Life Cycle Assessment of CO_2-based products

Niels de Beus, Online webinar, 23 November 2021

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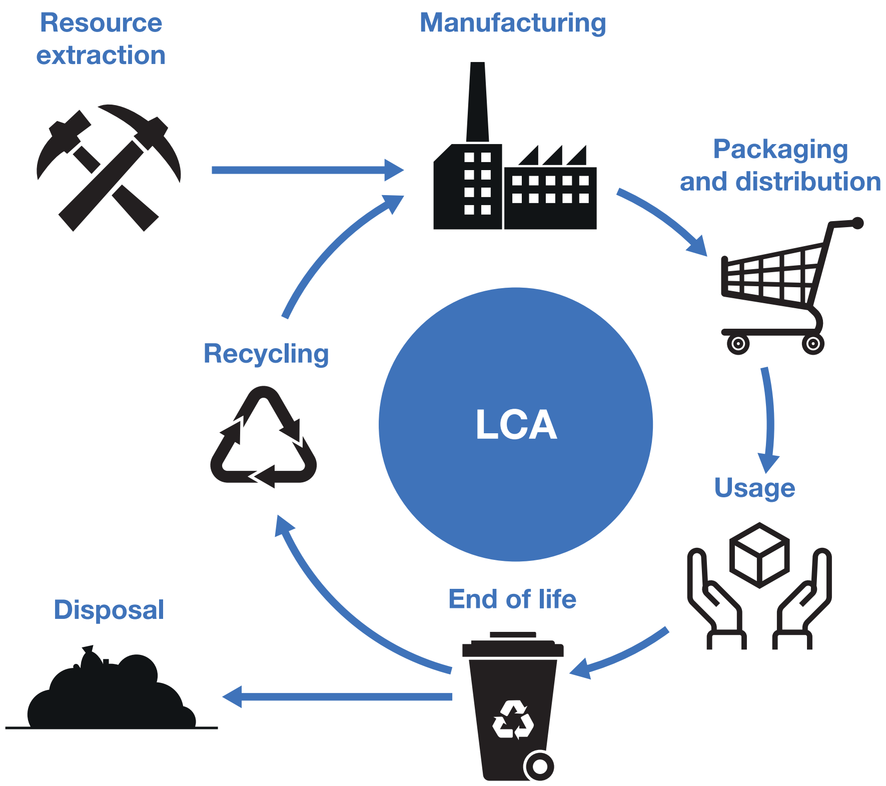
What is Life Cycle Assessment?

- Method to **assess** the **potential environmental impact** of a product or service throughout its entire life cycle. That is, from the supply of raw materials and production, to use, disposal or end-of-life waste management (cradle-to-grave)

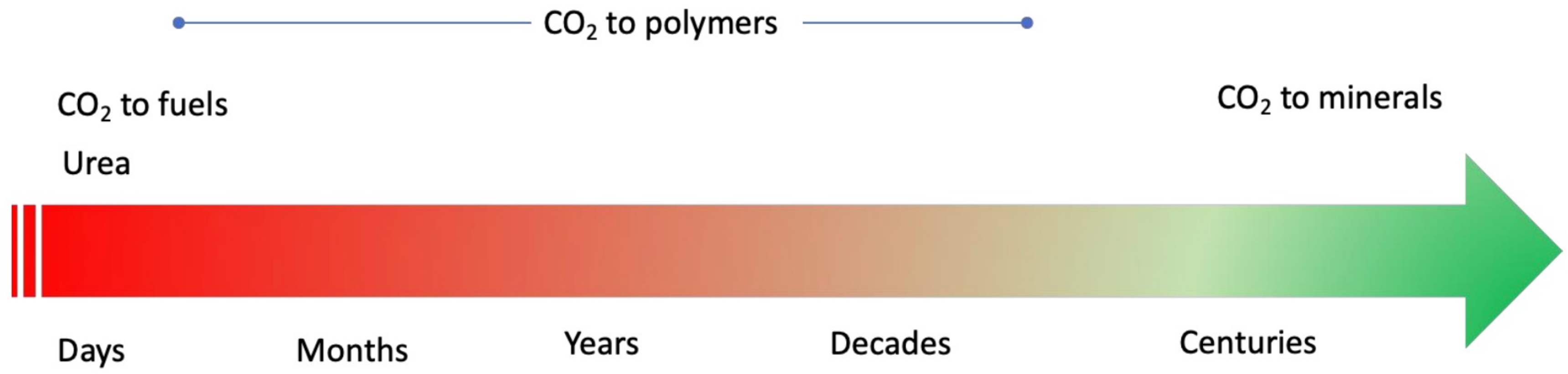
- It is an internationally standardised method under ISO 14040 and ISO 14044

- LCA assesses environmental impacts, such as global warming potential or eutrophication over the life cycle of a product or service, as well as the impacts on natural resources and/or human health



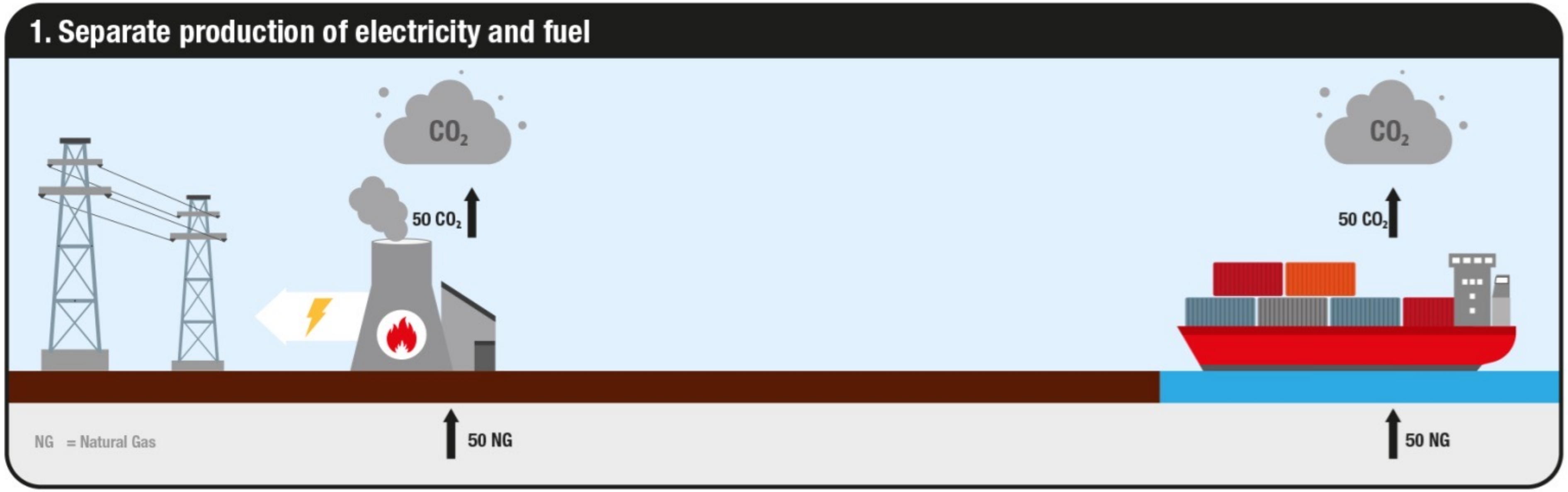
CCU (Carbon Capture and Utilization): Delayed emissions

- Delayed emissions of high relevance for CCU → **CO_2 is used instead of released**, but how long is the delay? For fuels, only a few months? For plastics, 20-30 or more years?
- Different ways to consider delayed emissions → **recommendations differ from complex scientific calculations to 500-year horizons** as a minimum threshold
  - Few to none CCU applications bind carbon for >500 years
- Other way of thinking: If the CCU product replaces a product derived from fossil resources, we have a **substitution**



System expansion:
Production of electricity and fuel

(The figures model ideal conditions without losses (100% efficiency))



Separate fossil electricity and fossil fuel production result in maximum GHG emissions (50 + 50 CO_2 = 100 CO_2)

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Production of electricity and fuel

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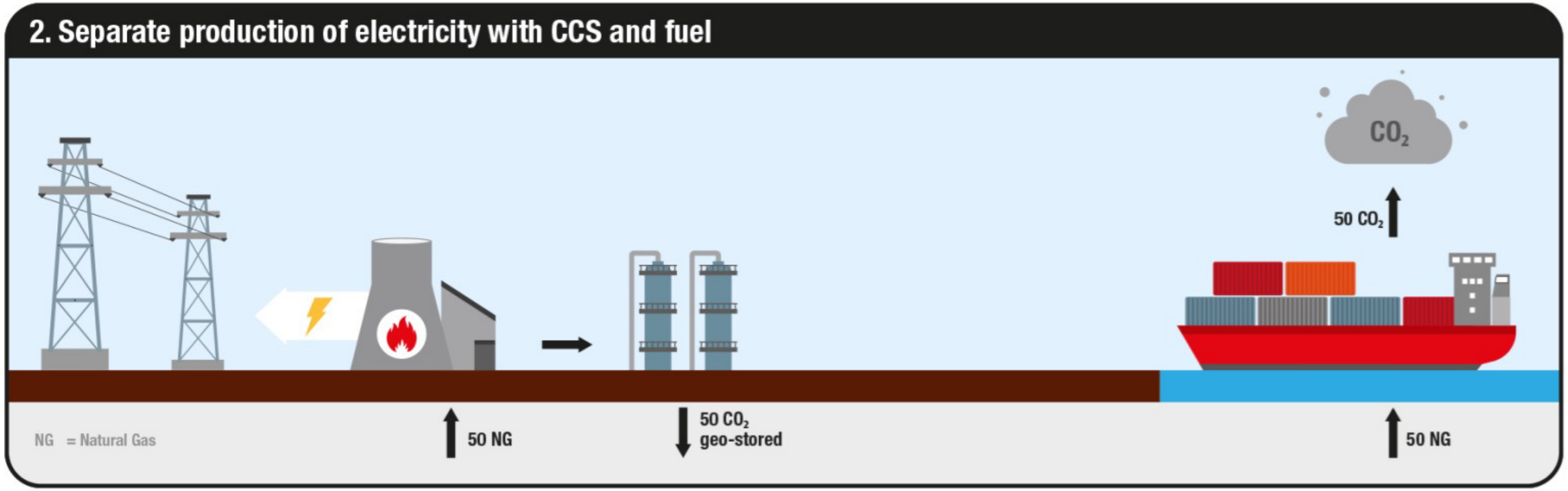
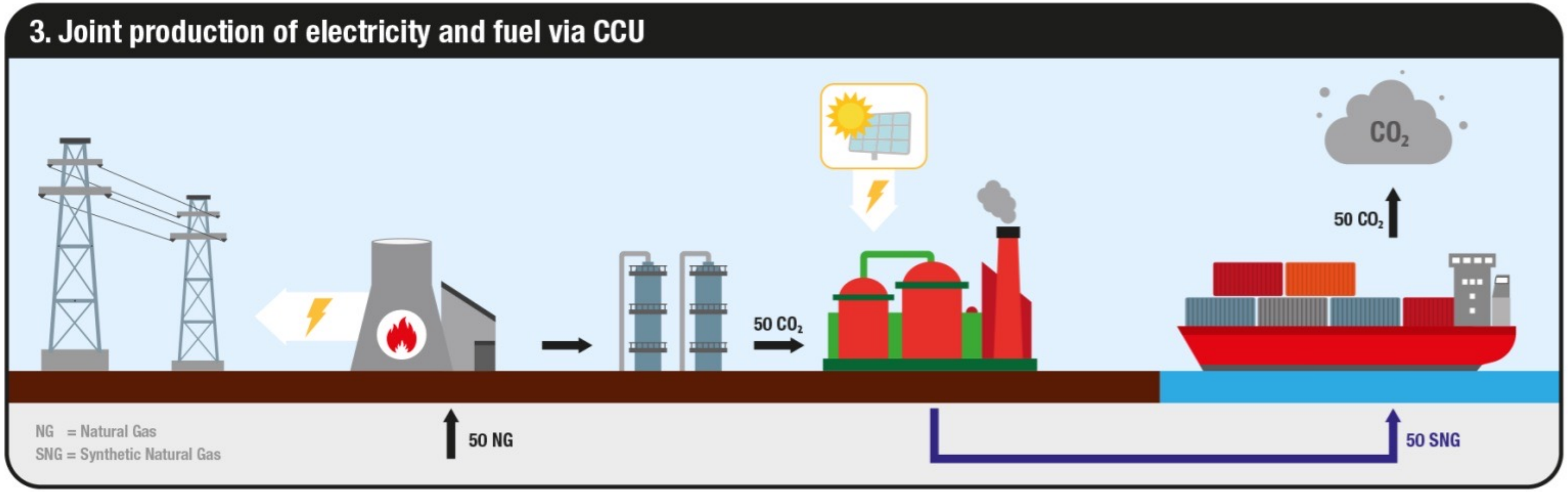


Carbon Capture and Sequestration (CCS) reduces the total CO_2 emissions by 50%.

System expansion:
Production of electricity and fuel

(The figures model ideal conditions without losses (100% efficiency))



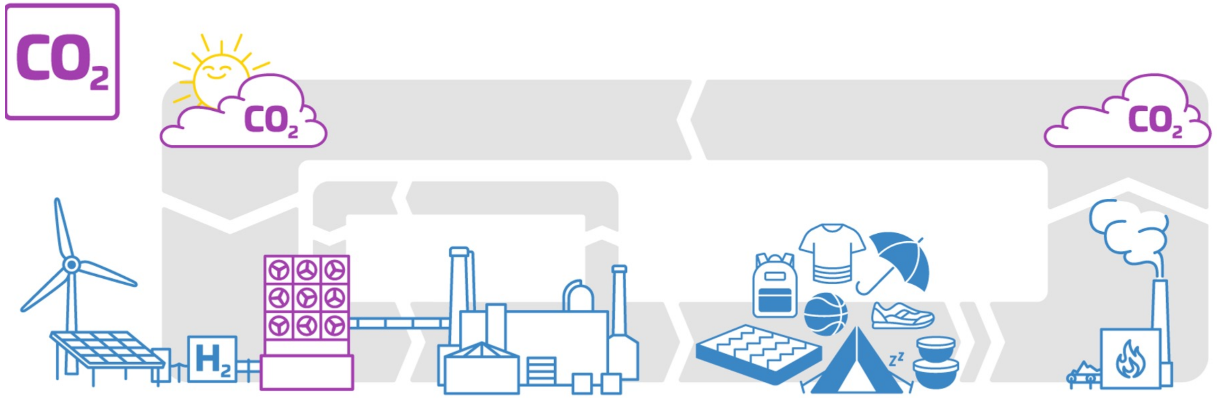
Carbon Capture and Utilization (CCU) also reduces total CO_2 emissions by 50% by using emissions from electricity production to produce fuels and substituting fossil natural gas (NG).

CCU: Electricity

- **CO_2 from industrial sources** is rarely a pure stream, but rather a mixture
- CO_2 is a naturally **stable** chemical, which often requires further processing steps.

- This usually requires **additional energy/electricity** for purification and utilisation
- The additional electricity will be **allocated to the process** and causes additional environmental impacts
- Dependent on the **grid mix this can lead to higher emissions** than what was avoided by CCU
- Running process on **additional** (produced on-site or purchased additionally) **renewable energy** is therefore often necessary
- **Purchased additionally**
  - RE currently limited, where to use it for maximum efficie
  - Purchased green electricity lowers RE in the grid mix
- **Producing on site**
  - Constructing required RE plants to cover energy needs good, but expensive solution

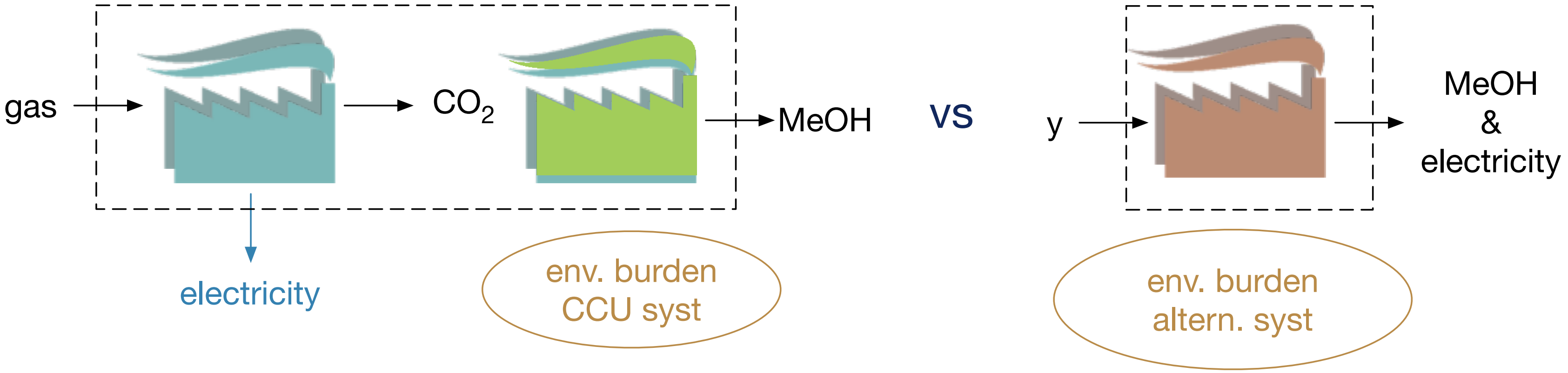
CCU: Credit and Burden



- Utilizing CO_2 has some peculiarities that have to be considered within the context of BioRECO$_2$VER:
  - By definition, **CO_2 is an elementary feedstock** for CCU plants. At the same time, it **also contributes to a fundamental impact category** (global warming potential, GWP)
  - For the emitting plant, **CO_2** is typically not the main product, often rather an **undesired side product**.
  - Upon utilisation of the CO_2 instead of emitting it to the atmosphere, it is of relevance **who gets the credit for reduction in CO_2 emission** or, in LCA terms words, how to allocate the CO_2 emission reduction between emitter and receiver of CO_2.
  - Because the CO_2 is usually a side product / waste from another process, **multi-functionality** occurs → **More than one product** (e.g. product from the original process and CCU product)

CCU: Credit and Burden
System expansion

- **System expansion**: comparison between CCU system (end-products) & a system with the same functions
  - Clearly determines environmental impact reductions
  - Strictly reflects physical relations ships
  - Can be complex
  - No product-specific assessment of the CO_2



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Example: Seperate production of electricity and methanol

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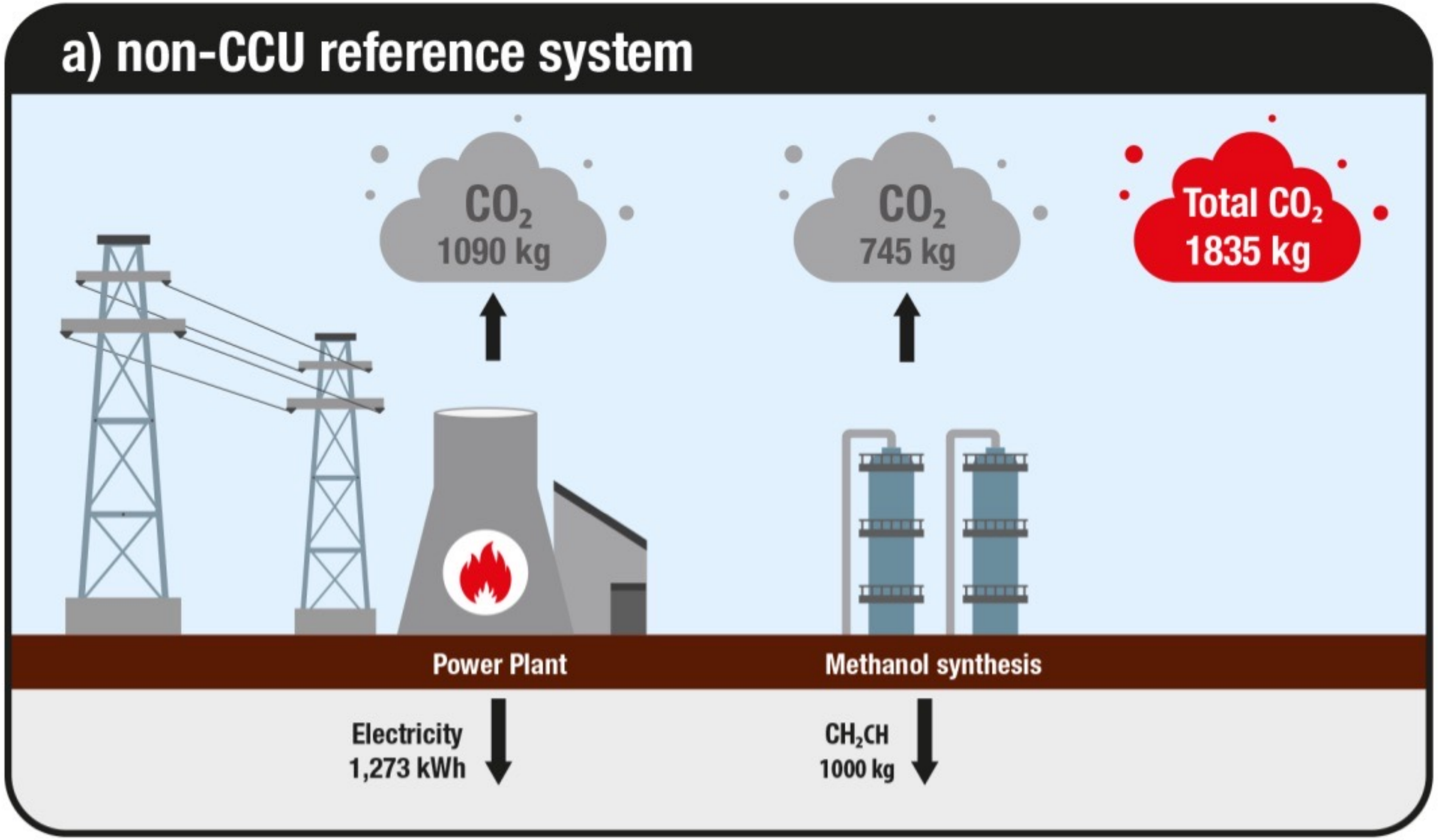
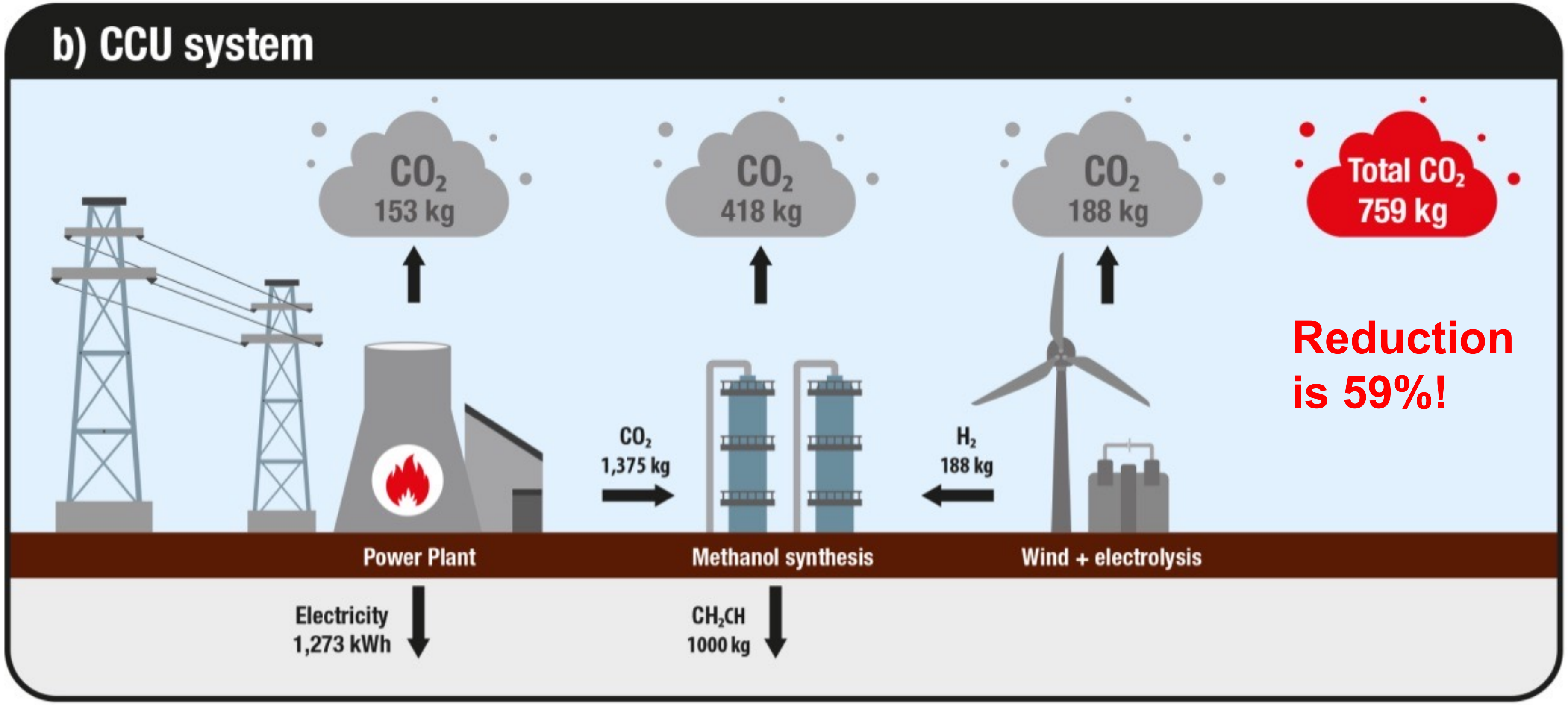


Example: Joint production of electricity and methanol via CCU & wind energy)



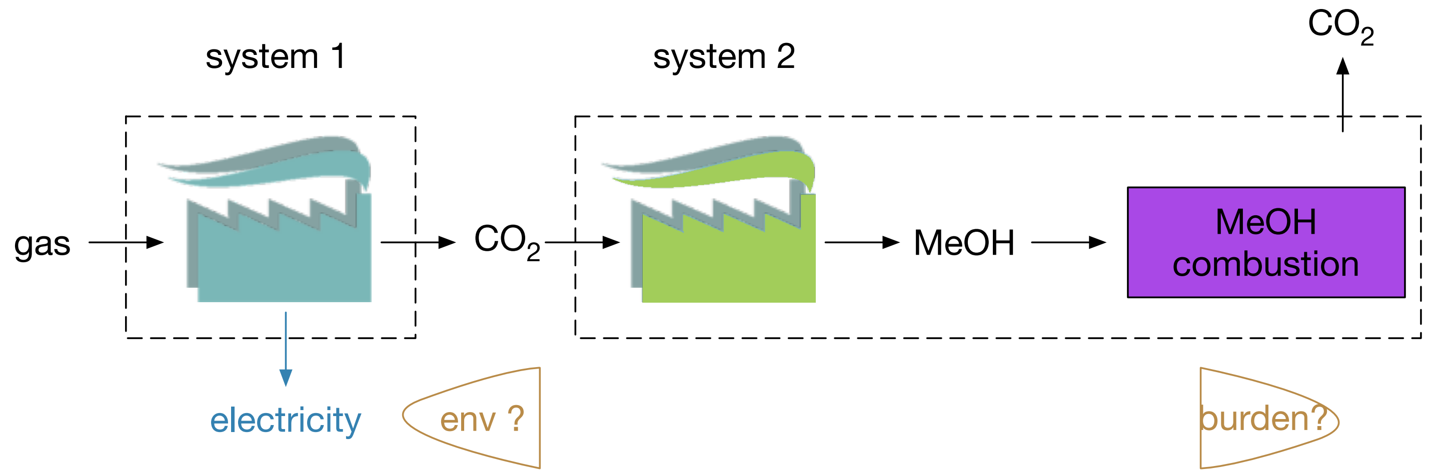
Reduction is 59%!

CCU: Credit and Burden Crediting

- **Substitution** (Avoided burden / credits)
  - Assigns all environmental burdens to a defined main function.
  - CCU would receive full burden of the process, but at the same time also receive credits for avoided production of the other product (here electricity) that would otherwise be provided through an alternative route

Credit and Burden of CCU: Allocation

- **Allocation**
- Environmental burden of is split between system 1 (electricity) & system 2 (MeOH)
- How to split? Most common suggestions are
  - **100:0** (giving merit to the CCU plant)
  - **50:50** (even split to provide incentives to both parties)
  - **0:100** (could be meaningful in an increasingly defossilised system (CO_2 valuable)



Comparison of different jet fuel feedstocks and pathways – CCU jet fuel is the best

	Jet fuel yield (GJ/ha*y)	GHG emissions without LUC (g CO_2 eq/MJ fuel)	GHG emissions with dLUC (g CO_2 eq/MJ fuel)	Green + blue water demand (m^3/GJ)
Crude oil		87.5		
Natural gas		101		
Rapeseed oil (HEFA)		55	98	
Jatropha oil (HEFA)	15 - 50	39		574
Palm oil (HEFA)	162	30	40 - 700	150
Algae oil (HEFA)	156 - 402	51		14 - 53
SRC (short rotation coppice)	47 - 171	18	- 2	112
PtL (solar)	580 - 1070			
PtL (wind)	470 - 1040	1 – 28 (*)		0.04 – 0.08

Summary, based on: Schmidt, P. et al. 2018: Power-to-Liquids as Renewable Fuel Option for Aviation: A Review. In: Chem. Ing. Tech. 2018, 90, No. 1-2, 127-140. / (*): In a today's mainly fossil energy landscape in material sourcing and construction.

Main take-aways LCA of CCU

- **CCU can be a relevant option for climate change mitigation**
  - through **substituting** fossil C or circulating atmospheric/bio-based C
- A critical issue to consider are the (usually **large**) **required amounts of energy** to transform the CO_2
- There is **no** standardised **agreement on** who receives **credit** for avoided emissions via CCU
- There are **different methods to allocate environmental burdens** between multiple functions/products
  - can lead to quite different results, **careful with comparisons!**

Thank you for your attention!

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