# Feedstocks

*Renewable sources of biomass for biobased products*

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# Feedstocks

- Why renewable?
- Which types?
- How to select a source?
- How to use the sugars?
- Sustainability

# Before the industrial revolution

**Agriculture, fishery, forestry provided all our needs**

- Transport
- Light and heat
- Products

# … We can return to this principle

**Biobased production can close cycles**

- Renewable crops and residues for our needs

**Higher per capita energy demand**

- Smart solutions are required
- Optimize yields

# Available feedstocks

FOOD CROPS

AGRICULTURAL WASTE

DEDICATED CROPS

WOOD CROPS

WASTE MATERIALS

# Categorizing types of biomass

“First generation”

Food crops

“Second generation”

Residues of food crops

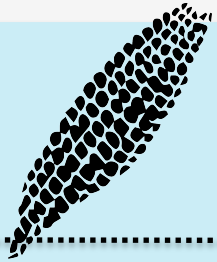
Dedicated energy crops

Wood crops

Waste materials

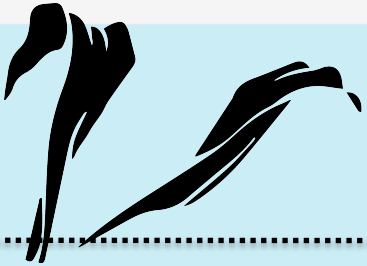
# Generation differences

## 1st



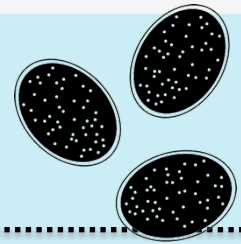
- **Easily digestible sugars**
- **Direct competition**
  with food, arable land, fresh water

## 2nd



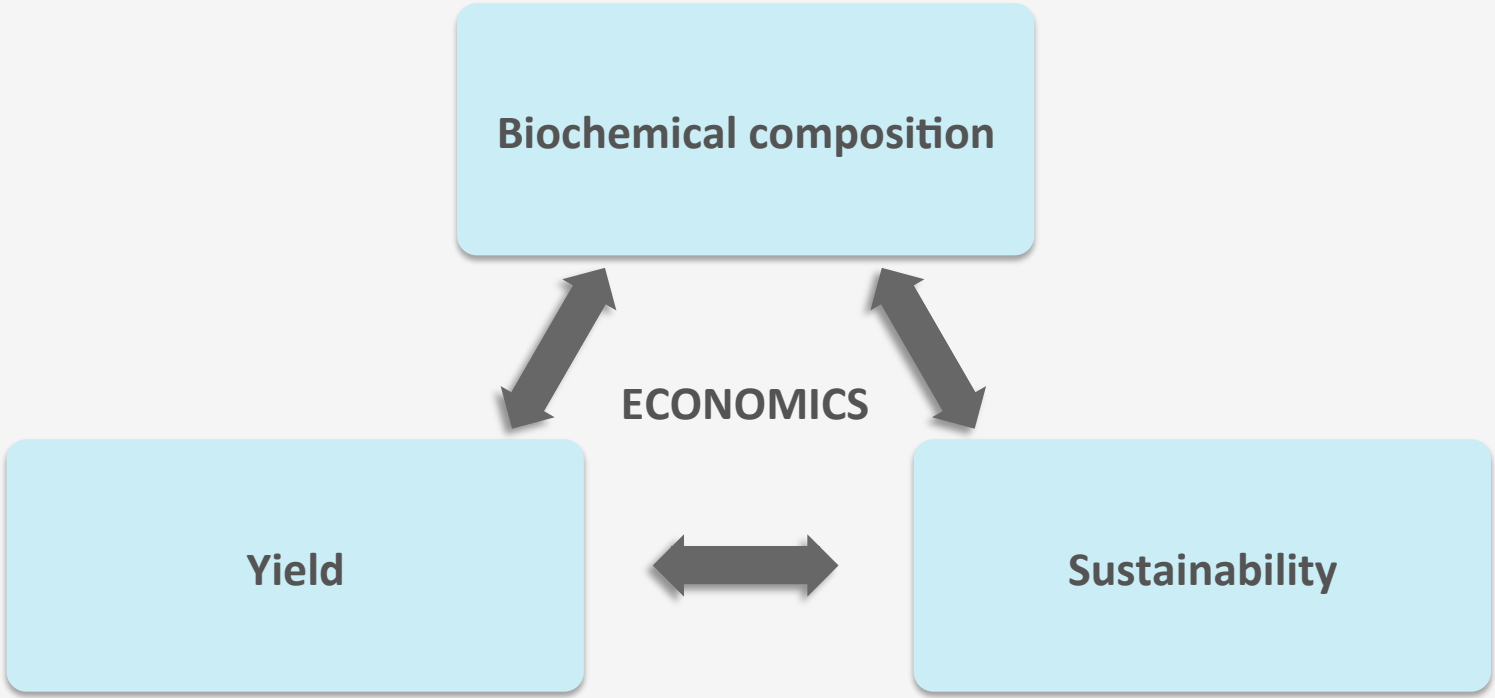
- **Lignocellulosic structure**
- **Reduce competition**
  by using waste, non-arable land, reducing water use

## 3rd

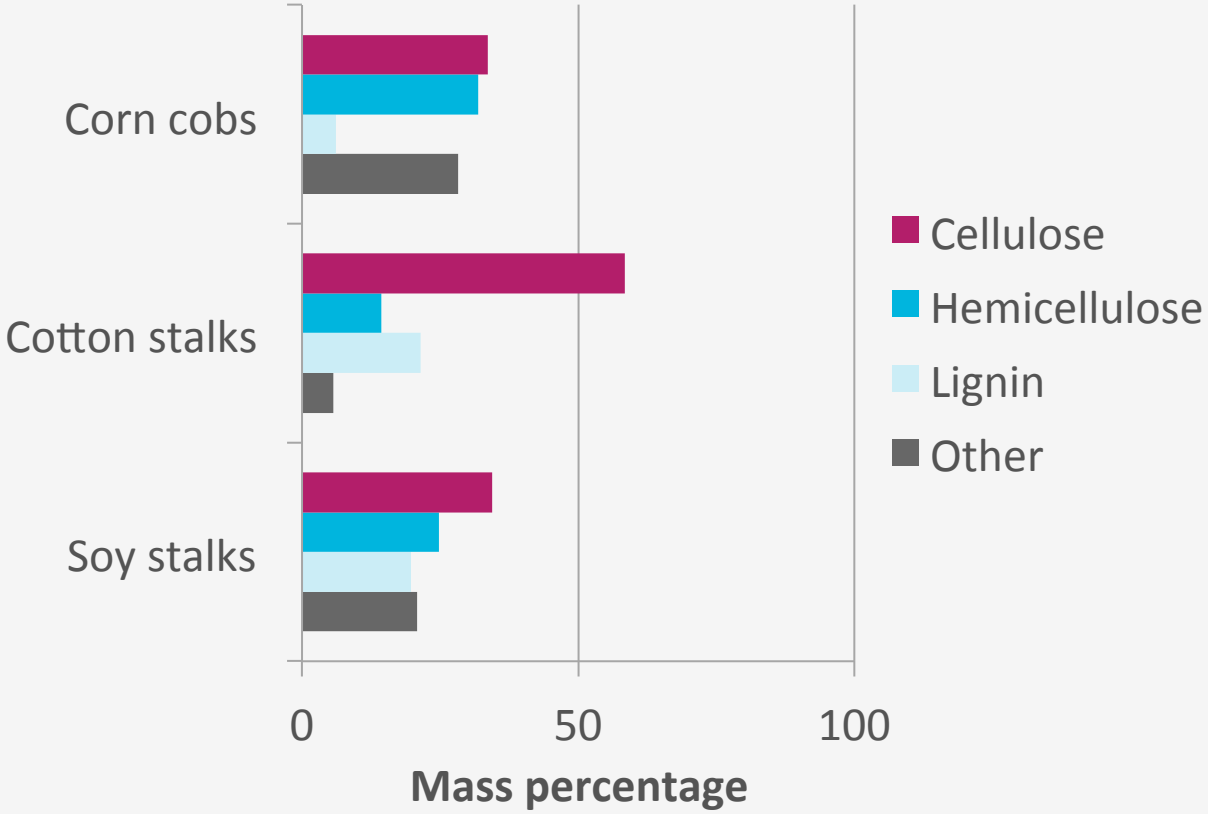


- **Lipids**
  and proteins, carbohydrates
- **Eliminate competition**
  aquatic and autotrophic

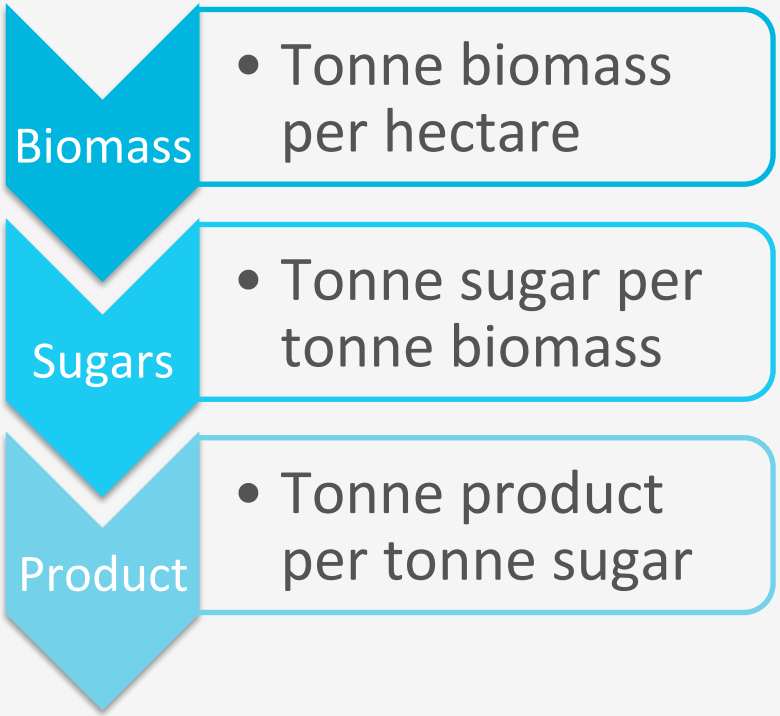
# How to select a crop?



# Selecting a feedstock: biochemical composition



# Selecting a feedstock: yield



# Selecting a feedstock: yield

**Biomass**
- Tonne biomass per hectare

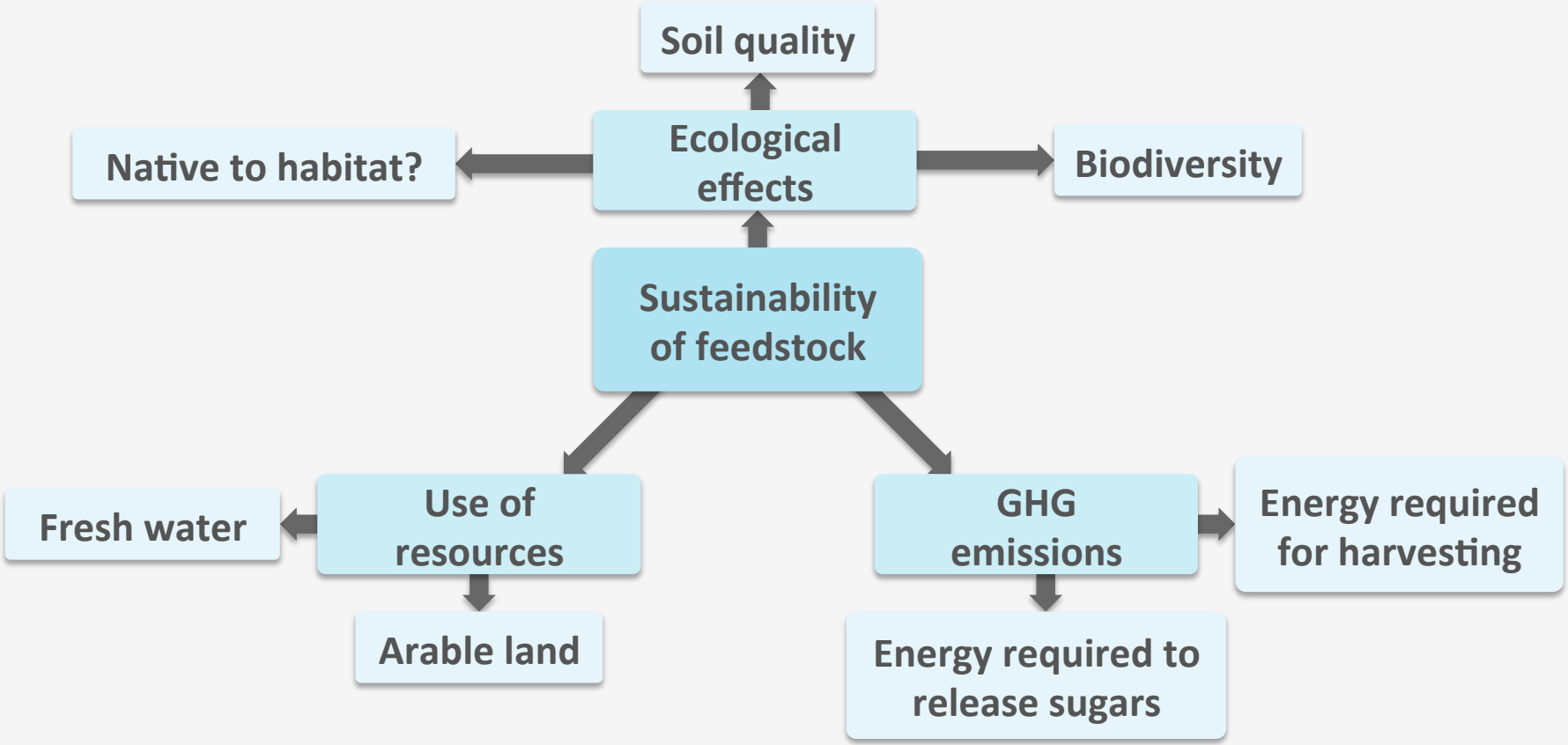
**Sugars**
- Tonne sugar per tonne biomass

**Product**
- Tonne product per tonne sugar

| | Total Dry Biomass Yield (t/ha) | Grain/seed yield (t/ha) | Easily accessed biofuel (GJ/ha) | Cellulosic (GJ/ha) | Combustion of residue (GJ/ha) | Combustion of total biomass (GJ/ha) |
|---|---|---|---|---|---|---|
| Sugarcane (Brazil) | 38.0 | 12.0 | 156.8 | 167.0 | 113.9 | 684.0 |
| Maize (USA) | 18.4 | 9.2 | 72.8 | 40.4 | 27.6 | 331.2 |
| Wheat (EU28) | 8.8 | 5.3 | 34.9 | 19.4 | 13.2 | 159.0 |
| Napier Grass (El Salvador) | 84.0 | 0.0 | 0.0 | 738.2 | 503.5 | 1512.0 |
| Miscanthus (Illinois) | 22.0 | 0.0 | 0.0 | 193.3 | 131.9 | 396.0 |
| Switchgrass (Illinois) | 10.0 | 0.0 | 0.0 | 87.9 | 59.9 | 180.0 |
| Rapeseed (EU28) | 5.6 | 2.8 | 33.2 | 12.3 | 8.4 | 112.9 |
| Soybean (USA) | 4.7 | 2.8 | 21.2 | 20.5 | 5.6 | 96.1 |
| Oil Palm (Indonesia) | 34.0 | 17.0 | 128.8 | 149.4 | 50.9 | 685.4 |
| Agave (Arizona) | 8.0 | 0.0 | 33.0 | 35.2 | 24.0 | 144.0 |
| SRC Willow (Sweden) | 10.0 | 0.0 | 0.0 | 43.9 | 30.0 | 180.0 |
| SRC Poplar (Italy) | 14.0 | 0.0 | 0.0 | 61.5 | 42.0 | 252.0 |
| SRF Eucalyptus (Brazil) | 18.2 | 0.0 | 0.0 | 80.0 | 54.5 | 327.6 |

Adopted from Bioenergy & Sustainability. Long, S.P., Karp, A., and Buckeridge, M.S. et al. (2014)

# Selecting a feedstock: sustainability



# Dedicated energy crops

**Engineered for sustainability:**

- Increase yield per hectare
- Decrease water use
- Grow on non-arable land, marginal soils
- Grow in native habitat

# Biomass composition

## Useful

### Cellulose

- Chain polymer
- C6 sugars

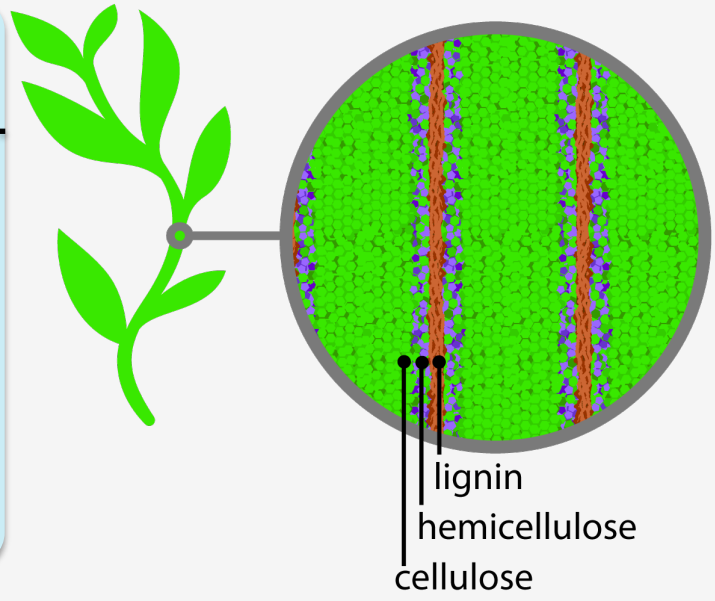
### Hemicellulose

- Chain polymer
- C6 and C5 sugars

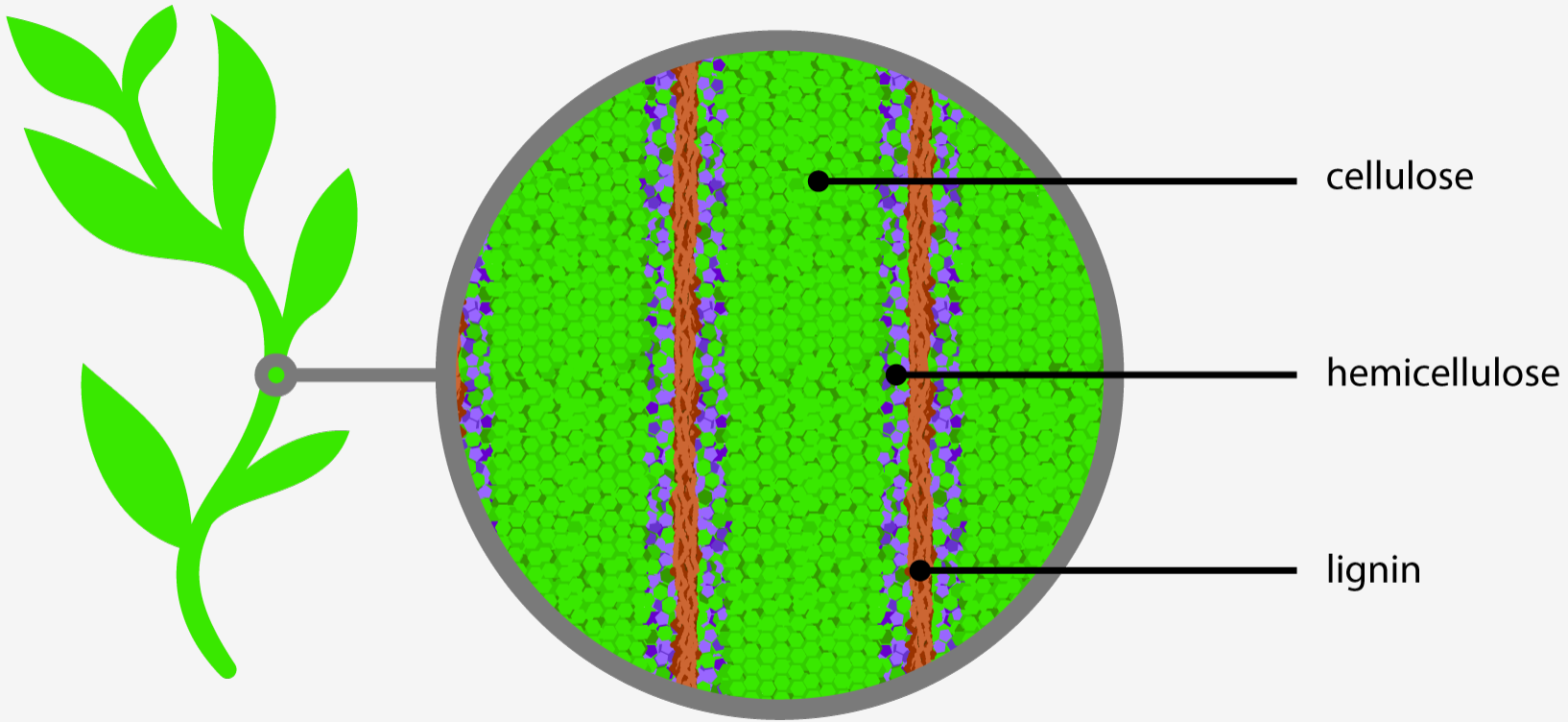
## Indigestible

### Lignin

- Complex polymer
- Irregular
- Tough by design

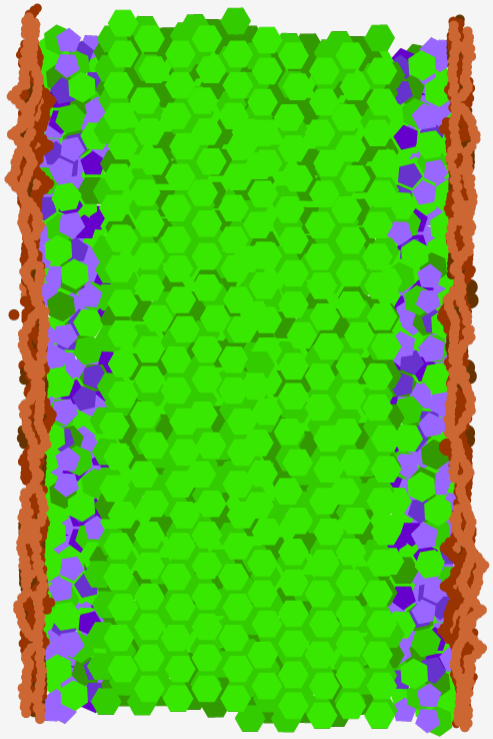


# Releasing sugars for fermentation




**Step 1** Open up plant structure

# Releasing sugars for fermentation



**Step 1** Open up plant structure

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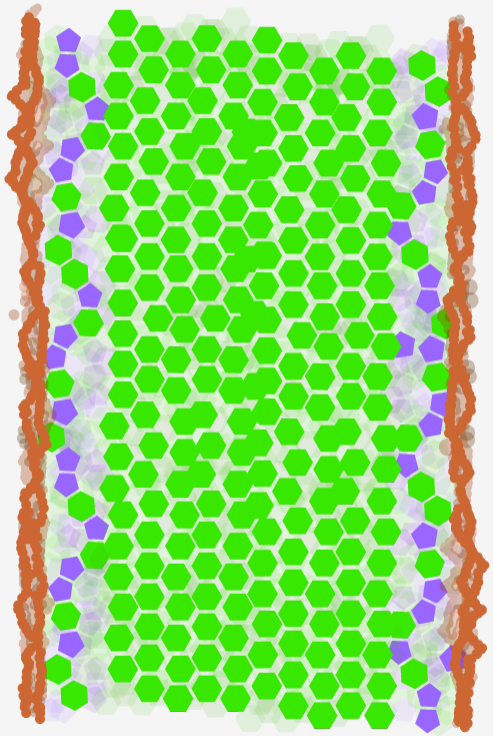

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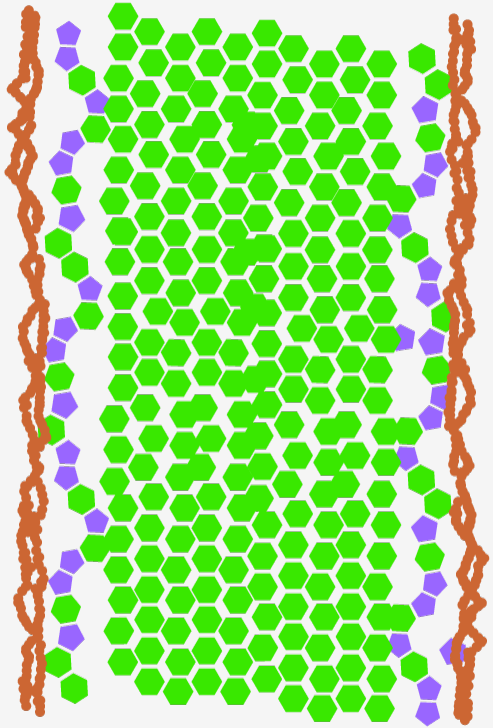

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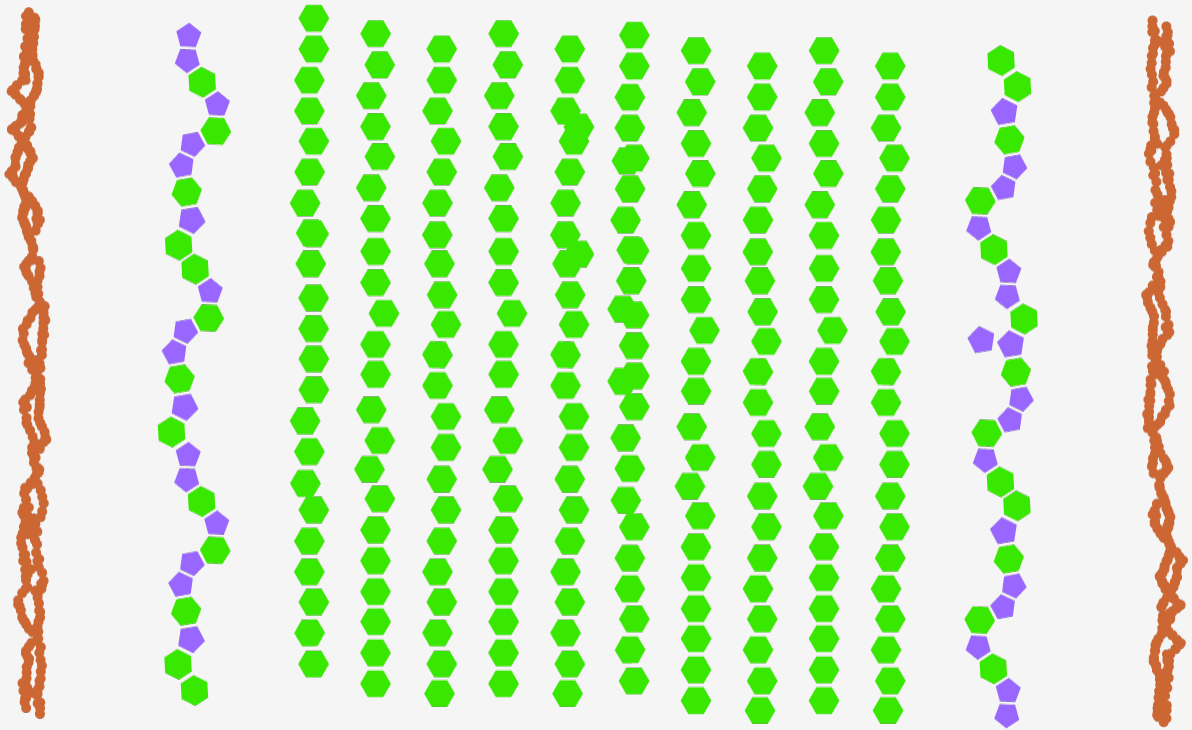
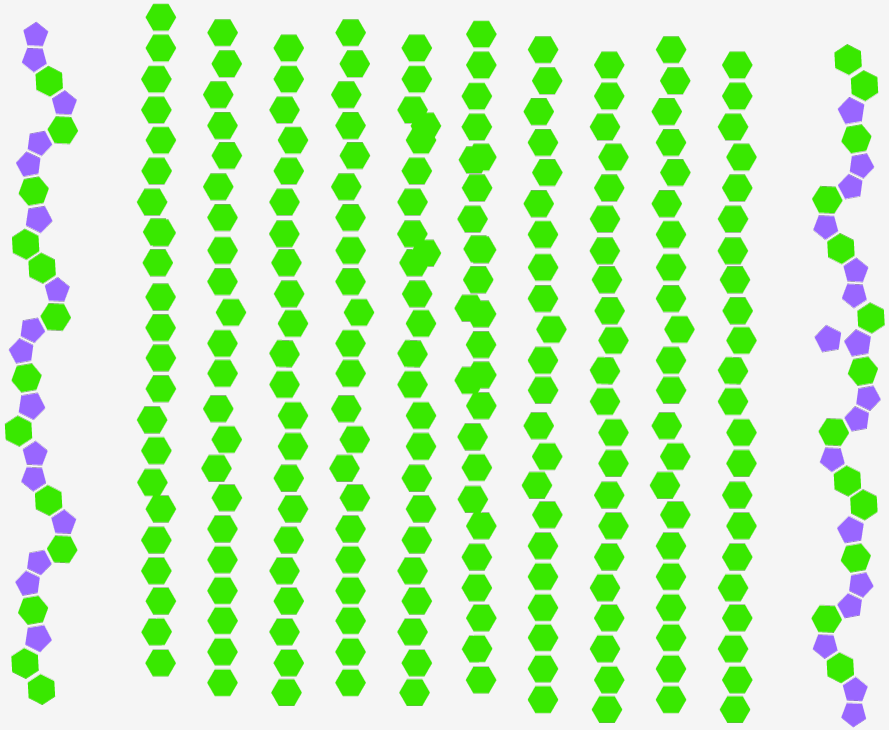


**Step 2** Lignin removal

# Releasing sugars for fermentation



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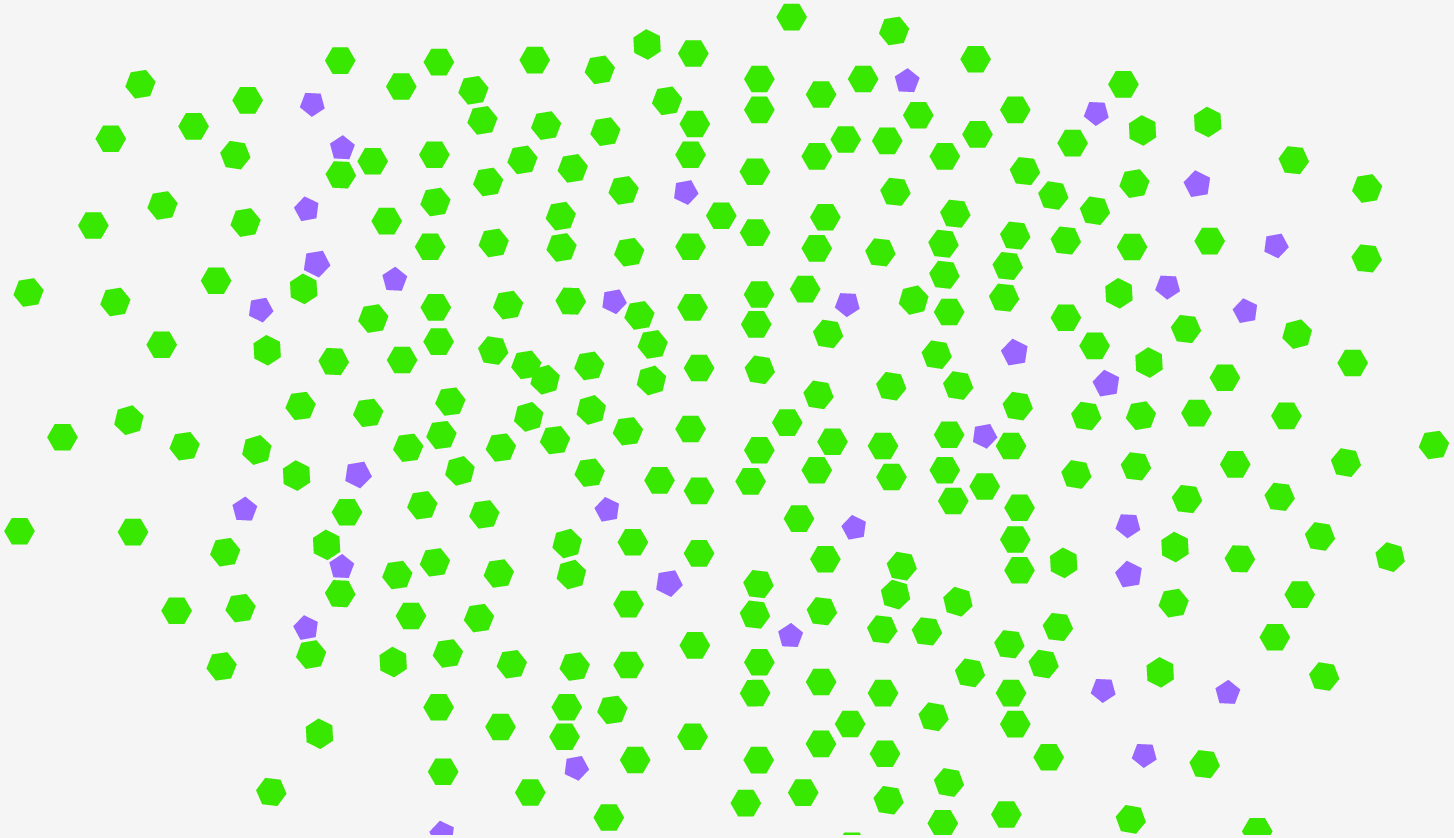
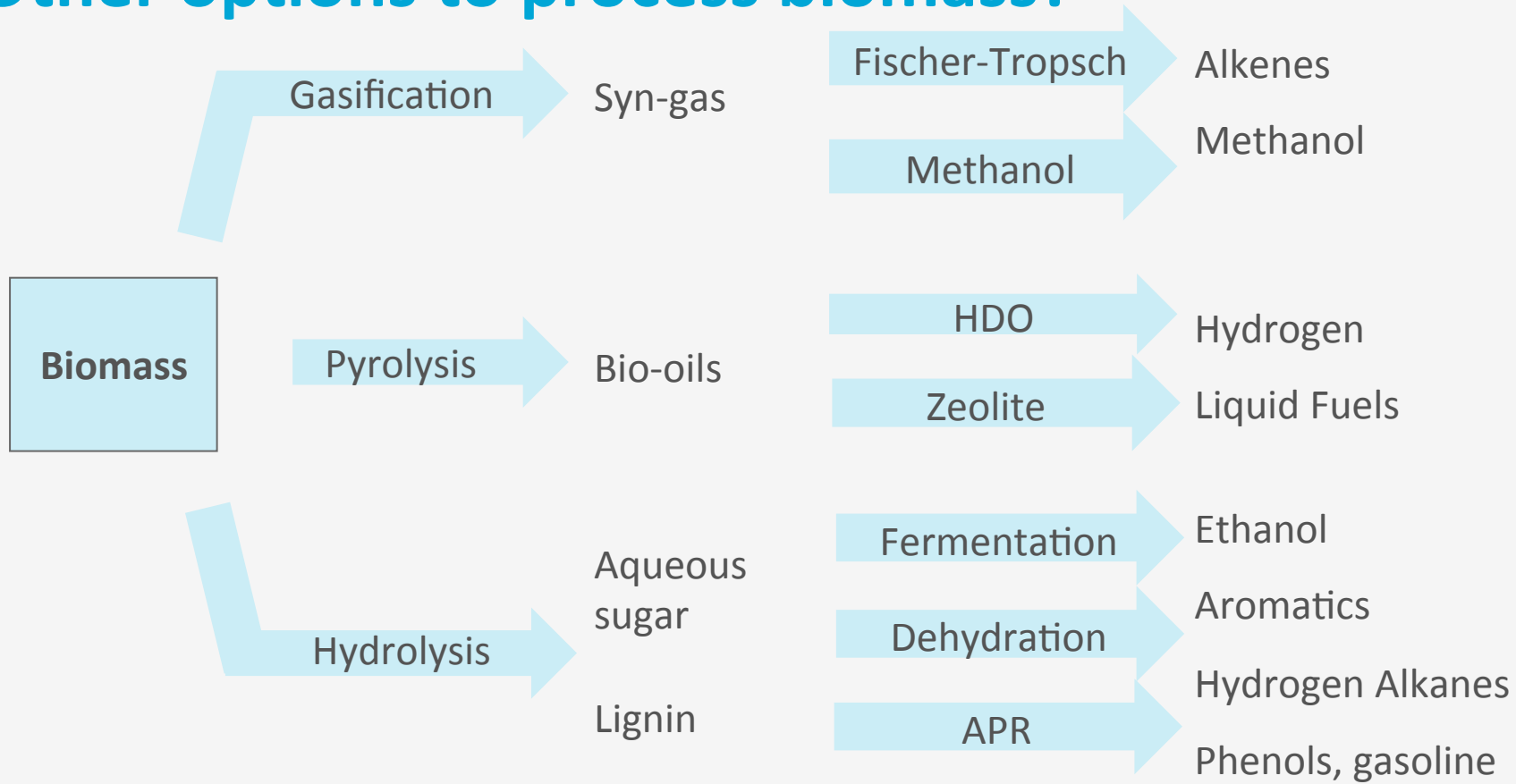


**Step 3** Hydrolysis

# Other options to process biomass?



# The biorenewable cycle

# Join us in the next unit!