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AMMONIA ENERGY ASSOCIATION

AEA Carbon Footprint Methodology

AEA conference

August 2023

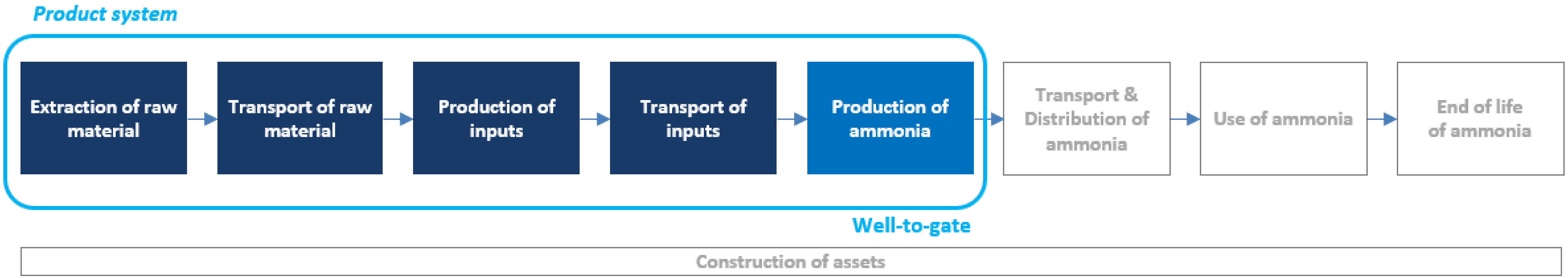
BRUSSELS • BOGOTA • WASHINGTON DC
PARIS • SANTIAGO • BEIJING

Scope of the AEA CFP methodology is well-to-gate

Emissions from the construction of assets and downstream emissions are excluded

Included emissions in the well-to-gate product system:

- Extraction of raw materials used for ammonia production
- All production stages needed to produce liquid ammonia at atmospheric pressure



Excluded emissions in the well-to-gate product system:

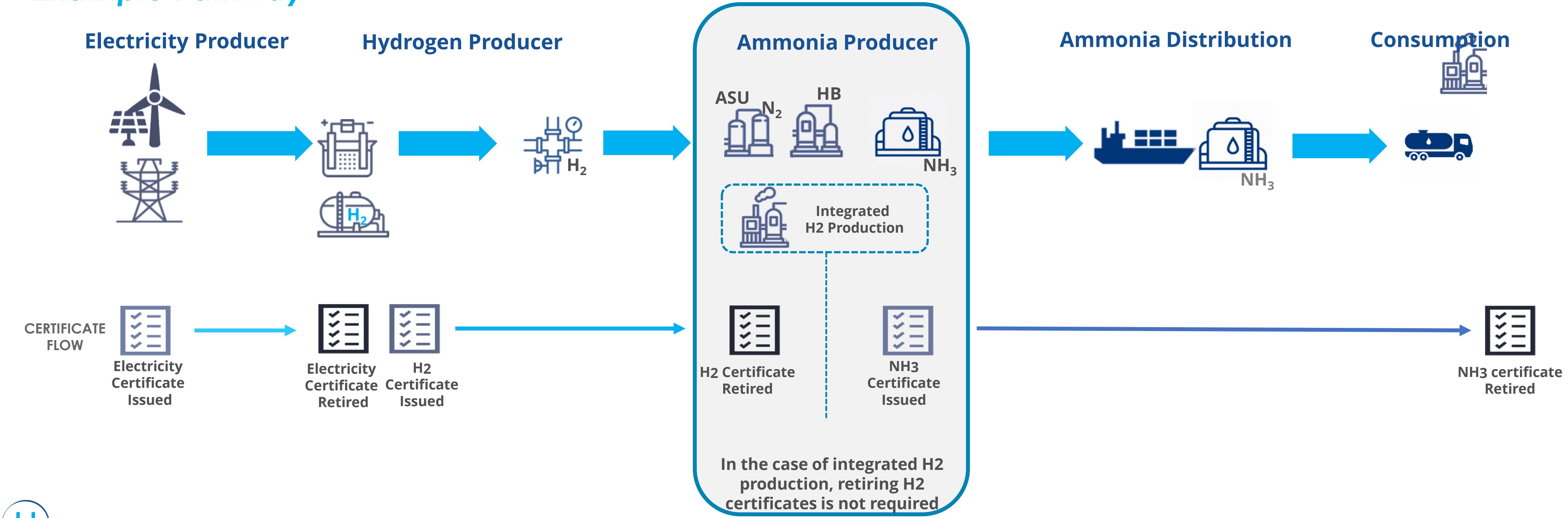
- Downstream GHG emissions from subsequent refrigeration, transportation, and use of ammonia
- GHG emissions from the construction of assets in the product system

Certification of inputs is required

AEA methodology is focused on the ammonia production and relevant inputs must be certified

Operators must **supply data and documentation** for **activities within their facility,** as well as for instances involving **external inputs like electricity, hydrogen, biomethane or Responsibly Sourced Gas.**

Example Pathway



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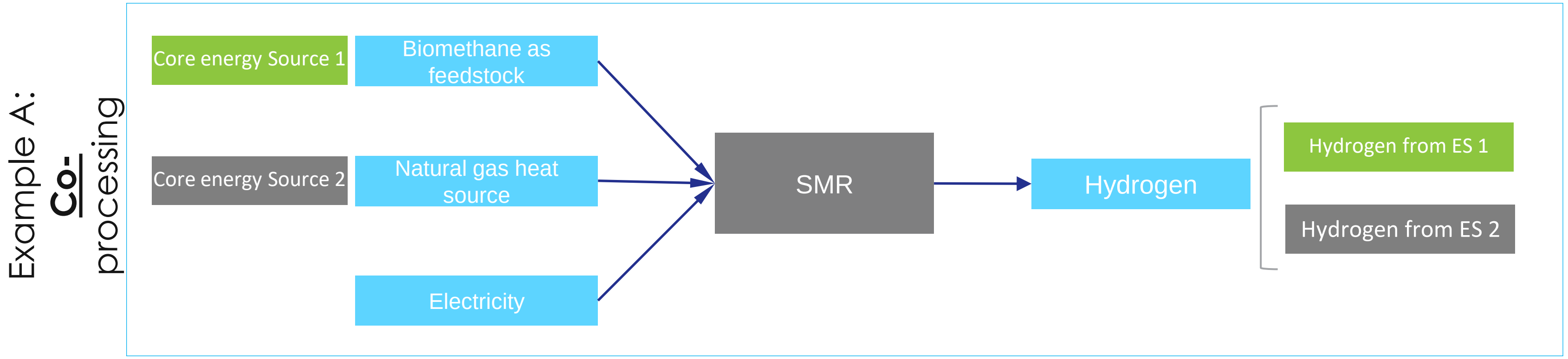
The principle of core energy inputs

Ammonia CFP can be calculated based on the principle of core energy inputs

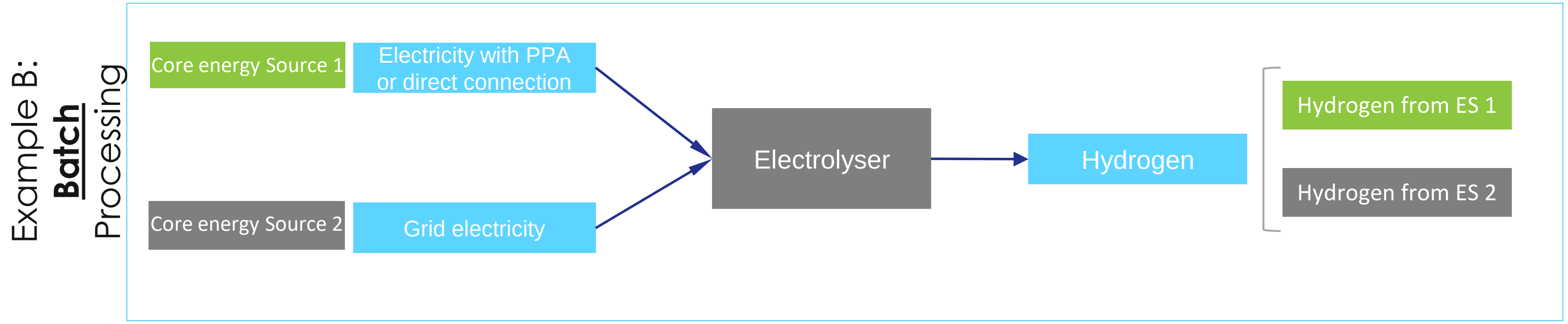
Core energy input:
Energy input contributing to the energy content of the ammonia

Hydrogen /ammonia produced from different core energy sources:

The share of renewable hydrogen is equal to share of renewable core energy input in total core energy input.



- Product not 100% renewable because heat is required to create the energy content of the product and heat is produced from natural gas
- Only a share of hydrogen is considered renewable, proportionally to the share of renewable input



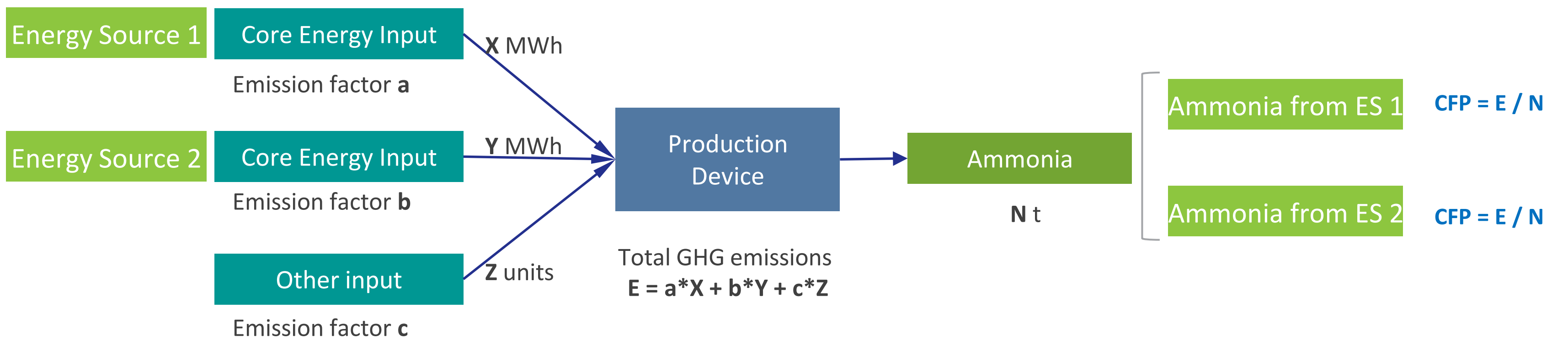
- Product not 100% renewable because electricity is not always sourced from fully renewable sources.
- The share of renewable hydrogen is proportional to the share of consumed electricity that is using a PPA

Ammonia CFP depends on the core energy input

CFP calculation method for co-processing can yield individual results for co-products or an average

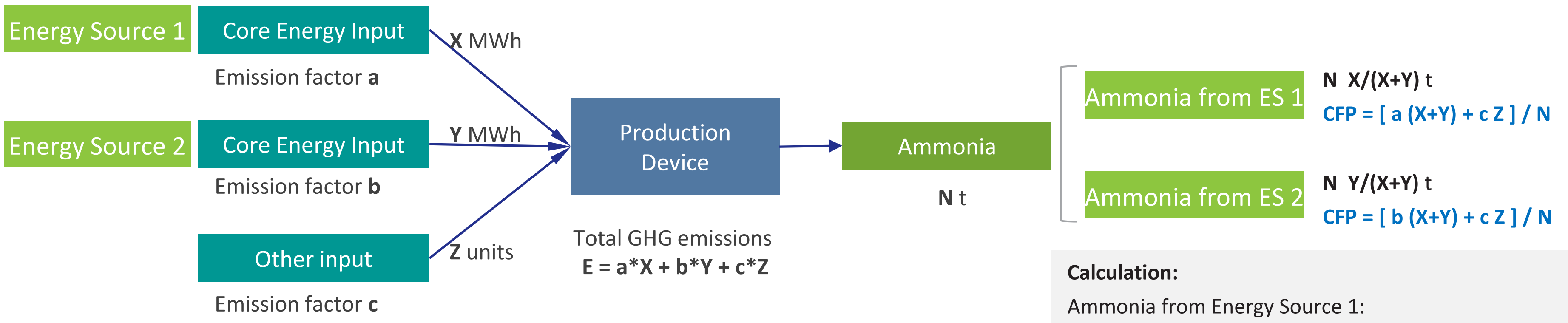
Option I

Average CFP for co-products



Option II

Individual CFP for co-products



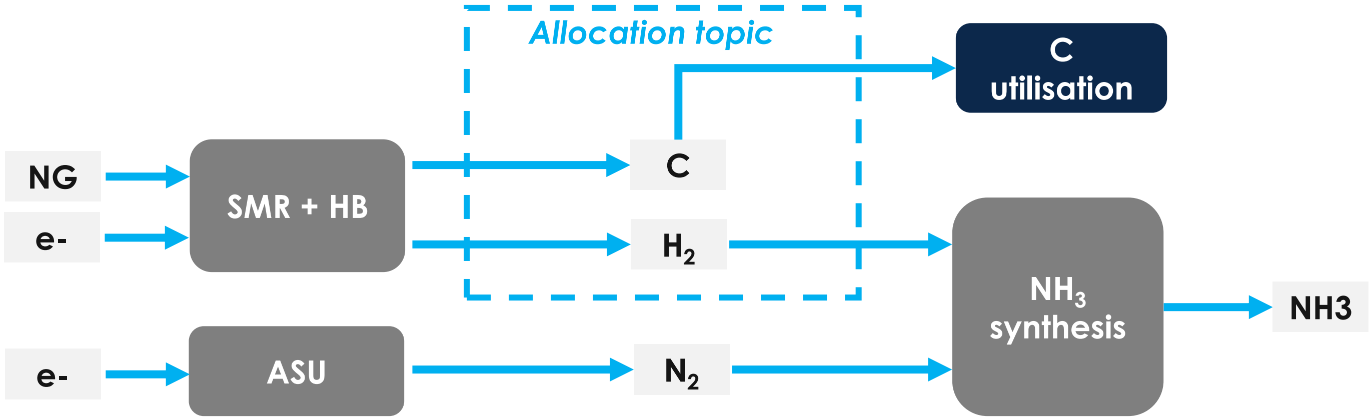
Calculation:

Ammonia from Energy Source 1:

Amount :	N X/(X+Y)
Emission assigned:	a X + X/(X+Y) c Z
ci:	[a X + X/(X+Y) c Z] / [N X/(X+Y)]

Allocating emissions to co-products of methane pyrolysis

Literature value assumptions for CFP calculation



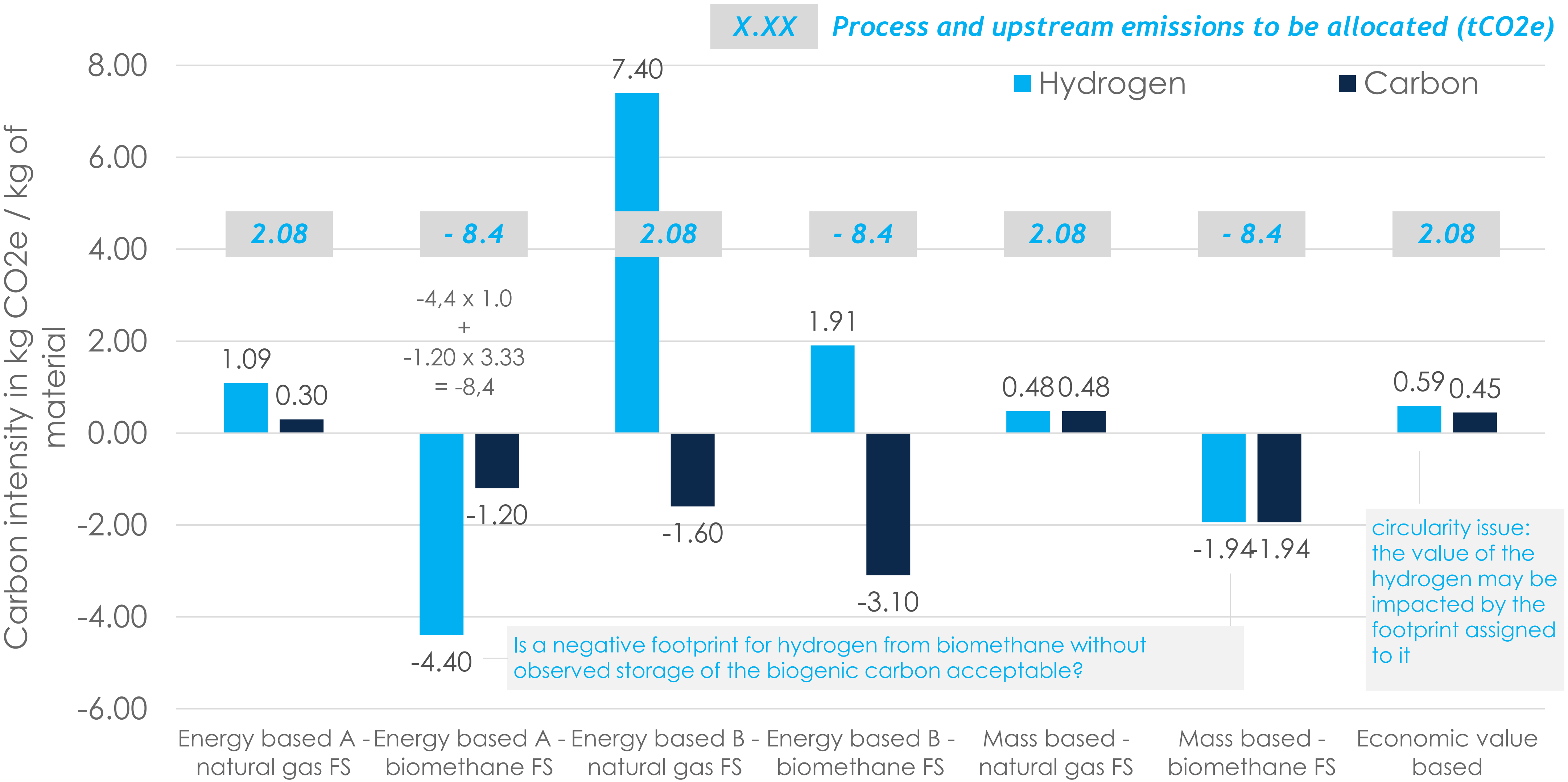
Inputs methane pyrolysis			
Type of input	Parameter	Value	Unit
Natural gas feedstock	Consumption	233	MJ/kg H2
	Upstr. emissions	9.7	g CO2e/MJ
NG for bed reactor	Consumption	9.5	kWh/kg H2
	Emission factor	65.9	g CO2e/MJ
Elec for plasma reactor	Consumption	27	kWh/kg H2
	Emission factor	0.0	g CO2e/MJ

Outputs methane pyrolysis			
Type of output	Parameter	Value	Unit
Hydrogen	Mass	1.0	kg
	Energy content	120	MJ/kg
	Economic value	2.0	USD/kg
Carbon	Mass	3.3	kg
	Energy content	30.2	MJ/kg
	Economic value	1.5	USD/kg

Inputs & Outputs Ammonia synthesis			
Type of input	Parameter	Value	Unit
Hydrogen	Consumption	0.17	kg H2/kg NH3
Nitrogen	Consumption	0.83	kg N2/kg NH3
	Emission factor	0.0	g CO2e/kg
Type of output			
Ammonia	Quantity	1.0	kg

Impact of different allocation methods on CFP of hydrogen

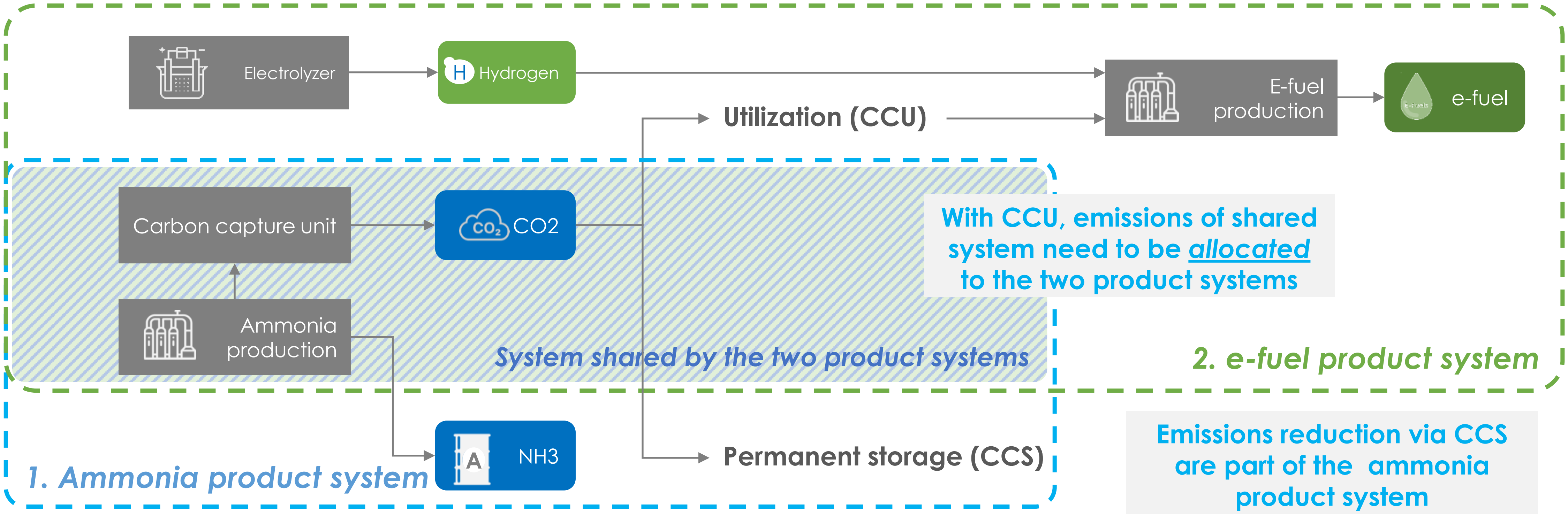
Significantly varying results for different methods of allocation for methane pyrolysis



Assignment of emissions reduction for CCU and CCS

AEA methodology addresses complex allocation situations

Example: CCU for e-fuel production

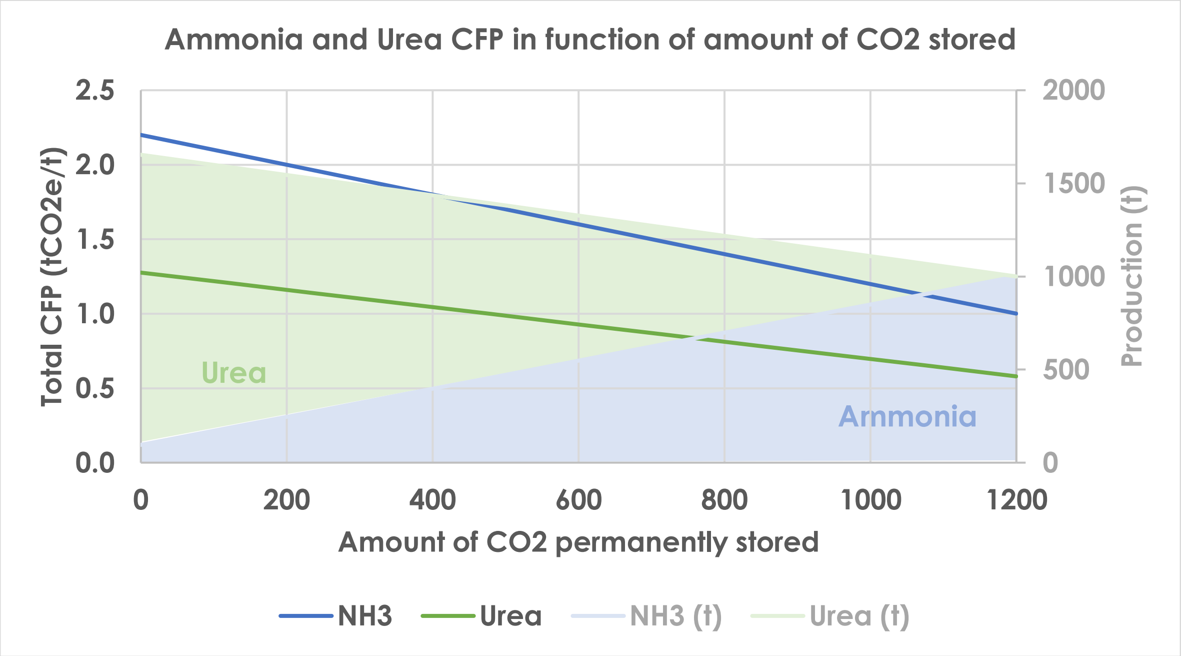


Accounting for CCS – Different approaches may be used

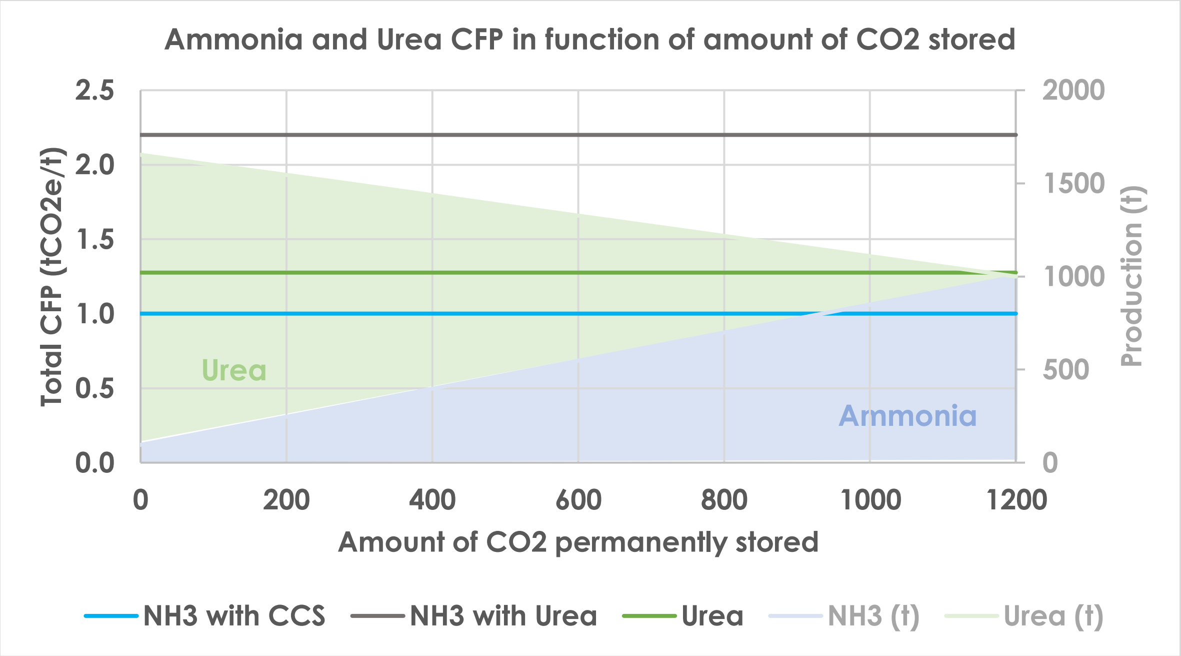
Plant division allows to assign the emissions reduction from CO_2 storage to the ammonia

Full capture of process CO_2 assumed

Straightforward LCA



Dynamic process splitting



Since both products are derived **from the same natural gas processing step**, It makes sense that the total CFP of *both* products decrease in proportion to the amount of avoided CO_2 emissions in that step thanks to CCS.

However, dynamic division is generally accepted, e.g. for quantifying impact on product CFP of an emissions reduction measure sized to address only a fraction of output