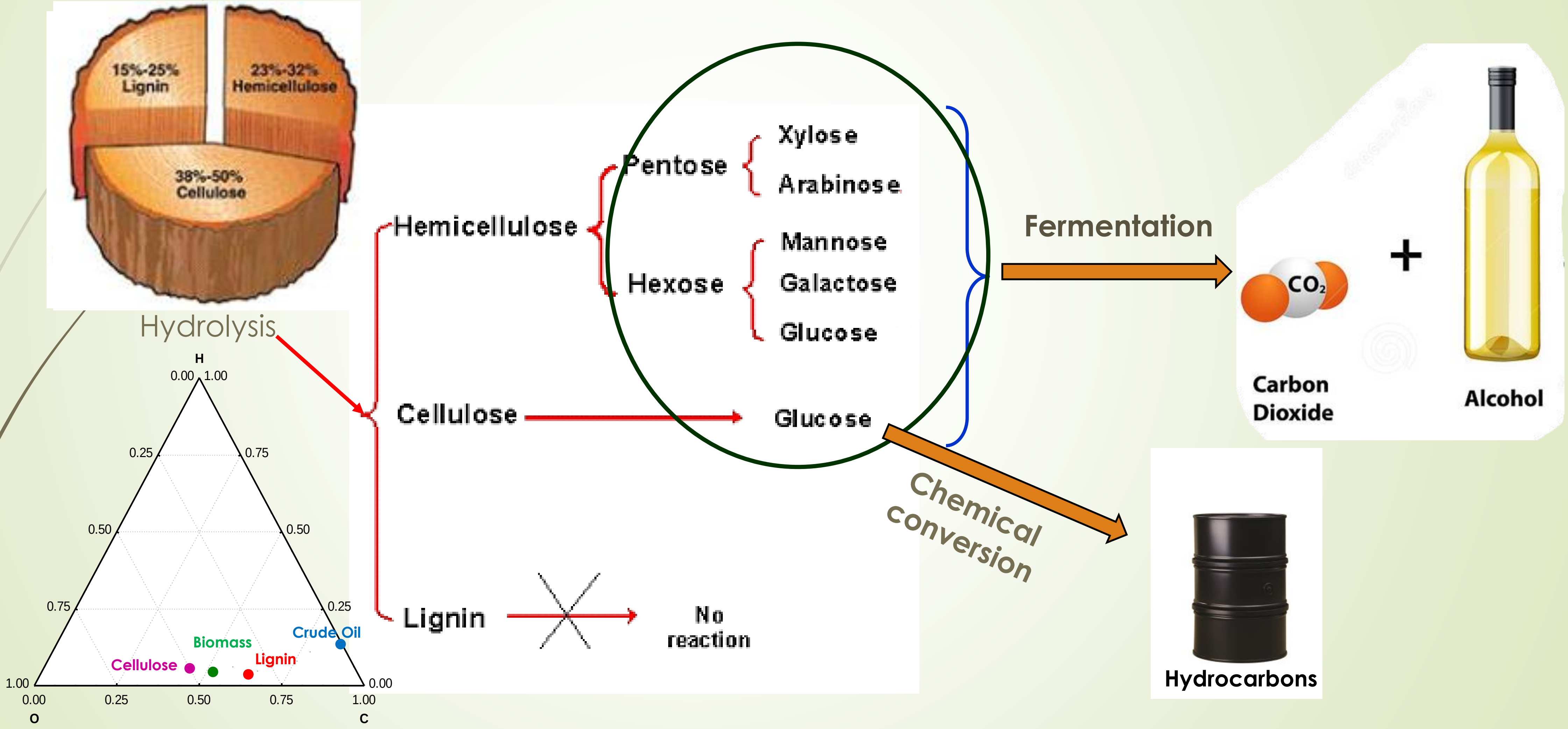


Sugar from lignocellulosic biomass

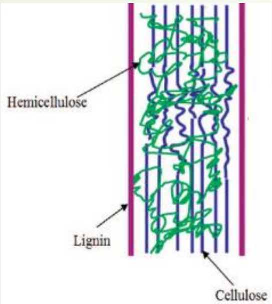
The hydrolysis of cellulose and hemicellulose contained in the lignocellulosic biomass to get sugars is a complex step that can be catalyzed by acids or enzymes.

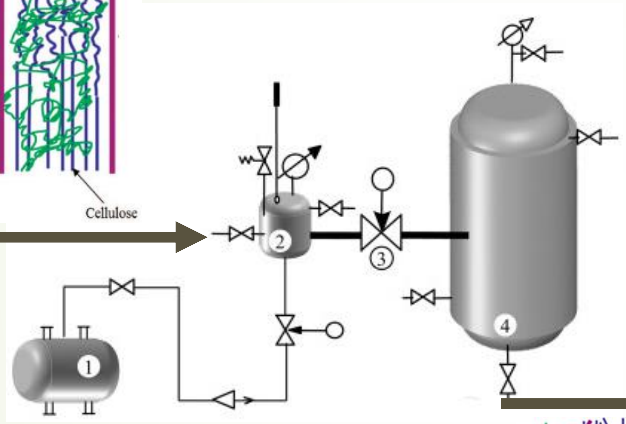


Oils from lignocellulosic biomass: the saccharification stage

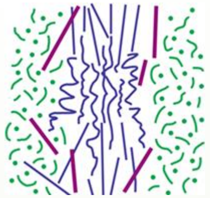
Biomass	Cellulose (%)	Hemicellulose (%)	Lignin (%)
Soft wood	45-50	25-35	25-35
Wheat straw	30	50	15
Corn stover	45	35	15

Agricultural waste – energy crops





Pretreatment (steam explosion)



Deconstructed Biomass

Enzymatic hydrolysis

Lignin

C5 and C6 sugar

Glucose
Mannose
Galactose
Xylose
Arabinose

Advanced bioethanol commercial plants

- **2G sugars and Bio-ethanol production plants from biomasses** with Proesa® technology in operation since 2013
- **Capacity:** ~ 25 kta bioethanol
- Bio-ethanol classified as «Advanced Biofuel» by EU legislation
- Biomass average use about 200 kta
- **Biomass Thermoelectric power station** serving the bio-ethanol plant, **fed with lignin** *(co-product of the production process)*
- **Bio-gas production plant from waste water**

https://versalis.eni.com/irj/go/km/docs/versalis/Contenuti%20Versalis/IT/Documenti/Documentazione/Licensing/Biotech_0_/Proesa.pdf

Operating	Country	Feedstock	ton/Y
Granbio	Brazil	Sugarcane Bagasse	62000
Henan Tianguan	China	Wheat straw, Corn stover	30000
Longive Biotech.	China	Corn cob	60000
Raizen	Brazil	Sugarcane Bagasse	31000
POET-DSM	USA	Agricultural residues	75000

Project	Country	Feedstock	ton/Y
Clariant	Romania	Cereal straw	50000
Fiberight LLC	USA	MSW	18000

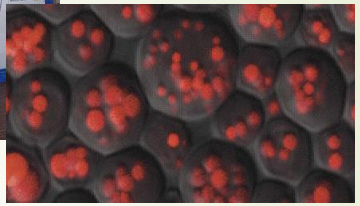
IEA Bioenergy – June 2021

< 400 kton/y
~ 0,5% of the global ethanol production (88 Mton in 2018)

Oils from lignocellulosic biomass: the fermentation stage technology

Lignocellulosic biomass

C5 - C6 Sugars for fermentation



Oleaginous yeasts

Microbial oil

UOP/Eni Ecofining™ for green diesel fuels

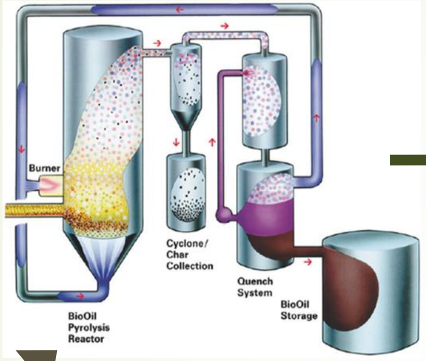
Oleaginous yeasts can accumulate up to 70% (dry weight) of triglicerides inside their cells.

Lipids yields : up to 20 kg per 100 kg dry biomass

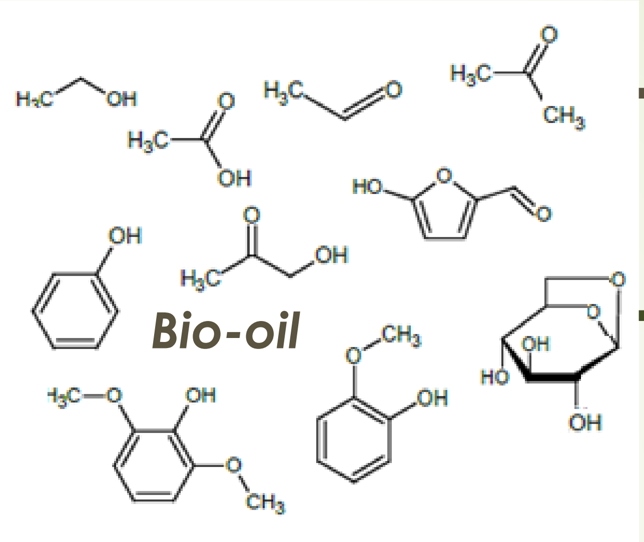
D. Bianchi, C. Perego, F. Capuano, in "Chemicals and Fuels from bio-based building blocks". F. Cavani et al. Ed's, 2016, Wiley-VCH, pp. 643-665

Waste biomass pyrolysis vs gasification

500°C



Pyrolysis



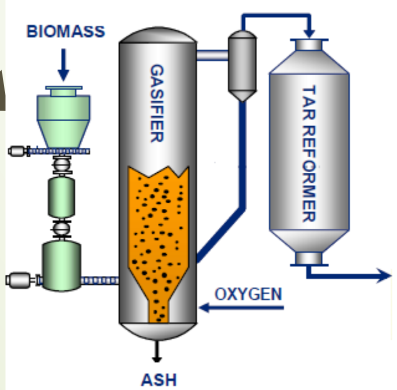
upgrading

Biofuels
(under development)

Power generation
Commercial process:
Ensyn/UOP (CDN),
Dynamotive (CDN),
Fortum (SF),
BTG-Empyro (NL)

Dry lignocellulosic biomass

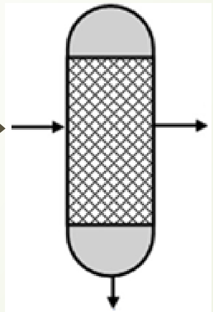
800-1000°C



Gasification

$CO + H_2$

Bio-syngas



Fisher Tropsch or MeOH synthesis

Biofuels
Technologies
Red Rocks (US): operation
Total/Axens/IFP (FR): under costruction
Velocys (US):planned
Choren (Ge): closed
Sundrop (US): cancelled

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