Western Norway University of Applied Sciences

NTRANS
Norwegian Centre for Energy Transition Strategies

Environmental aspects of 2nd generation lignocellulose ethanol

SDG Conference Bergen – Day Zero

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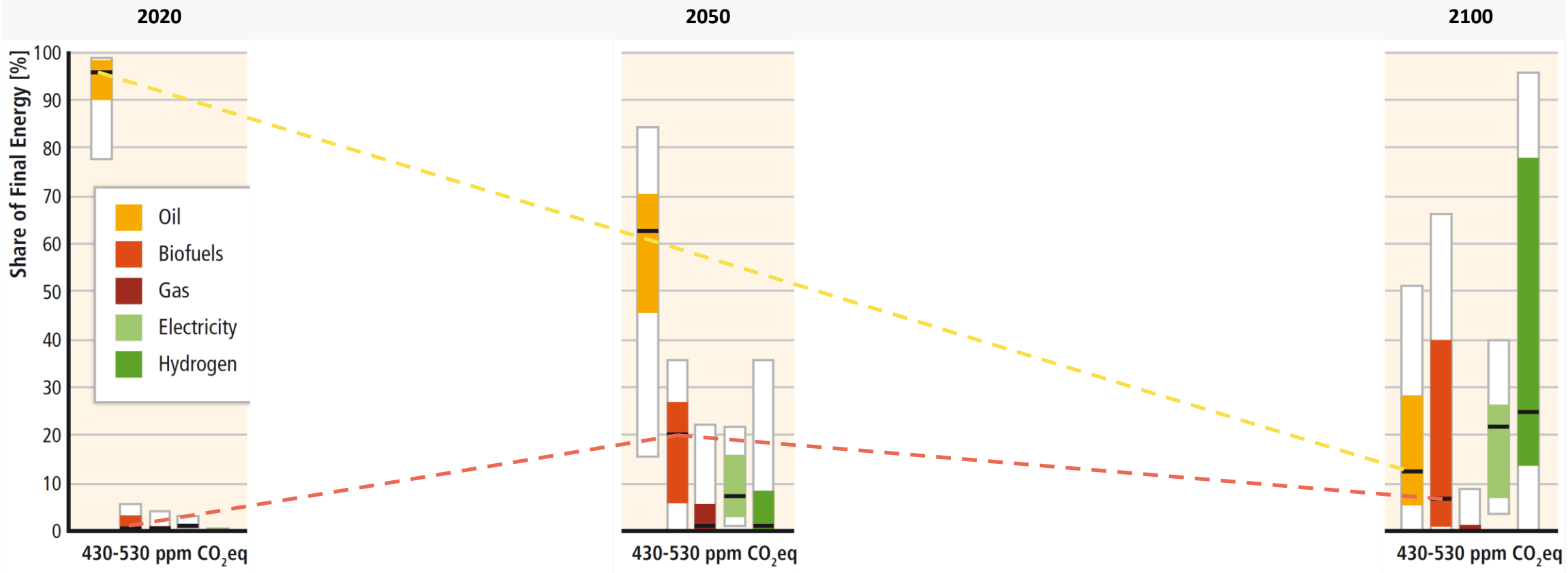
Bergen
05.02.2020

Role of Biofuels in the Transport Sector 2020—2100



n = 127

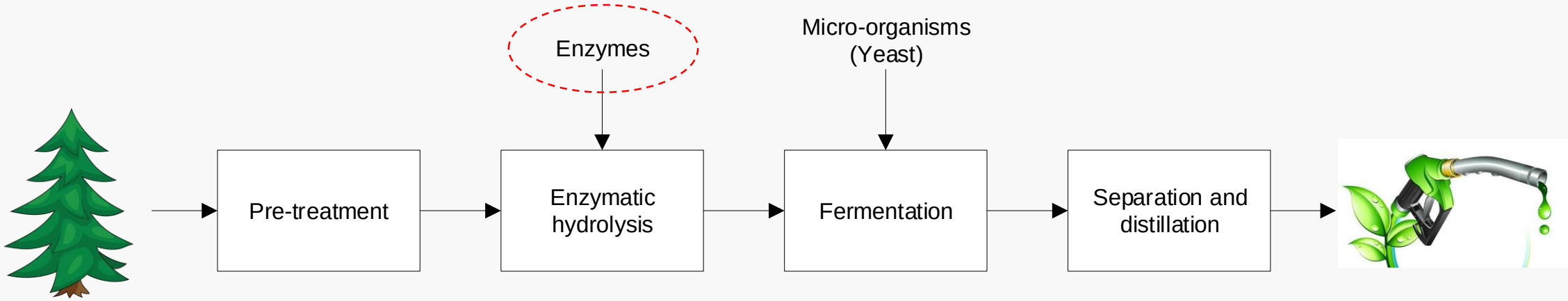
n = 127

n = 96

Source: IPCC

Biofuels & LCAs of Lignocellulose Ethanol

- Biofuel Classification
  - Conventional (commercial, e.g. 1st gen.)
  - Advanced (under development, e.g. 2nd & 3rd gen.)
    - …
    - Lignocellulose ethanol



Source: adapted from NREL, google images

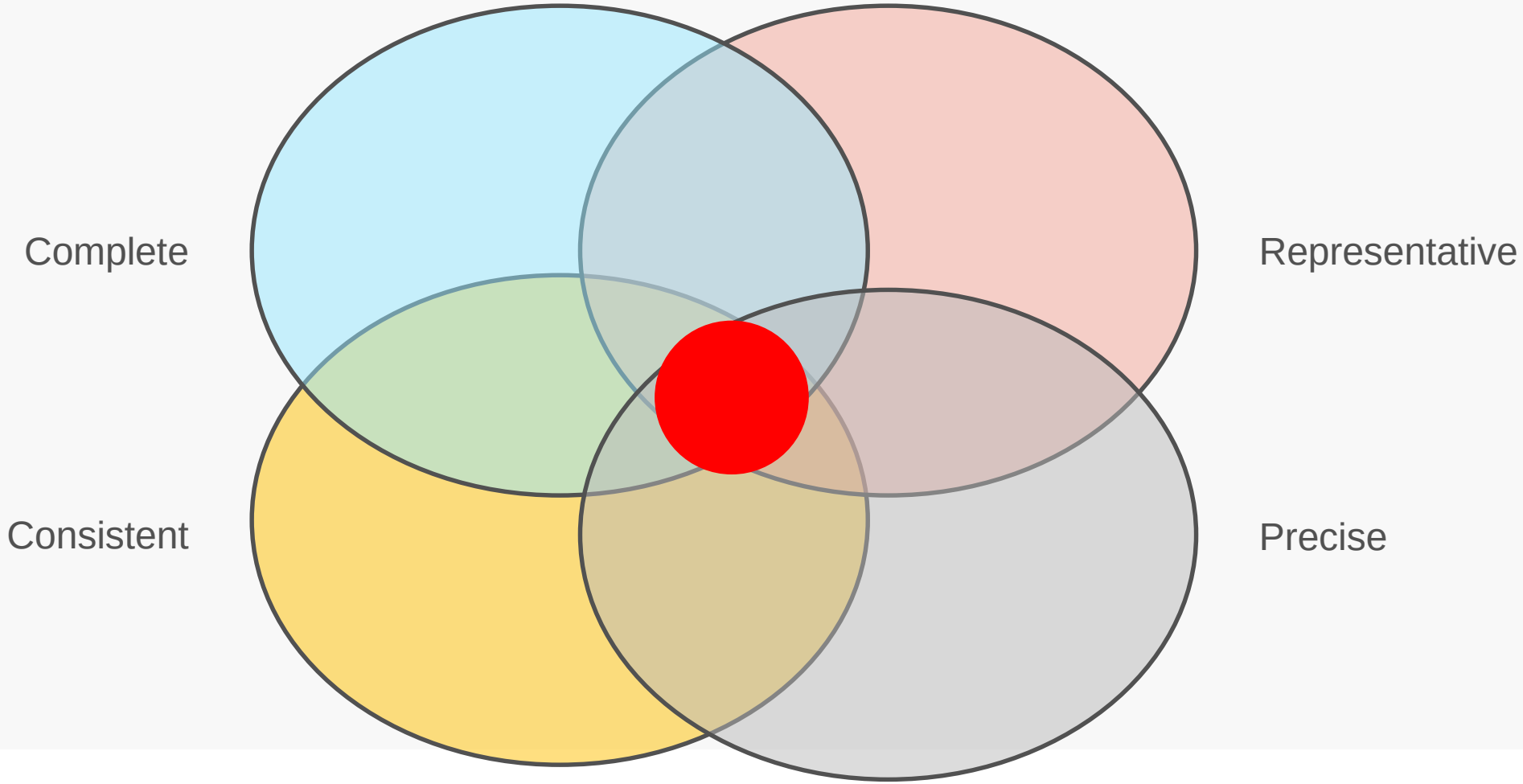
LCAs of Lignocellulose Ethanol & Cellulase Enzyme (CE) Production

- The cellulase enzyme phase in LCA's of lignocellulose ethanol, is often:
  - Not transparent, or
  - Excluded
- With authors citing lack of data

Source: adapted from NREL

Data Considerations

- A robust life cycle assessment is data intensive!

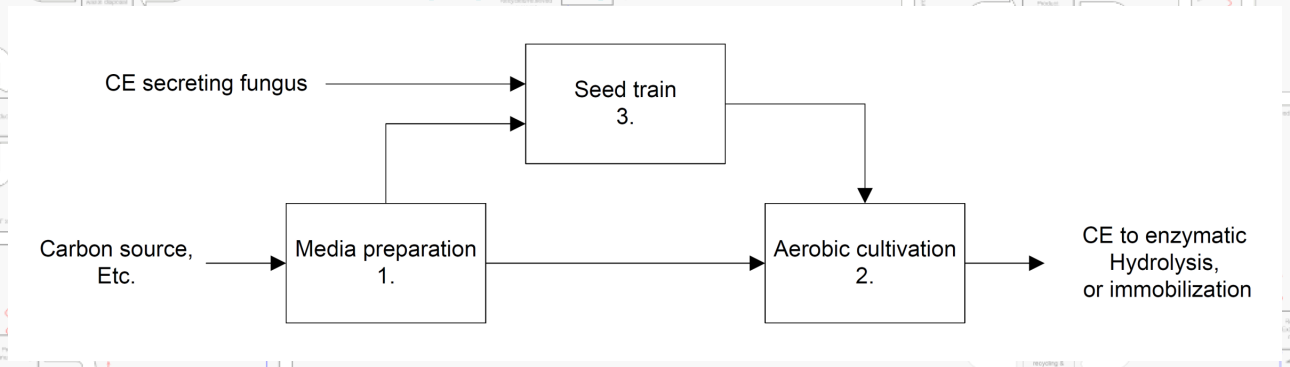


Data Considerations

1. Foreground

Life cycle inventory

- (in)consistent
- (in)complete



2. Background

Database(s)

- (un)representive
- proxy

Source: adapted from NREL

1. Solving for (in)complete- and (in)consistent data

- The US National Renewable Energy Laboratory (NREL) has published an techno-economic assessment for lignocellulose ethanol since 1999 (Wooley et al. 1999)
- Note: the majority of contemporary LCAs of lignocellulose ethanol are based on these reports.
  - Incl. cellulase enzyme production grown on:
    - Glucose (2001—present)
    - Pre-treated softwood (1999—2003)
    - Molasses (not included)

- (in)consistent: temporally, technologically, and geographically
- (in)complete

1. Solving for (in)complete- and (in)consistent data con't

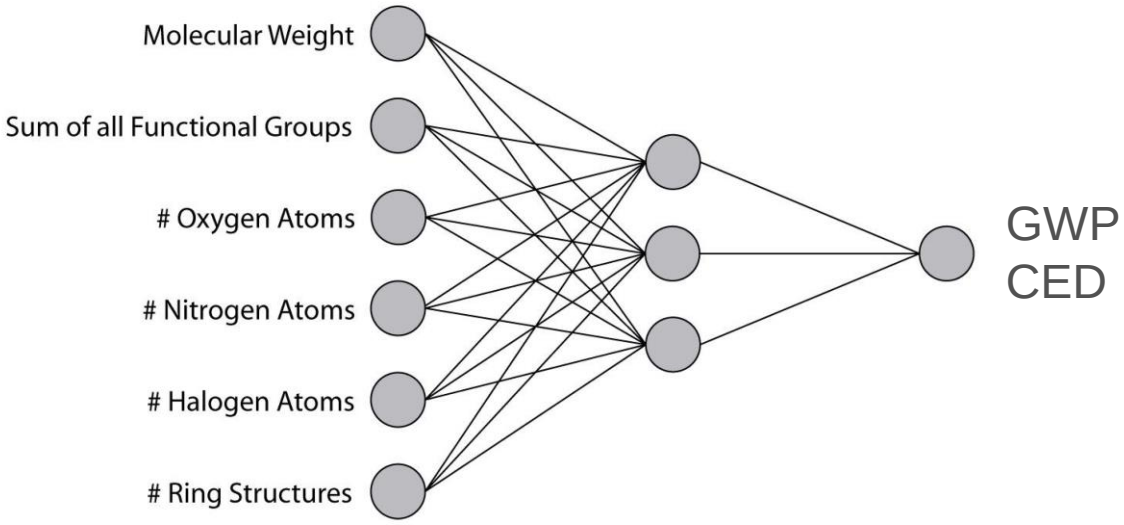
- Studied the chemistry involved in the production of cellulase enzyme,
- Stoichiometrically balanced all 3 scenario's reactions based on the most recent technology iteration, and using the glucose scenario as a control.
- All other inputs/outputs then scaled accordingly.

	Case A	Case B	Case C	Unit
Product				
CE	1.0			kg
Input				
Materials/fuels				
Water	19.0			kg
Carbon source	4.7			kg
Ammonium sulphate	0.037			kg
Potassium phosphate	0.053			kg
Magnesium sulphate	0.008			kg
Calcium chloride	0.011			kg
Polysorbate 80	0.005			kg
Corn steep liquor	0.269			kg
Sulphur dioxide	0.028			kg
Ammonia	0.189			kg
Antifoam (corn oil)	0.026			kg
Energy				
Electricity	6.3			kWh
Heating	2.9			MJ
Cooling	59.8			MJ
Emissions				
Carbon dioxide	3.8			kg

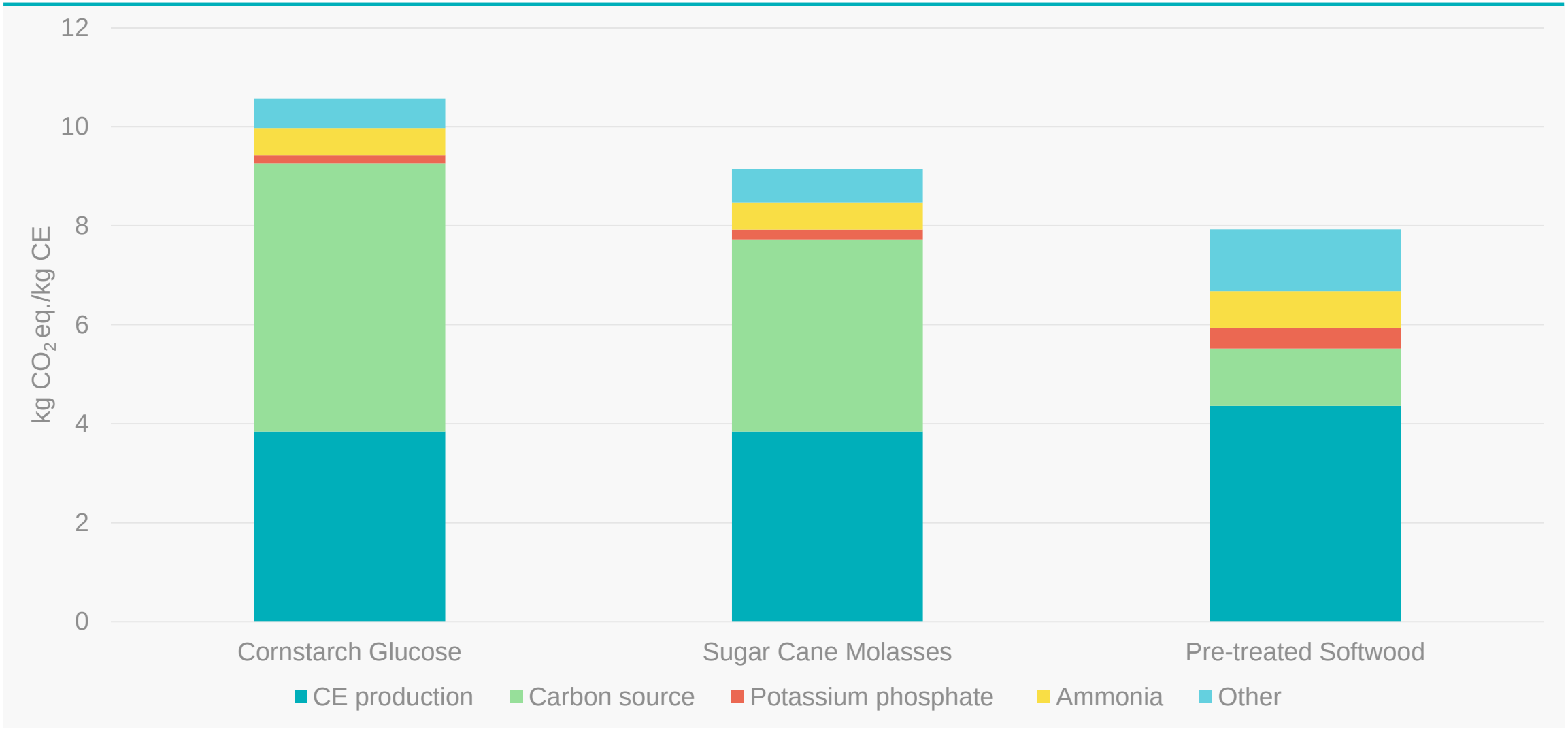
2. Solving for (un)representative data

- Foreground vs. background
- Recipe vs.
- Polysorbate 80
  - I. Exclude → (in)complete
  - II. Proxy → (un)representative
  - III. Construct an inventory
    - a. Collect industry data
    - b. Novel approach

- Molecular-Structure-Based Models of Chemical inventories using Neural Networks (Wernet et al. 2008, 2009)



Results – Cellulase Enzyme Production



Results – Lignocellulose Ethanol

- Contribution of cellulase enzyme to lignocellulose ethanol:

$$2 \rightarrow 22\ g\ CO_2\ eq./MJ$$

- Dependent on case, i.e. glucose, molasses, pre-treated softwood, and dosing values
- Or between 4 – 40 % of total Global Warming Potential ($9.3 \rightarrow 50.3\ g\ CO_2\ eq./MJ$)
- i.e. marginal – to central environmental impact wrt lignocellulose ethanol.

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Thank you