How shipping can contribute to reduce the overall CO2 footprint.

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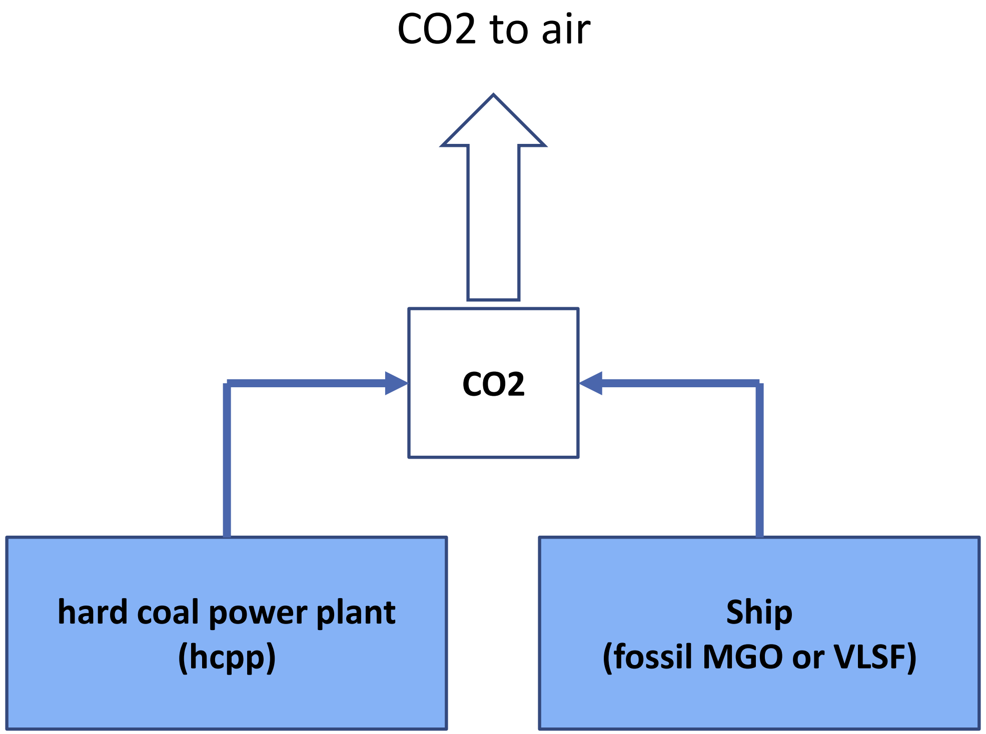
CASE-1: Business as usual
- CO_2 emissions Tank to Wake -

Combined emissions from hard coal power plants (hcpp) and ships without CC

- **758** g(CO_2)/kWh = **100%**; different conversion efficiencies of ship and hcpp considered



Hard coal power plant (hcpp):

- CO_2 emissions per electrical energy unit without Carbon Capture (CC):
  - 1099 g(CO_2)/kWh(el); with 40 % power plant efficiency

Ship emissions:

- CO_2 emissions per energy unit shaft power (shp) without Carbon Capture (CC):
  - 556 g(CO_2)/kWh(shp); with 48 % ship engine efficiency and MGO as fuel

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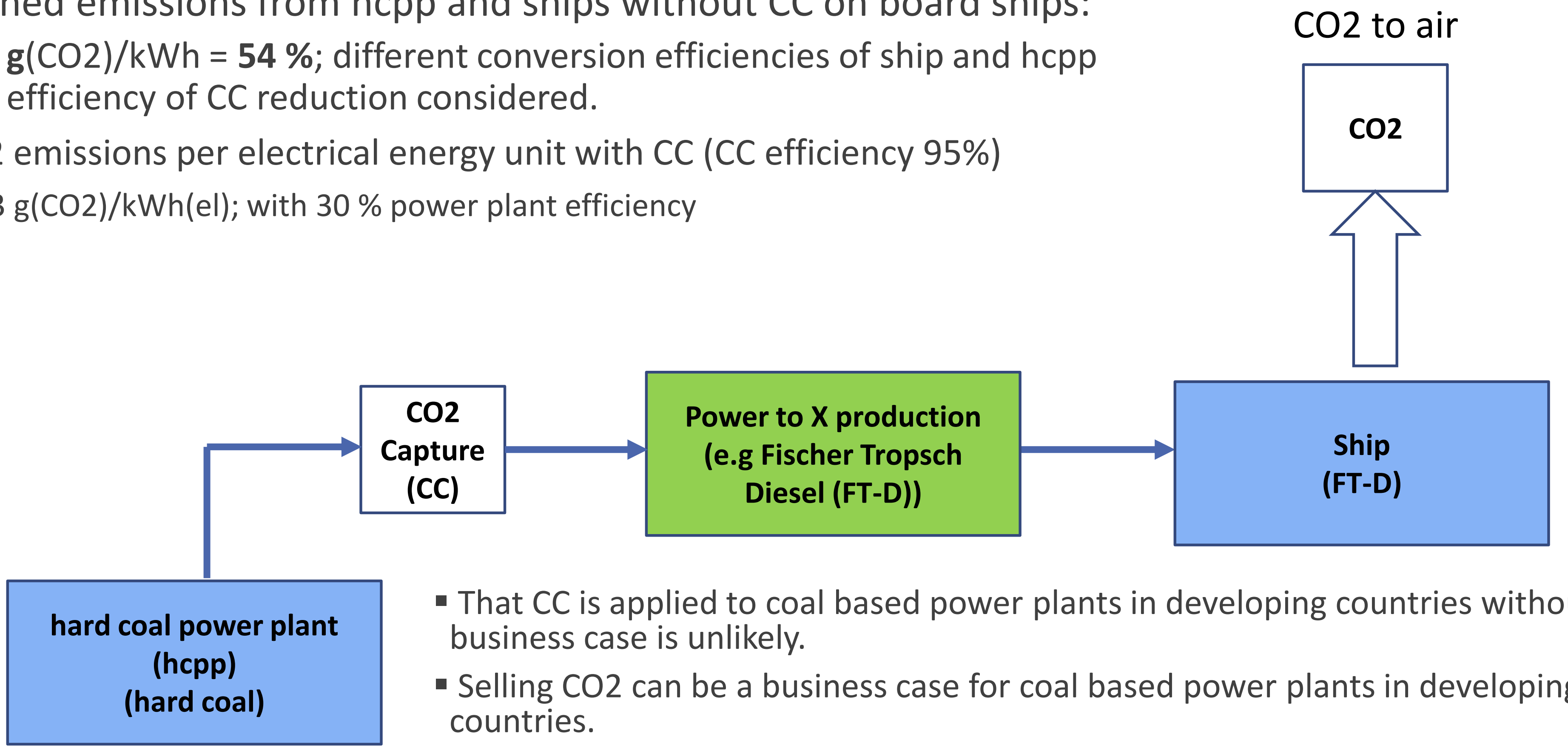
CASE-2: Easy and fast way to get overall CO_2 emissions down in one step - CO_2 emissions Tank to Wake -

Combined emissions from hcpp and ships without CC on board ships:

- **406 g**(CO_2)/kWh = **54 %**; different conversion efficiencies of ship and hcpp and efficiency of CC reduction considered.
- CO_2 emissions per electrical energy unit with CC (CC efficiency 95%)
  - 73 g(CO_2)/kWh(el); with 30 % power plant efficiency



- That CC is applied to coal based power plants in developing countries without a business case is unlikely.
- Selling CO_2 can be a business case for coal based power plants in developing countries.
- Shipping can contribute to CO_2 reduction by using PtX fuel with CO_2 from coal fired power plants in developing countries.
- **Result:** substituting all 300 mio t/a ship fuel by FT-D has the potential to **reduce CO_2 emissions by more than 900 mio t/a without** any **CC on board ships**.

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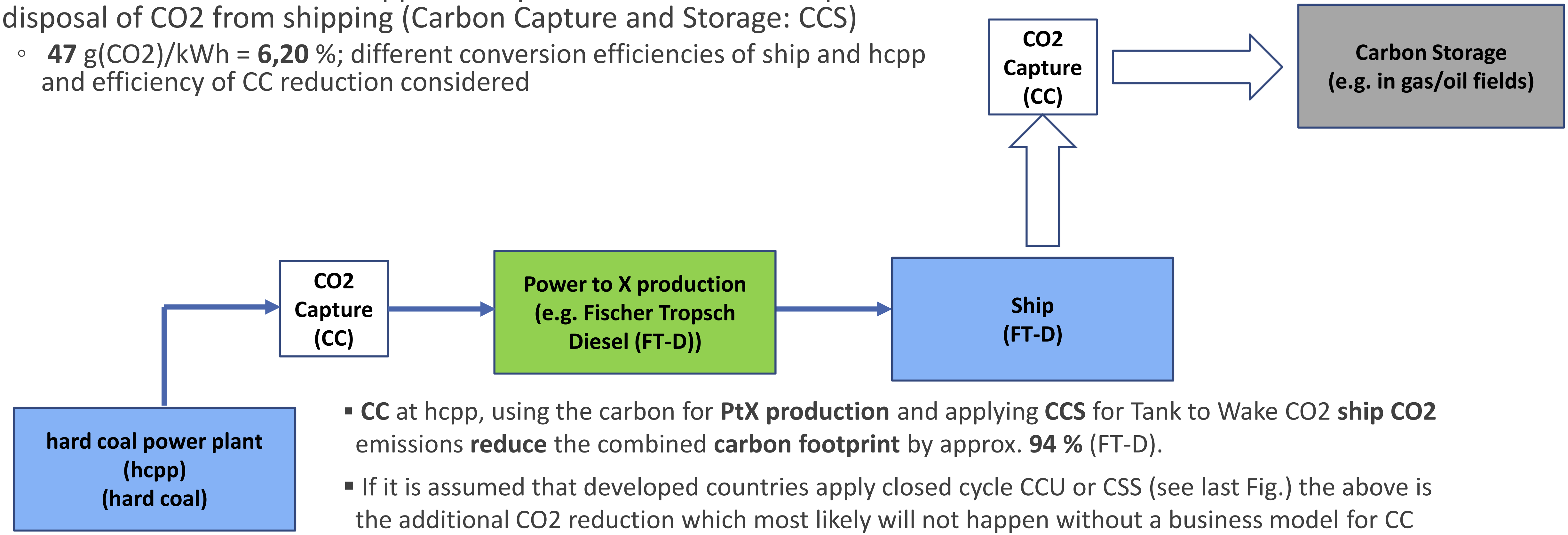
CASE-3: Get overall CO2 emissions down by CCU and CCS
- CO2 emissions Tank to Wake -

Combined emissions from hcpp and ships with CC on board ships and disposal of CO2 from shipping (Carbon Capture and Storage: CCS)

- **47** g(CO2)/kWh = **6,20** %; different conversion efficiencies of ship and hcpp and efficiency of CC reduction considered



- **CC** at hcpp, using the carbon for **PtX production** and applying **CCS** for Tank to Wake CO2 **ship CO2** emissions **reduce** the combined **carbon footprint** by approx. **94 %** (FT-D).
- If it is assumed that developed countries apply closed cycle CCU or CSS (see last Fig.) the above is the additional CO2 reduction which most likely will not happen without a business model for CC at hcpp in developing countries.
- **Result: substituting** all 300 mio t/a **ship fuel by FT-D** has the potential to **reduce CO2 emissions by more than 2000 mio t/a** if CCS is applied for ships. **This is** approx. **2 times** the **CO2 emissions from shipping** only!

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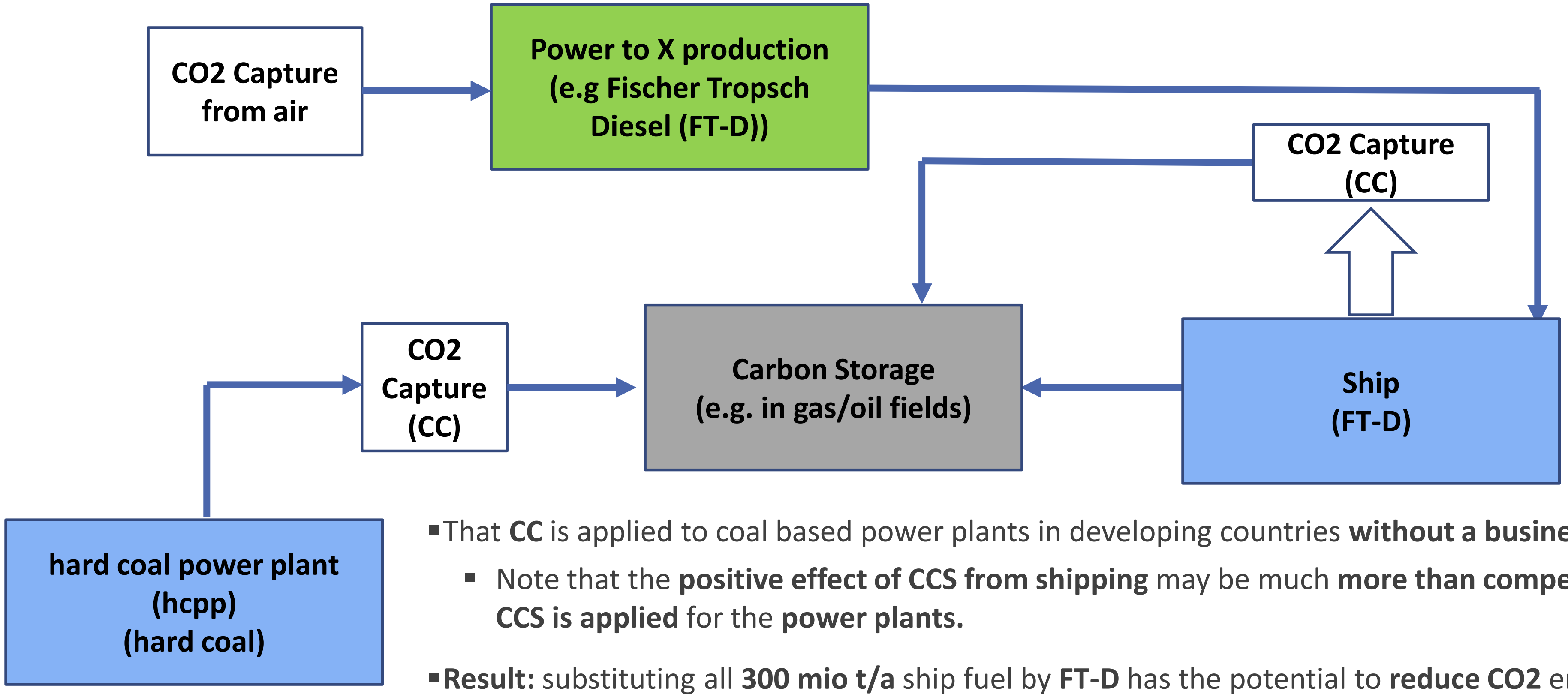
CASE-4: The most promoted, expensive, time consuming way to reduce overall CO2 emissions. Use of PtX fuel produced with CO2 from direct air CO2 capture - CO2 emissions Tank to Wake -

Combined emissions from hcpp and ships with CC on board ships and disposal of CO2 from shipping (Carbon Capture and Storage: CCS)

- **0,044** g(CO2)/kWh = **0,006 %**; This would be **99%** of the reference emissions
- The effect for ship CO2 emissions is practical the same as it is when using Hydrogen or Ammonia!



- That **CC** is applied to coal based power plants in developing countries **without a business case** - as assumed here - **is unlikely.**
  - Note that the **positive effect of CCS from shipping** may be much **more than compensated** by power plant emissions **if no CCS is applied** for the **power plants.**
- **Result:** substituting all **300 mio t/a** ship fuel by **FT-D** has the potential to **reduce CO2** emissions **by** approx. **1000 mio t/a if CCS is applied for ships. Another 1000 mio t/a must come from CCS of hcpp for** approx. **the same effect as for case 3**.

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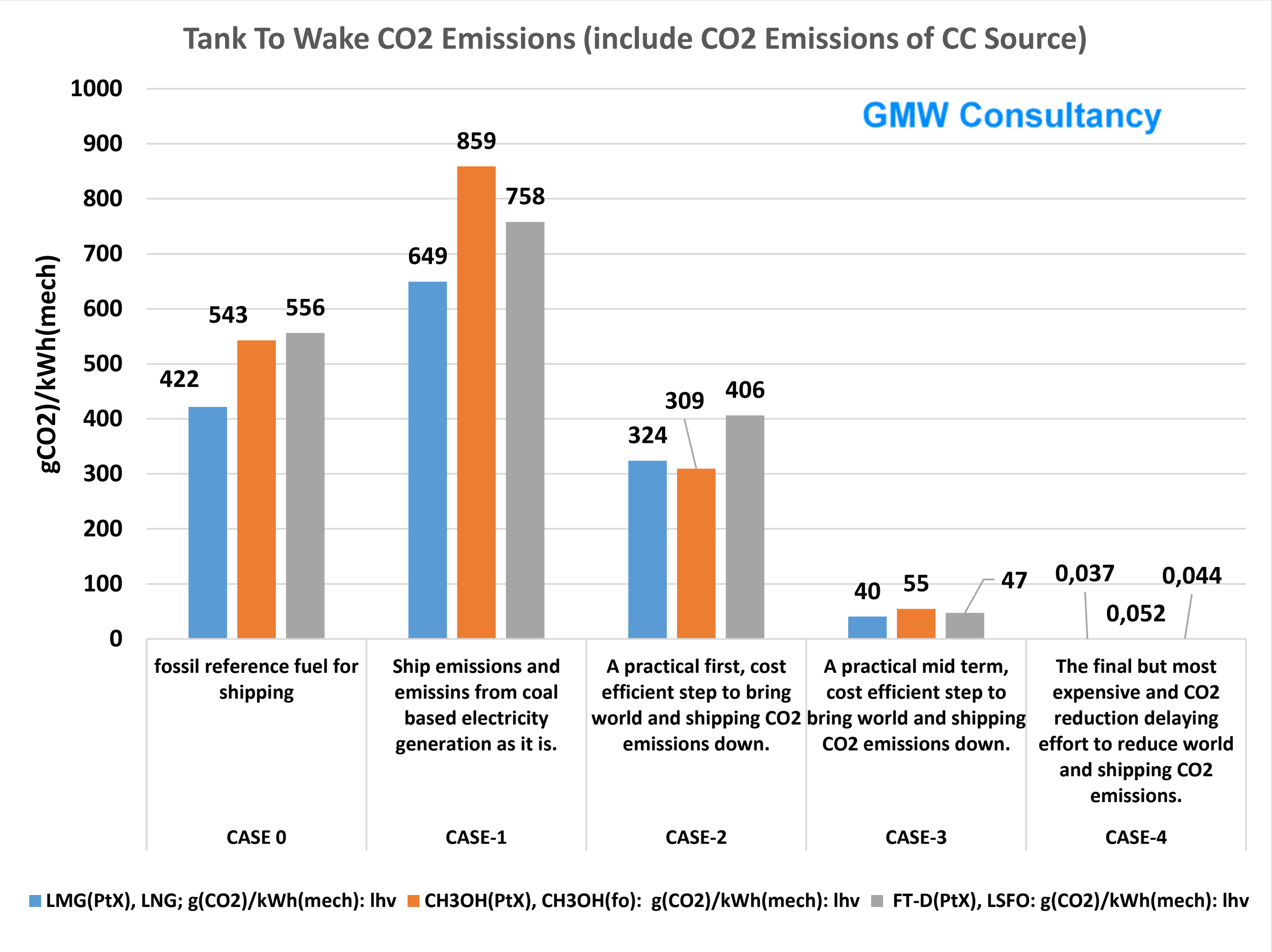
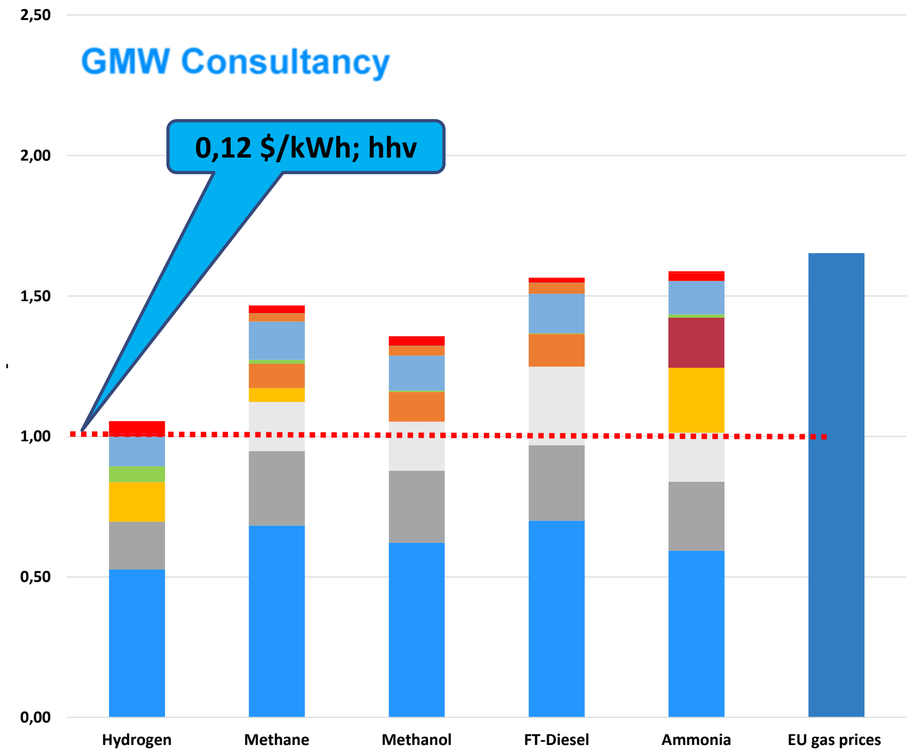
- CO_2 reduction on shore and in shipping by using CO_2 from hard coal fired power plants for PtX production -

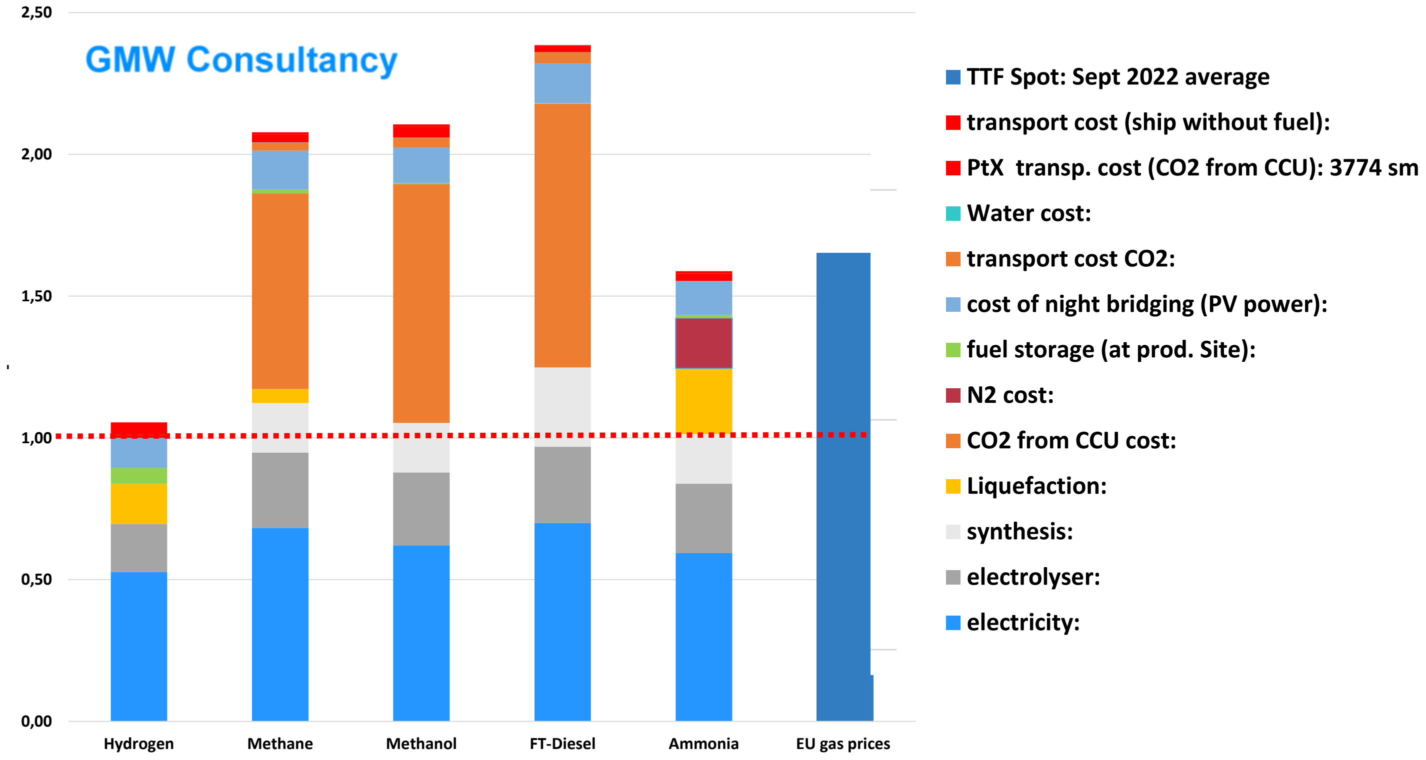
- CASE-0: Fossil fuel for shipping.
- CASE-1: Business as usual in shipping and at hard coal fired power plants. No CC for CO2 released from ship. No CC for CO2 released from hard coal fired power plant (hcpp).
- CASE-2: The use of PtX in shipping with CCU from hard coal power plant. No CC for ships.
- CASE-3: The use of PtX in shipping with CCU from hard coal power plant. CCS for CO2 released from ships.
- CASE-4: The closed cycle use of PtX with CC from air. Power generation (shipping) with CCS for CO2 released from ships and hcpp.



PtX using CC from industry is the most promising way to reduce overall CO2 emissions.
- CC from air makes the business case difficult because capture efforts are high.-



CC from industry processes



CC from air

- If CO2 with CCU from industrial sources or bio mass is used the PtX cost for Methane, Methanol and FT-Fuel are approx. 60 % higher than production cost of liquefied hydrogen. **No further infrastructure costs** are needed.
- If CO2 with CC from air is used the PtX cost of Methane, Methanol and FT-Fuel are more than 100 % higher than production cost of liquefied hydrogen. For **Hydrogen and Ammonia high infrastructure efforts** are needed.
- **Only for CC from air PtX Ammonia** become **favourable** compared **to PtX Methane, Methanol, FT-Diesel**.

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Any Questions?
Here you can get the answers.

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Add on: How a closed cycle CCU concept may work
- case: PtX Methane -