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Carbon Footprint Methodology

AEA Annual Conference

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BRUSELAS • PARÍS • ROTTERDAM • WASHINGTON D.C. • SANTIAGO • BOGOTÁ

Agenda

- CCUS & Emissions Reductions
  - Definitions
  - Straightforward Approach
  - Dynamic Plant Splitting Approach
  - Variable CCS & Urea

- Handling Multifunctionality & Allocation Principles
  - Steam
  - Solid Carbon (Methane Pyrolysis)

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CCUS Definitions & Emissions Reduction

Carbon Capture & Storage Definition

The AEA scheme allows for emissions reductions with long-term CCS

- **Carbon Capture & Storage**
  - Captured CO_2 is CO_2 that is extracted from the process and then available for conditioning and storage
  - After capture, CO_2 can be transported via pipeline to underground geological storage sites
  - It is assumed that **the assured geological storage period to be considered long-term will be 100 years**[1], although this will be subject to local regulatory requirements applicable to the participant
  - **Permanently storing CO_2 resulting from ammonia production reduces the CFP of ammonia**

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[1] IPCC, 2005: IPCC Special Report on Carbon Dioxide Capture and Storage. Prepared by Working Group III of the Intergovernmental Panel on Climate Change [Metz, B., O. Davidson, H. C. de Coninck, M. Loos, and L. A. Meyer (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 442 pp. P. 197

Carbon Capture & Utilization Definition

The AEA scheme allows for emissions reductions with only long-term CCU

- **Carbon Capture & Utilization**
  - Once carbon is captured, it can be subsequently utilized in various commercial products

Long-term (30+ years).

Long-Term CCU Explained

- Long-term CCU: Permanent or semi-permanent sequestration of CO_2.
- Example: Transformation of CO_2 into a mineral carbonate
- **Eligible for emissions reduction due to long-term CO_2 storage.**

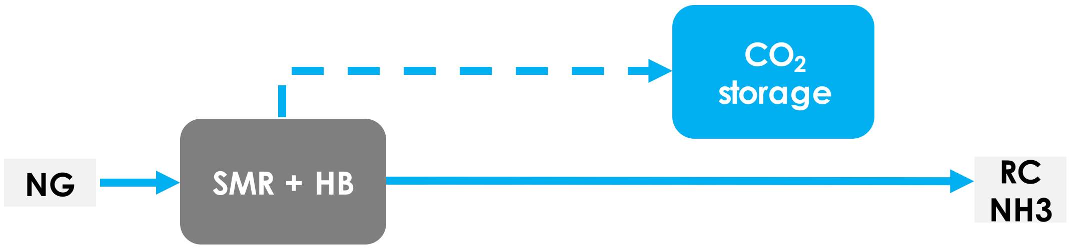
Short-term (<30 years)

Short-Term CCU Explained

- Short-term CCU: Temporary storage of CO_2 in products with a lifespan of less than 30 years.
- Example: Urea for fertilizer – CO_2 released when applied to fields.
- **No emissions reduction due to temporary carbon sequestration.**

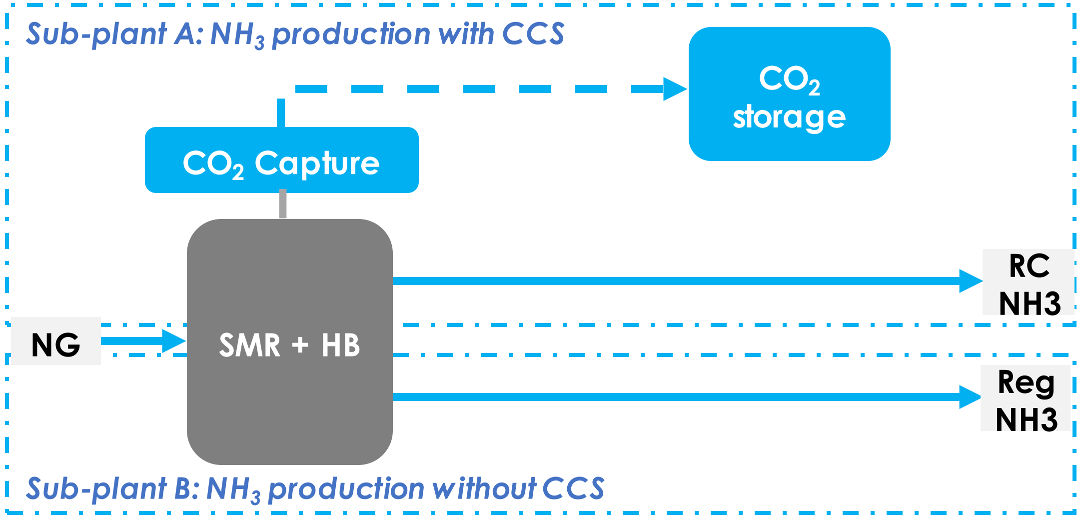
Straightforward & Dynamic Plant Splitting Approach

Two approaches to calculate the emissions reduction from CCS


CO_2 storage
NG
SMR + HB
RC NH3

Straightforward LCA Approach

CCS reduces the footprint of all the ammonia produced


Sub-plant A: NH_3 production with CCS
CO_2 storage
CO_2 Capture
NG
SMR + HB
RC NH3
Reg NH3
Sub-plant B: NH_3 production without CCS

Dynamic Plant Splitting Approach

CCS reduces only part of the ammonia produced, and the rest keeps the regular footprint

Conditions for Applying DPS:

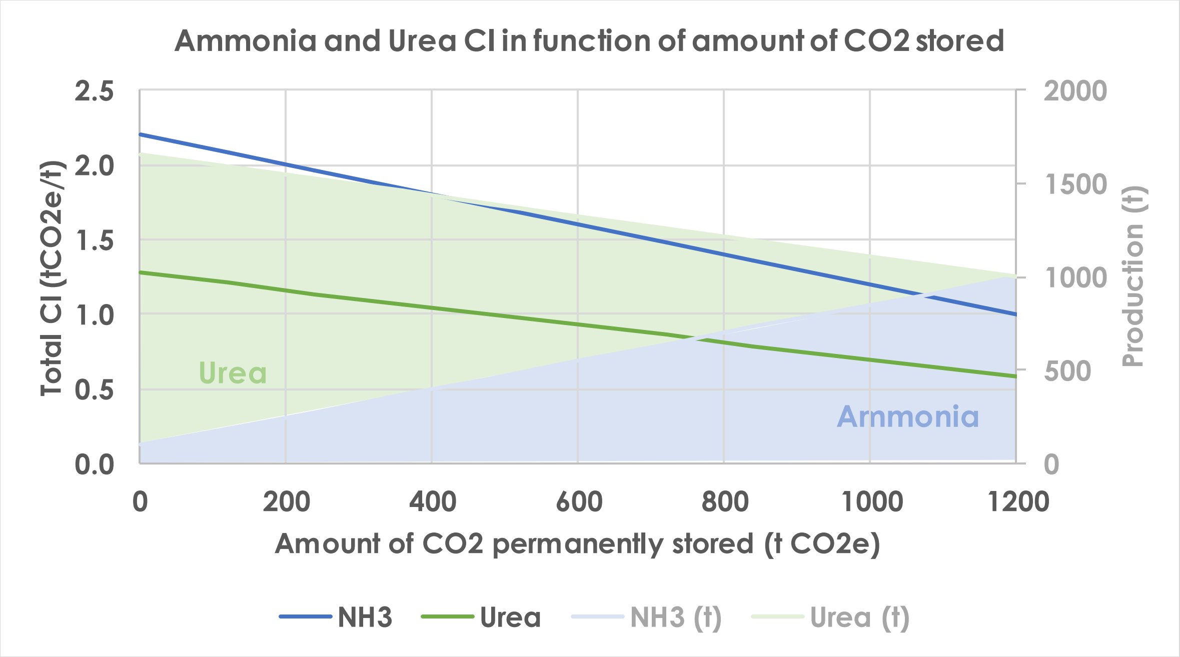
- Ammonia production plants that apply CCS which has fluctuating CO_2 sequestration rates over time.

Accounting for CCS in case of multiple products

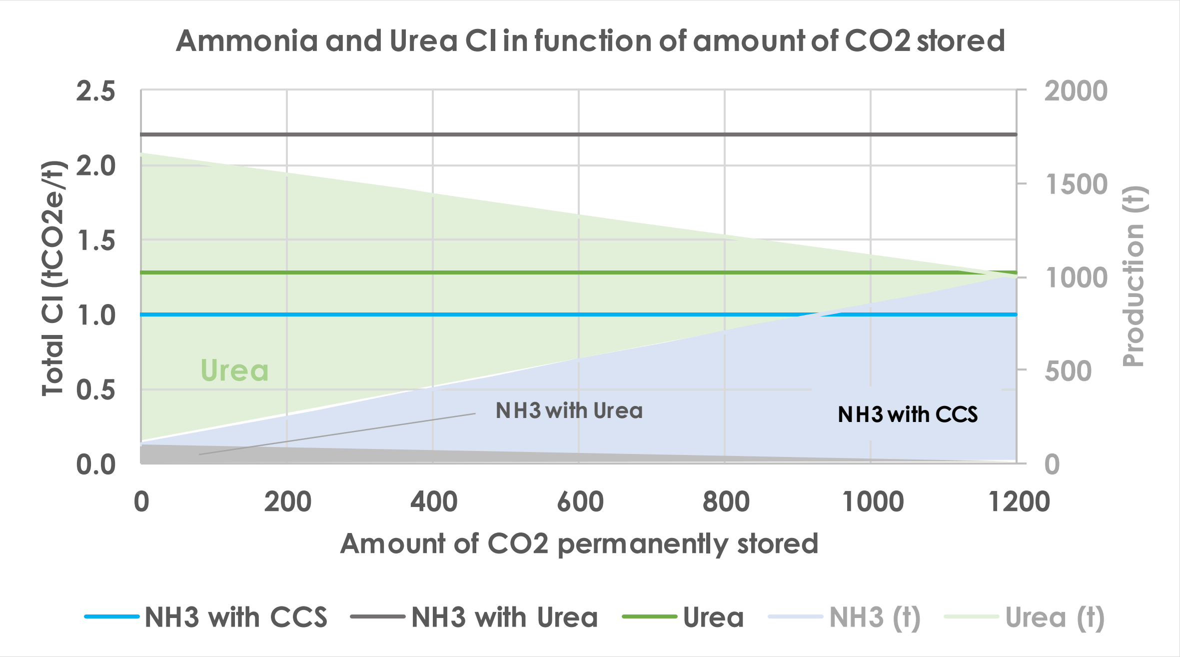
When coproducing urea, there are at least two ways to assign the emissions reduction

The examples below assume that all the CO2 not used in urea, is geologically stored.

Straightforward LCA



Dynamic Plant Splitting



The total CFP of both products decrease in proportion to the amount of avoided CO_2 emissions due to CCS.

However, with dynamic plant splitting, an amount of low-carbon NH3 is produced in proportion to the amount of avoided CO2 emissions due to CCS.

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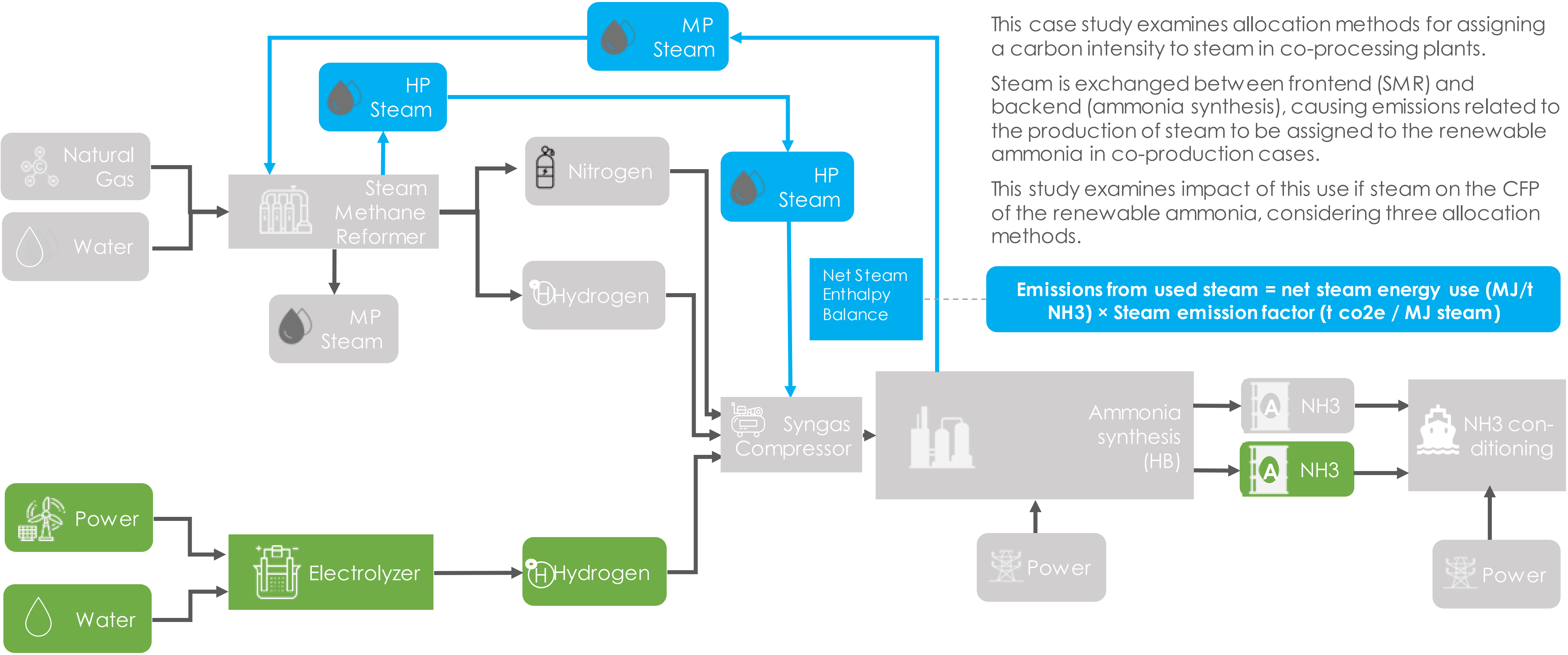
Handling Multifunctionality & Allocation Principles

Emissions From Steam Used to Produce Renewable NH_3

Steam exported from conventional SMR used to compress H_2 and N_2 for renewable NH_3



This case study examines allocation methods for assigning a carbon intensity to steam in co-processing plants.

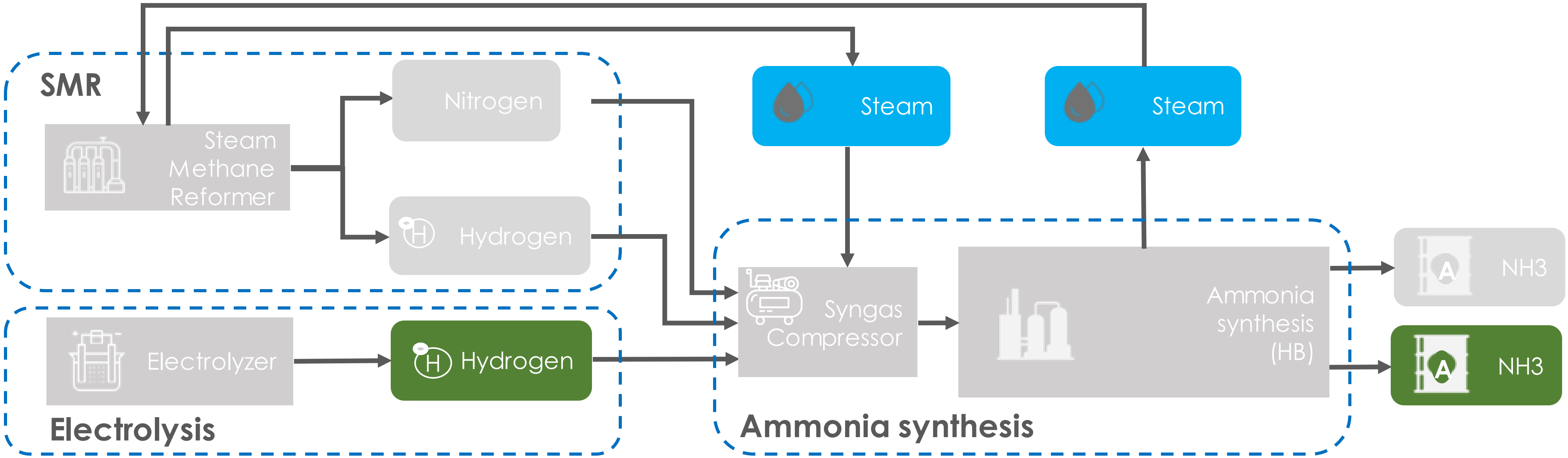
Steam is exchanged between frontend (SMR) and backend (ammonia synthesis), causing emissions related to the production of steam to be assigned to the renewable ammonia in co-production cases.

This study examines impact of this use if steam on the CFP of the renewable ammonia, considering three allocation methods.

Emissions from used steam = net steam energy use (MJ/t NH3) × Steam emission factor (t co2e / MJ steam)

Assigning a CFP to Co-Produced Steam

Different variants of energy-based allocation methods can be applied



Emissions Allocated to Net Steam Consumption		
1) Energy losses fully assigned to main reformer products (hydrogen)	**2) Steam also carries emissions related to process energy losses**	**3) System expansion considering that the steam replaces steam from a boiler**
Steam is only assigned the emissions of heat input required to generate the steam in a heat exchanger, considering 98% efficiency	**Steam is allocated the upstream and process emissions in proportion to its energy content (steam energy content vs hydrogen energy content)**	**Steam is allocated the emissions of heat input required to generate the steam in a natural gas fired boiler**, considering 90% efficiency

Steam CFP Varies Slightly By Approach Used

… and the ammonia CFP also varies slightly

Example shows small variations in steam CFP when applying the three different options of allocation methods.

	Option 1	Option 2	Option 3
Description of Approach	**Steam is only assigned the emissions of heat input required to generate the steam in a heat exchanger**, considering 98% efficiency	**Steam is allocated the upstream and process emissions in proportion to its energy content**	**Steam is allocated the emissions of heat input required to generate the steam in a natural gas fired boiler**, considering 90% efficiency
Steam CFP in g CO_2e/MJ	**67.2** (fixed value)	**73.5** (process dependent)	**73.2** (fixed value)
Renewable Ammonia in kg CO_2e/kg	**0.356**	**0.372**	**0.371**

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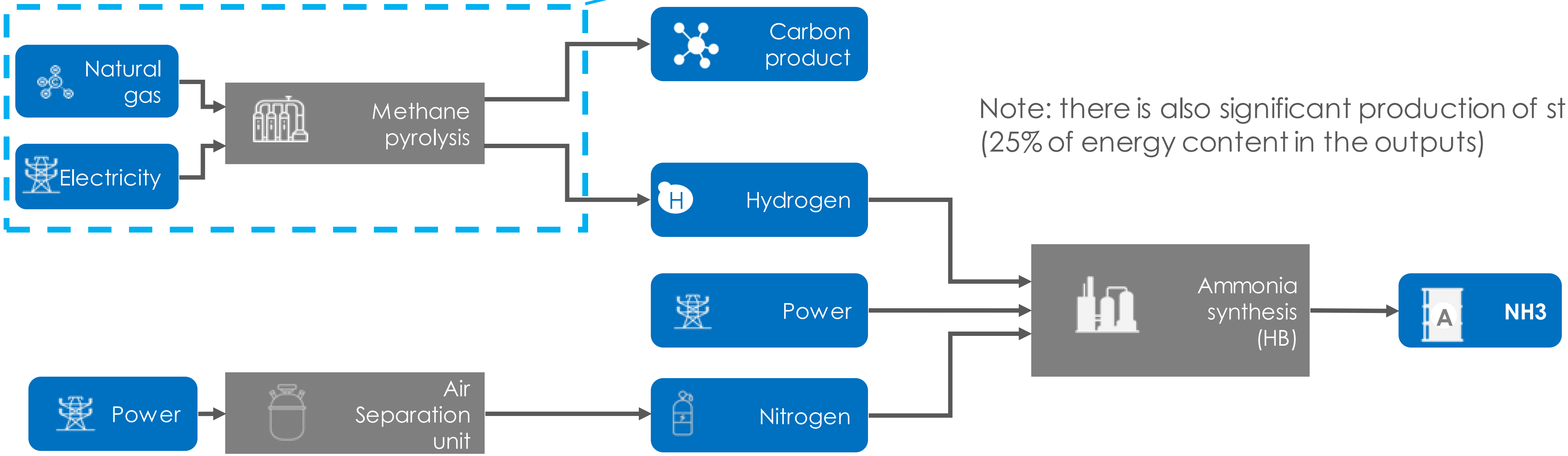
Allocating Emissions using Methane Pyrolysis for H_2 & NH_3

Ammonia CFP depends emissions allocation to the Carbon and H_2

Different carbon products possible:

- Carbon black
- High purity carbon
- Carbon

How to allocate the upstream and process emission of methane pyrolysis to the two co-products: the carbon product (e.g., carbon black) **and hydrogen?**

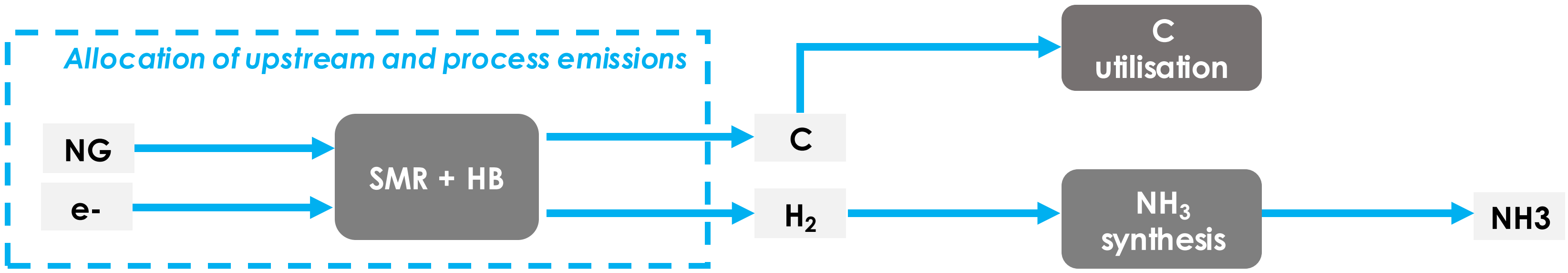


Note: there is also significant production of steam (25% of energy content in the outputs)

Source
S. Timmerberg, et.al.: *Hydrogen and hydrogen-derived fuels through methane decomposition of natural gas – GHG emissions and cost*, Energy Conversion and Management, 2020.

Allocation Methods Assessed

…following allocation method hierarchy specified by ISO 14067



	Application subject to various conditions **System expansion by substitution**	**Physical causality based allocation**	**Energy based allocation A**	*Variant* **Energy based allocation B**	**Mass based allocation**	**Value based allocation**	**No allocation – carbon is stored**
DESCRIPTION	Emissions assigned to hydrogen based on emissions of reference hydrogen production	Impact on pyrolysis process emissions of making H_2 available for use assigned to the H_2	Emissions assigned to co-products based on their respective energy content	Emissions assigned to co-products based on their respective energy content, with adjustment for carbon content	Emissions assigned to co-products based on their respective mass	Emissions assigned to co-products based on their respective economic value	The process yields only one product: hydrogen, therefore allocation is not needed
RATIONALE	Which reference production would H2 from NG pyrolysis substitute? → **Not considered applicable here**	Emissions assigned based on the change of emissions caused by making an extra unit of co-product available (keeping other co-product quantities constant)	Energy content of the products is made up by the energy content of the inputs Always assigns the same process emissions per MJ to all the co-products	Considers difference in emissions from separate production	Mass of the products is made up by the mass of the inputs Not suitable for steam Generally, not considered suitable for H_2 due to its low molecular weight	Value is a fundamental basis for splitting the emissions between the products	When hydrogen production by pyrolysis will yield mor carbon than needed by the applications, the carbon will need to be permanently stored

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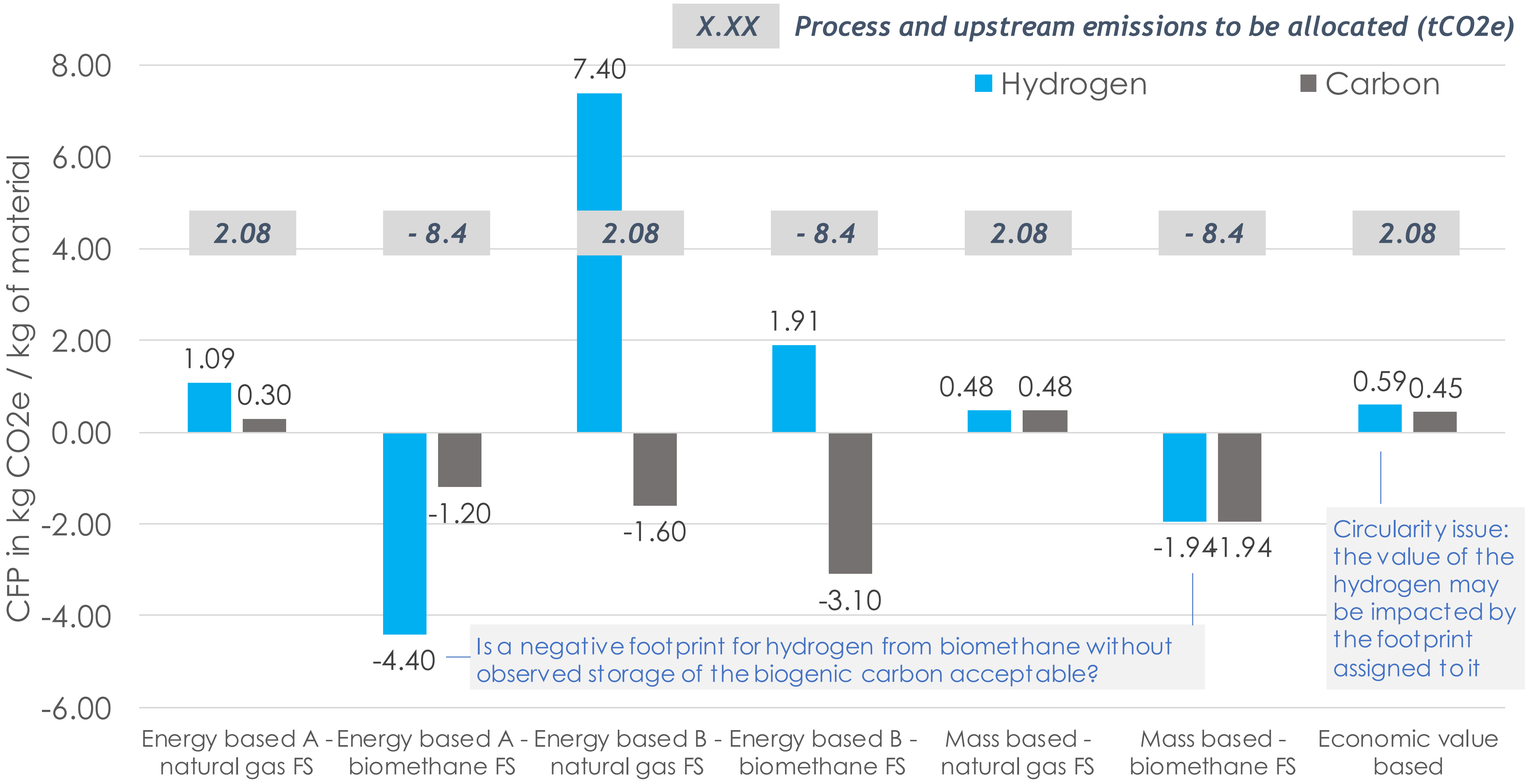
Impact of Allocation Methods on CFP of Hydrogen

Significantly varying results for different methods of allocation



Is a negative footprint for hydrogen from biomethane without observed storage of the biogenic carbon acceptable?

Circularity issue: the value of the hydrogen may be impacted by the footprint assigned to it

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