GHG calculations for renewable transport fuels in the EU Renewable Energy Directive

RED II carbon accounting method
for renewable fuels in the EU market

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Carbon accounting course
RED II method for calculating the carbon impact of renewable fuel compared with fossil

Goal of the method

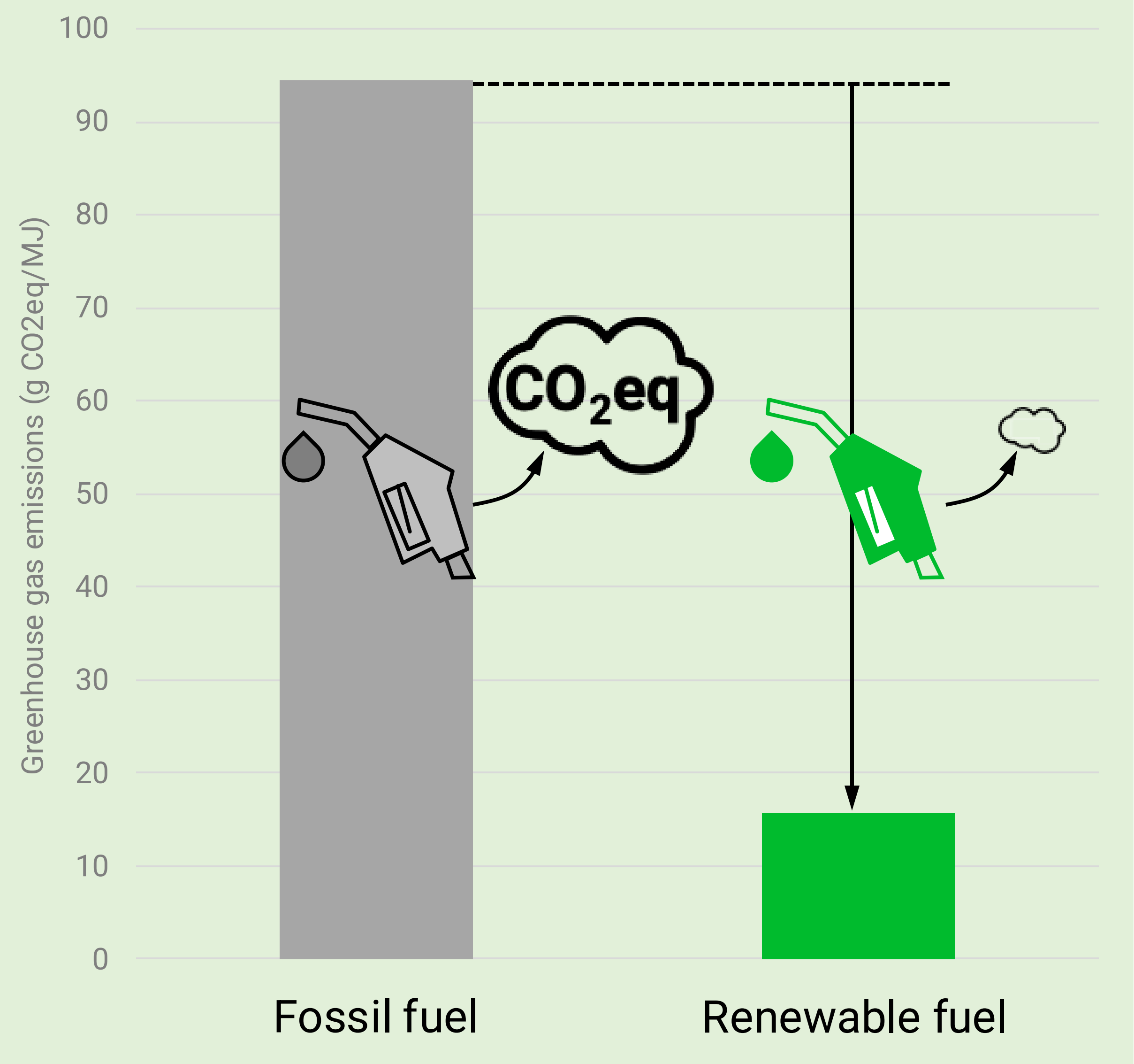
- Demonstrate how much greenhouse gas emissions are avoided by replacing a fossil fuel with a renewable fuel

Result

- The carbon footprint of the renewable fuel is calculated
- The result is expressed in g CO_2eq/MJ
  - The CO_2 ***equivalent*** combines the impact of all greenhouse gases involved
  - The impact is expressed on basis of energy content, thus per MJ LHV (Lower Heating Value)
- The result is compared with a fossil comparator
- The difference represents the greenhouse gas savings
  - Usually expressed as a percentage
  - From this, one can also derive the total amount of savings, for instance per batch or per year

Requirement in EU renewable fuels legislation

- All renewable fuels must achieve certain savings
- These savings should be proven by certification



Greenhouse gas emission reduction thresholds

All renewable fuels must pass a minimum emission reduction threshold (as part of their sustainability criteria)

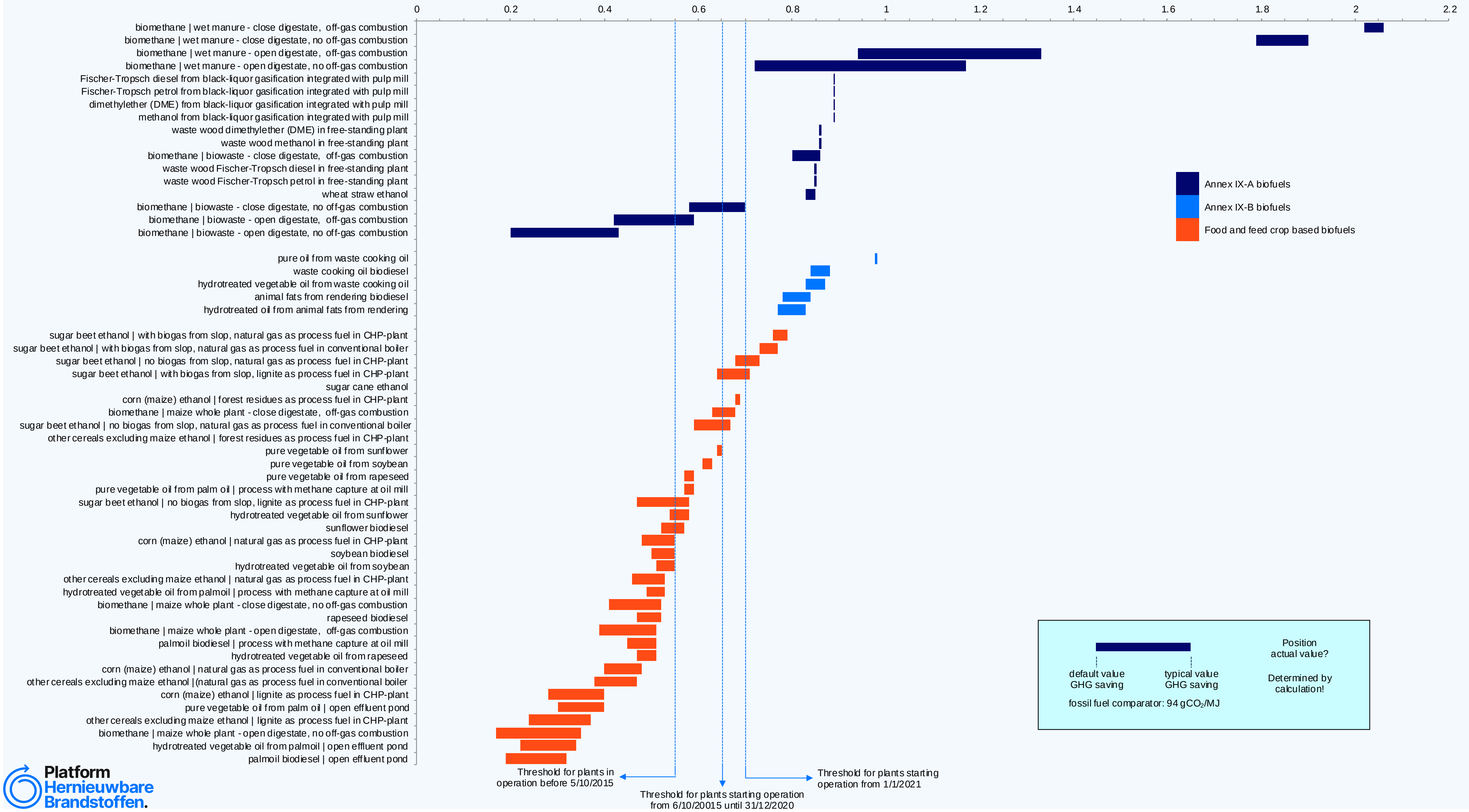
- Different thresholds exist, and depend on type of fuel and age of the conversion installation
- The 2009 RED I introduced a generic threshold of 35%, which was increased by the 2015 ILUC Directive and the 2018 RED II
- RED thresholds also apply to FuelEU Maritime, ReFuelEU Aviation and ETS

2018 RED II greenhouse gas emission reduction thresholds for renewable fuels used in transport

- 50% for biofuels and biogas, produced in installations that were in operation on or before 5 October 2015
- 60% for biofuels and biogas, produced in installations that started operation from 6 October 2015 until 31 December 2020
- 65% for biofuels and biogas, produced in installations that start operation from 1 January 2021
- 70% for renewable fuels of non-biological origin (any date)
- 70% for recycled carbon fuels (any date)

RED II fossil comparator

- For biofuels, renewable fuels of non-biological origin (RFNBOs) and recycled carbon fuels (RCFs), the comparator $E_{F(t)}$ is 94 g CO_{2eq}/MJ
- For bioliquids for the production of electricity, the fossil fuel comparator $EC_{F(e)}$ is 183 g CO_{2eq}/MJ
- For bioliquids for the heating and/or cooling, the fossil fuel comparator $EC_{F(h\&c)}$ is 80 g CO_{2eq}/MJ



Platform Hernieuwbare Brandstoffen.

[EC 2018, Renewable Energy Directive, (EU)2018/2001, Annex V.A and .B, and Annex IV]

Increasing necessity to know the actual greenhouse gas emission

Actual greenhouse gas emission

→ The greenhouse gas emission, calculated according to the RED accounting rules
& Certified by an EC approved voluntary certification scheme

Default values are often not sufficient to meet increasing RED II thresholds

- Thresholds increase
- Default values are threefold conservative
    - Typical values are based on literature >10 years old
    - Literature is always behind on practice
    - Default values are on purpose conservative compared to typical
      (default emissions from processing are defined as 40% higher than typical)

2023 RED II amendment greenhouse gas intensity targets appreciates actual values

- Already practice in German market
- RED II amendment moves from volume obligation to greenhouse gas intensity reduction obligation

→ Better performance gives higher €/tonne value

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RED II greenhouse gas accounting methodology for renewable fuels

RED II includes detailed accounting methodology

- RED II Annex V methodology to calculate the actual greenhouse gas emissions from the production and use of biofuels
- Annex of the Commission Delegated Regulation on greenhouse gas emissions of renewable fuels of non-biological origin (RFNBOs) and recycled carbon fuels (RCFs)

Main formula (for biofuels)

$$E = e_{ec} + e_l + e_p + e_{td} + e_u - e_{sca} - e_{ccs} - e_{ccr}$$

With

e_{ec} = emissions from extraction or cultivation of raw materials

e_l = emissions from land carbon stock changes, explained below ep = emissions from processing

e_{td} = emissions from transport and distribution

e_u = emissions from fuel in use

e_{sca} = emission savings from soil carbon accumulation via improved agricultural management

e_{ccs} = emission savings from CO_2 capture and geological storage

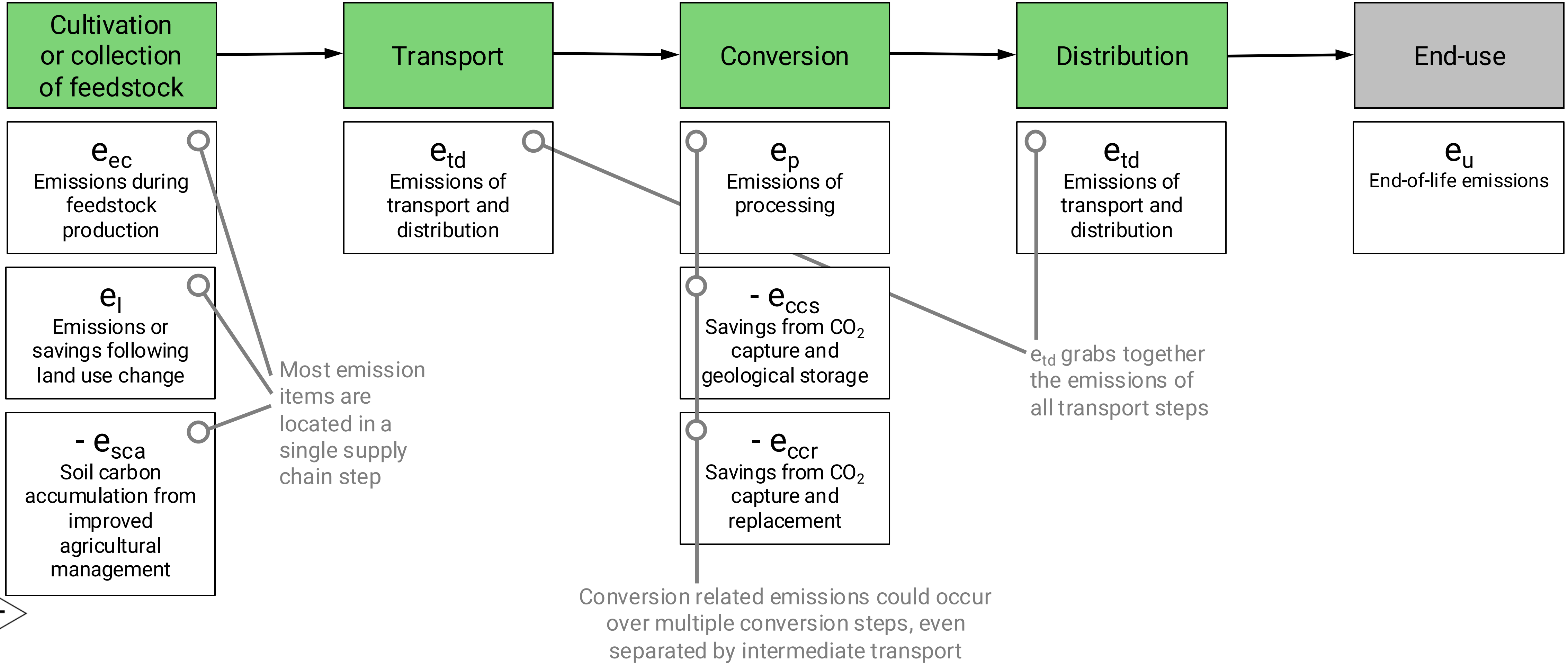
e_{ccr} = emission savings from CO_2 capture and replacement

- Note that emissions from fuel in use e_u are zero for renewable fuels, since these emissions are equal to the amount of CO_2 that was absorbed from the atmosphere during the cultivation of the original crop

RED II greenhouse gas accounting methodology for renewable fuels

Simplified layout of biofuels supply chains

- In reality, supply chains can have multiple feedstocks, multiple conversion steps, etcetera



Example calculation

RED II calculation method for the greenhouse gas impact of renewable fuels
Overall approach

1. Map and understand the supply chain
2. Make inventory of activities
3. Understand mass and energy balances, and main flow volumes
4. Apply impact factors to activities
5. Account for co-products via energy allocation
6. Aggregate the impacts

RED II calculation method for the greenhouse gas impact of renewable fuels
1. Map the supply chain

Example: production of ethanol from wheat straw

Collection of wheat straw → Wheat straw transport → Pre-treatment, Hydrolysis & Fermentation → Ethanol distribution → End-use

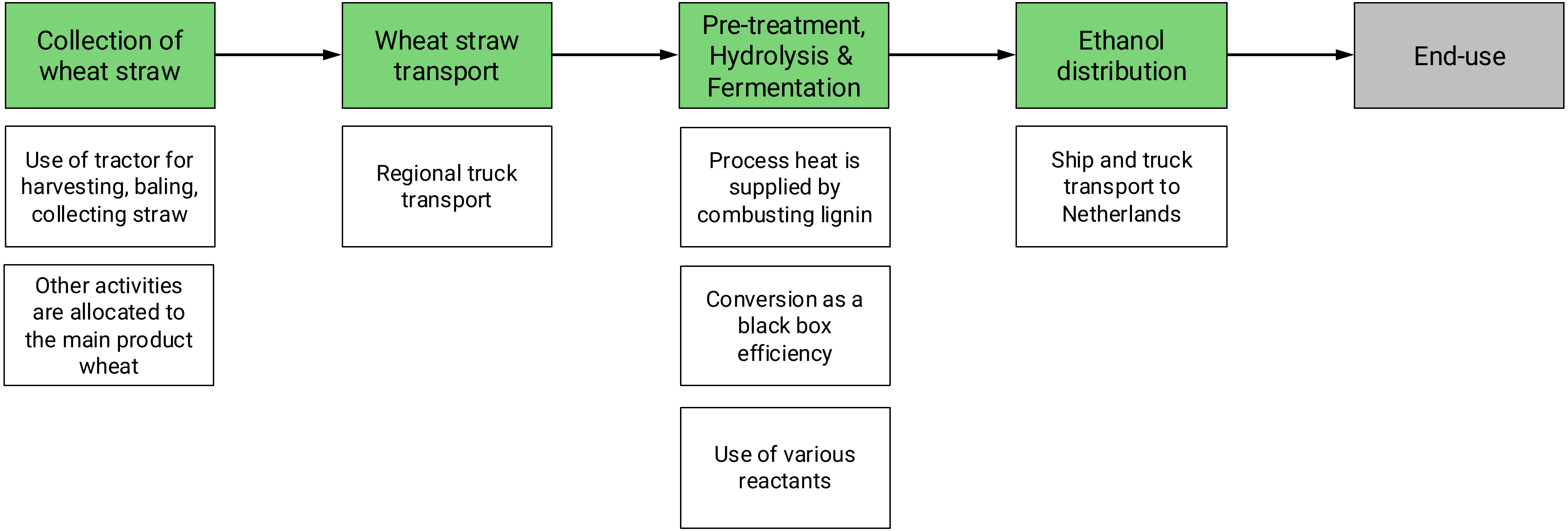
- Part of the straw is harvested
- Remainder is ploughed in the soil to enhance soil structure and soil carbon

- Straw is chopped and pre-treated with steam
- Enzymes are used to convert the (hemi)cellulose to sugars
- C5 and C6 sugars are fermented to ethanol
- Lignin is separated and used to generate process heat

- Ethanol is traded, blended in gasoline and used in vehicles

RED II calculation method for the greenhouse gas impact of renewable fuels
2. Make inventory of activities

Example: production of ethanol from wheat straw



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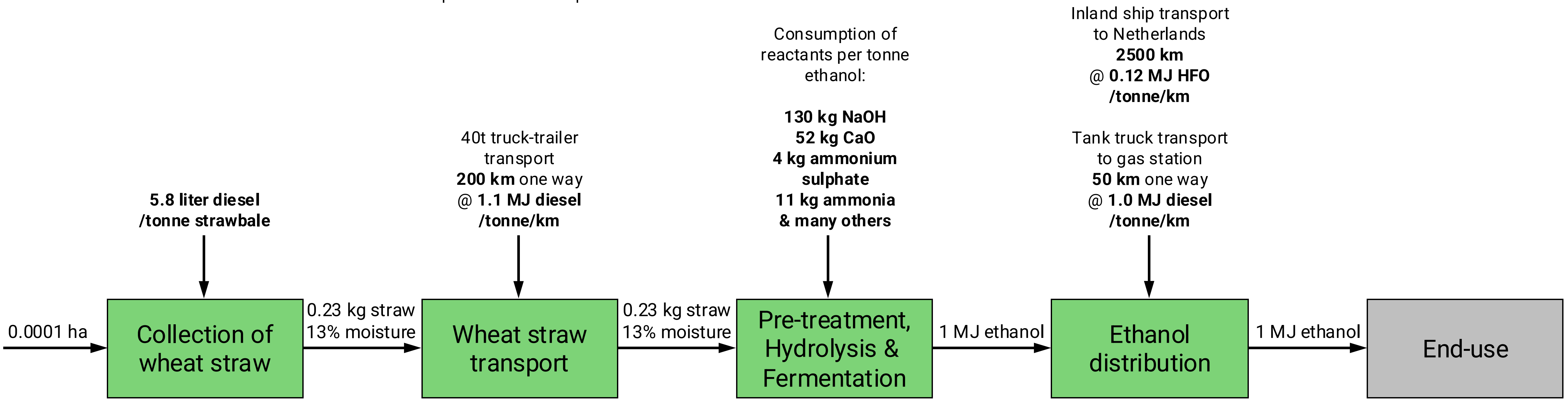
RED II calculation method for the greenhouse gas impact of renewable fuels
3. Understand mass and energy balances, and main flow volumes

- Obtain or search detailed information about all activities
- Understand all material inputs and outputs



[JRC 2019, Definition of input data to assess GHG default emissions from biofuels in EU legislation (version 1d) | JRC 2017, Solid and gaseous bioenergy pathways: input values and GHG emissions (version 2) | CE Delft 2020, STREAM Freight Transport 2020 Emissions of freight transport modes | RVO 2014, Biograce 4d]

RED II calculation method for the greenhouse gas impact of renewable fuels
4. Apply impact factors to activities

Activities cause impacts

- Each activity has an impact, either directly, or upstream, or both
- Energy and material use causes impacts
  - Diesel use in a tractor: requires oil exploration, refining, and causes emissiosn during use
  - Fertiliser: Production requies natural gas, some factories cause N_2O emissions, application causes field-N_2O emissions
  - Phosphate and sulphate ingredients for the hydrolysis-fermentation process require mining

Examples

- 86 kg diesel/ha/year × 4.1 kg CO_2eq/kg = 353 kg CO_2eq/ha/year
  - 4.1 kg CO_2eq is the well-to-wheel emission for the full supply and use of 1 kg fossil diesel
- 109 kg N-fertiliser/ha/year × 5.88 kg CO_2eq/kg = 641 kg CO_2eq/ha/year
- Field-N_2O emissions must be calculated separately

The impact from capital goods is negligible

- Construction of tractors and trucks, factories, gas stations is generally ignored
- Exception could be when the capital good is expected to have a significant impact, for instance batteries in electric vehicles

Suggested data sources for impact factors

- Several JRC reports
- Biograce 4d
- EU PEF database
- ISCC guidance

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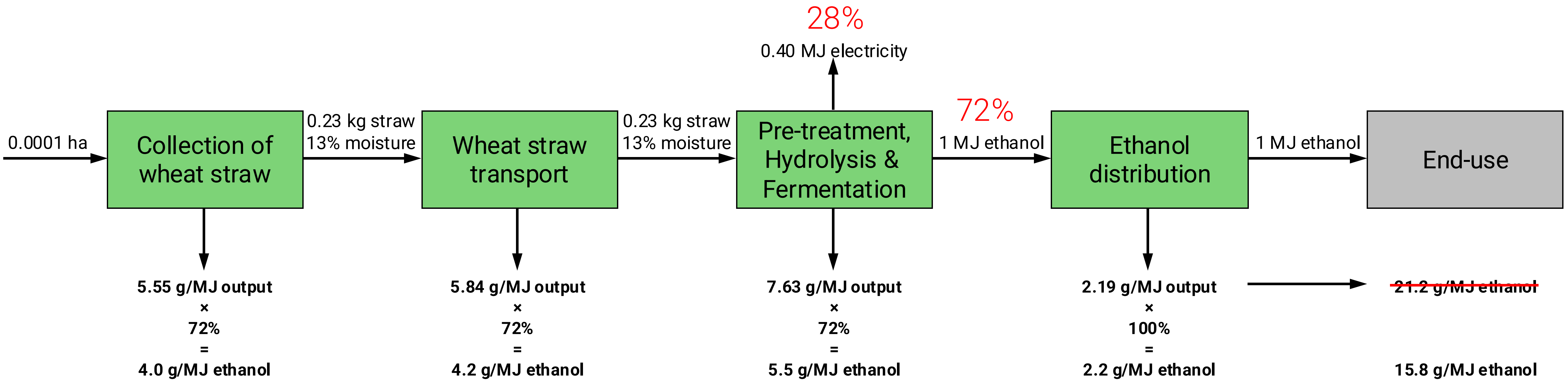
RED II calculation method for the greenhouse gas impact of renewable fuels
5. Account for co-products

- Co-products carry part of the environmental & climate burden caused by the supply chains
- RED methodology = energy allocation
  - At a point where multiple products are produced, the upstream climate impact is distributed
  - Such that each energy unit, i.e. MJ gets the same burden or g CO_2eq/MJ



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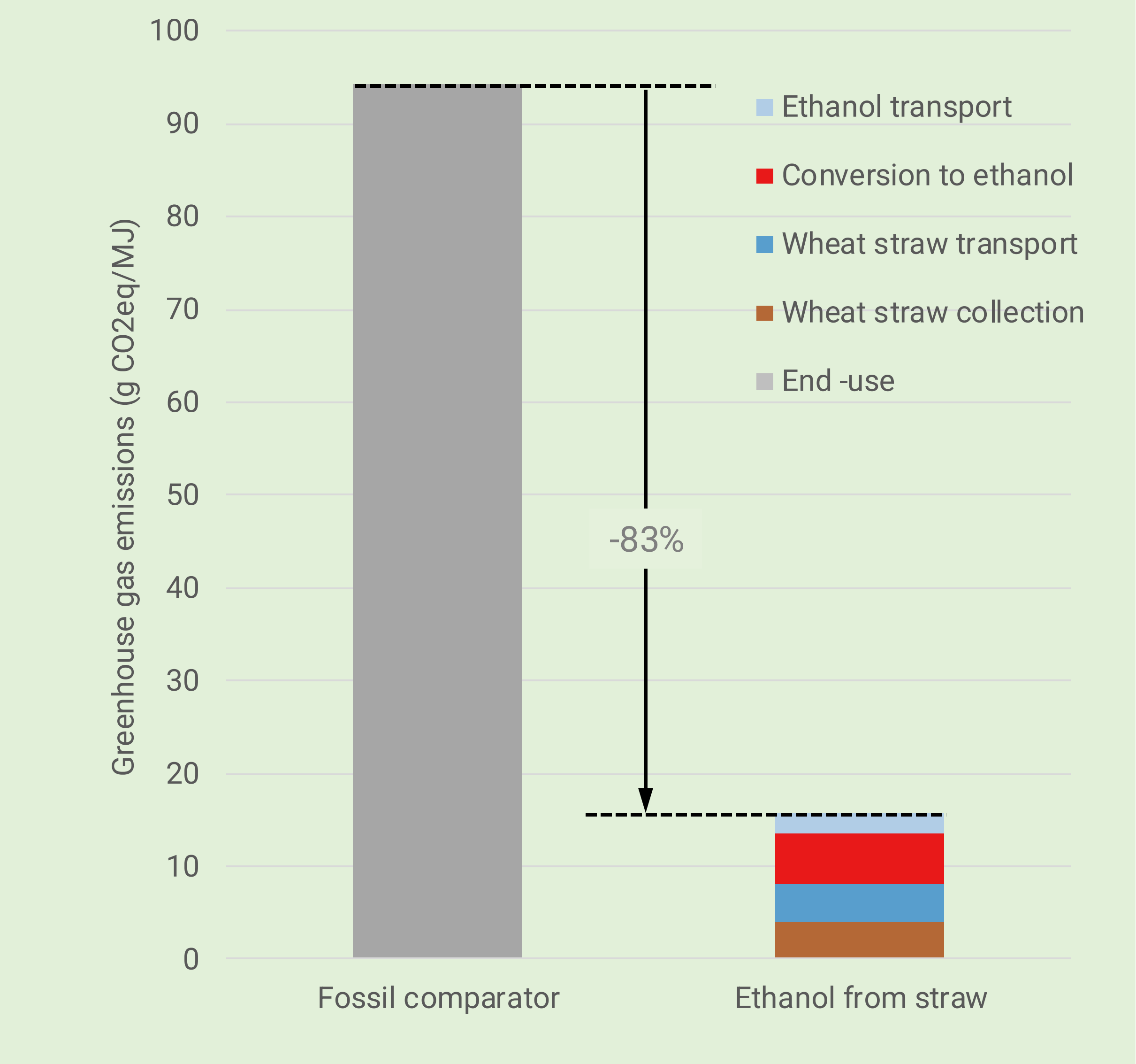
RED II calculation method for the greenhouse gas impact of renewable fuels
6. Aggregate the impacts

Result

- The production of ethanol from straw in Romania (applying parameters from literature & own assumptions) has a supply chain greenhouse gas emission of 15.8 g CO_2eq/MJ
- All the main steps have a significant contribution to the total emission
- Ethanol transport from the production site to the Port of Rotterdam causes less emissions than the local transport of the straw feedstock
- Process emissions are mainly caused by three reactants:
  - 30% by antifoam agent (propylene glycol assumed)
  - 33% by sodium hydroxide (NaOH)
  - 30% by calcium oxide (CaO)
  - It is unknown in how far the use of these reactants can be reduced, or if they could be sourced with lower carbon footprint than what was found in literature
- Co-produced lignin is used to provide process energy (thereby saving natural gas), and for the co-production of electricity, which carries away 28% of the upstream climate impact



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Extensions and variations

In some cases, special credits apply

- Credit for carbon capture and storage $\mathbf{e_{CCS}}$ or replacement $\mathbf{e_{CCR}}$
- Credit for activity that increases soil carbon accumulation, via improved agricultural management practice $\mathbf{e_{sca}}$
- Credit for carbon stock changes caused by direct land-use change $\mathbf{e_{l}}$

The carbon footprint of recycled carbon fuels (RCFs) is calculated in similar manner, but

- Elastic sources (that would increase if the demand would increase) are not allowed
- For rigid sources (their volume would not increase with demand) their current use would need to be compensated

Also the carbon footprint for e-fuels (RFNBOs: Renewable Fuels of Non Biological Origin) is calculated in similar manner, but

- The renewable electricity must comply with additionality rules to avoid canibalising on existing renewable electricity capacity
- CO_2 of fossil origin can only be used until 2041 (except from power generation: until 2036)
- If CO_2 is sourced from an ETS obliged facility, then the emissions are assumed to take place and allowances are required
- If CO_2 is sourced from a biofuel producer (e.g. from ethanol), the biofuel producer cannot claim carbon capture credit e_{CCR}

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