

# System Effects of Implementing Electrofuels for Decarbonisation of the Transport Sector in a Danish Perspective

Brian Vad Mathiesen & Christian Bundgaard  
Sustainable energy planning group, Aalborg University  
[christianb@plan.aau.dk](mailto:christianb@plan.aau.dk)

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# The role of electrofuels

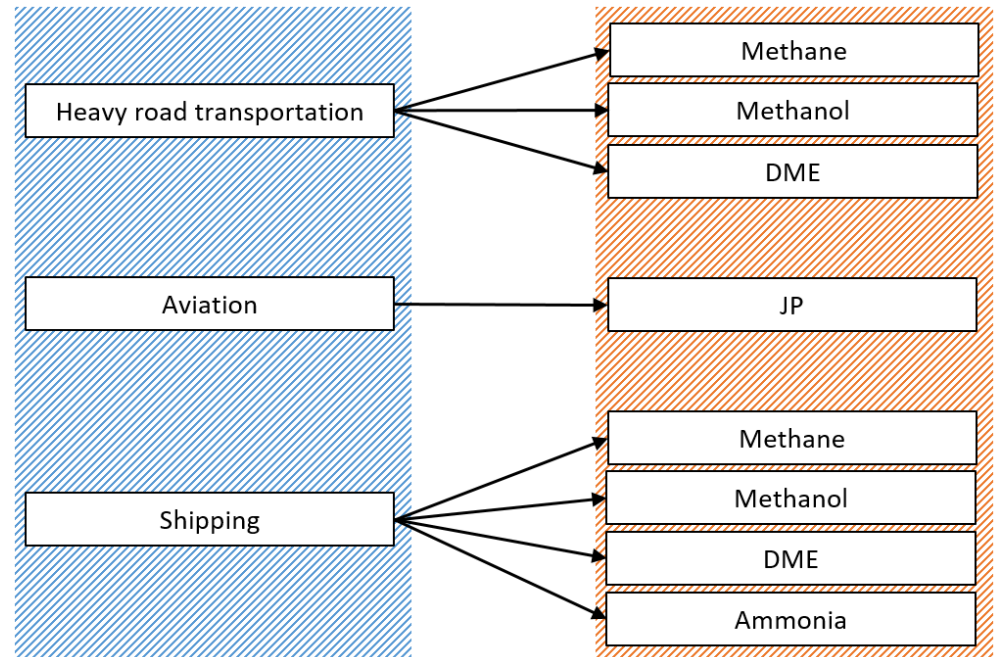
- Integration of fluctuating renewable energy sources
- Decarbonisation of transport not suited for direct electrification
- Sustainable utilisation of biomass

# Electrofuels and production methods

- 3 types of transport
  - Heavy road transportation
  - Aviation
  - Shipping

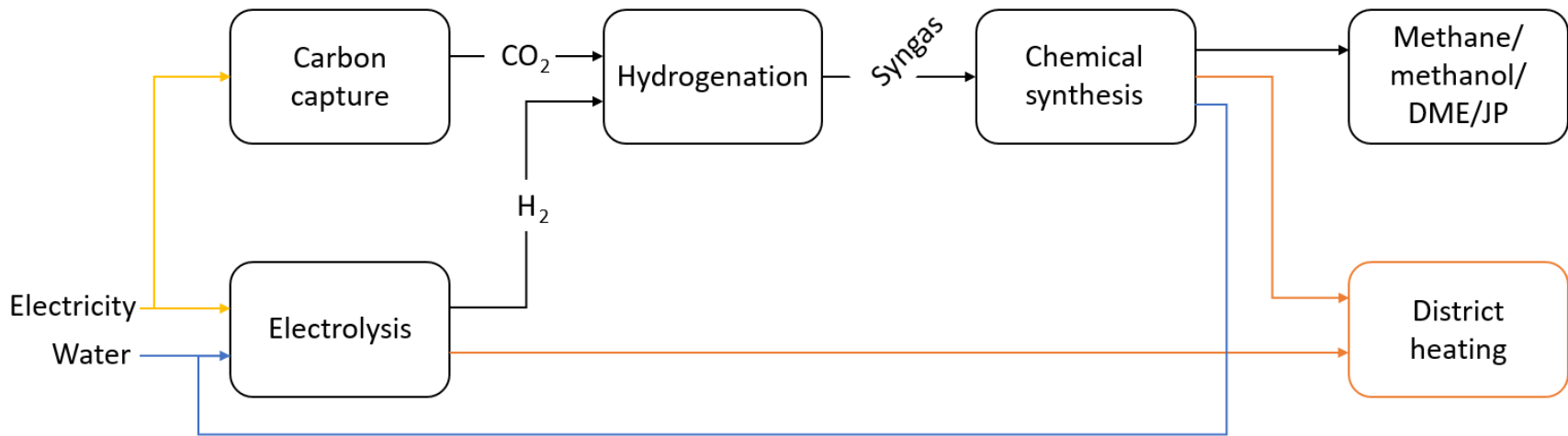
- 5 types of fuel
  - Methane
  - Methanol
  - DME
  - JP
  - Ammonia

- 4 types of production
  - Gasification
  - Point source (high) – Post combustion capture at large biomass CHP, 400 €/ton/year
  - Point source (low) – Biogas upgrade, 20 €/ton/year
  - Nitrogen capture



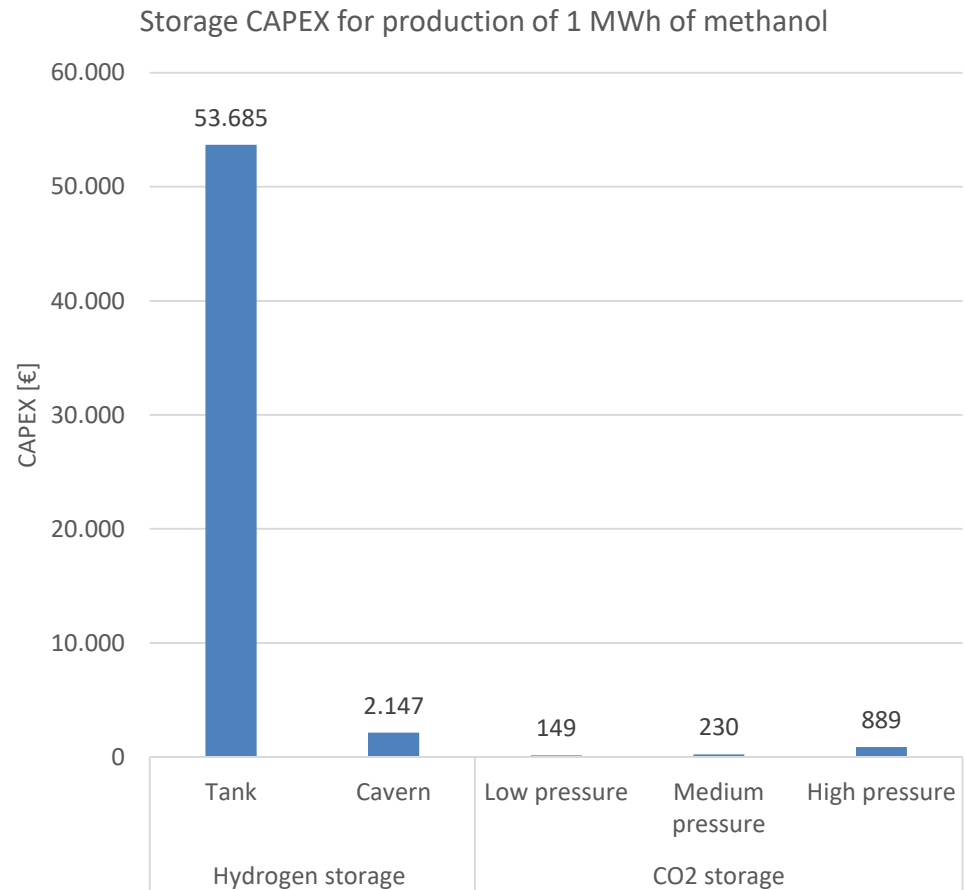
# Two possibilities for flexibility

- Dynamic operation of the electrolysis in relation to the electricity price (70 % buffer capacity)
- The fuel synthesis is assumed to be able to be operated dynamically, but not in direct dependence on the electrolysis
- Two possibilities for flexibility
  1. Hydrogen storage
  2. Buffer capacity of CO<sub>2</sub>/N<sub>2</sub> capture and CO<sub>2</sub>/N<sub>2</sub> storage



# Significant price difference for hydrogen and CO<sub>2</sub> storage

- Hydrogen storage
  - Tank @ 200 bar: 45 €/kWh<sup>1</sup>
  - Cavern: 1,8 €/kWh<sup>1</sup>
- CO<sub>2</sub> storage
  - Low pressure: 568 €/ton<sup>2</sup>
  - Medium pressure: 875 €/ton<sup>2</sup>
  - High pressure: 3.380 €/ton<sup>2</sup>
- 1 MWh of methanol
  - 36 kg of hydrogen
  - 263 kg of CO<sub>2</sub>



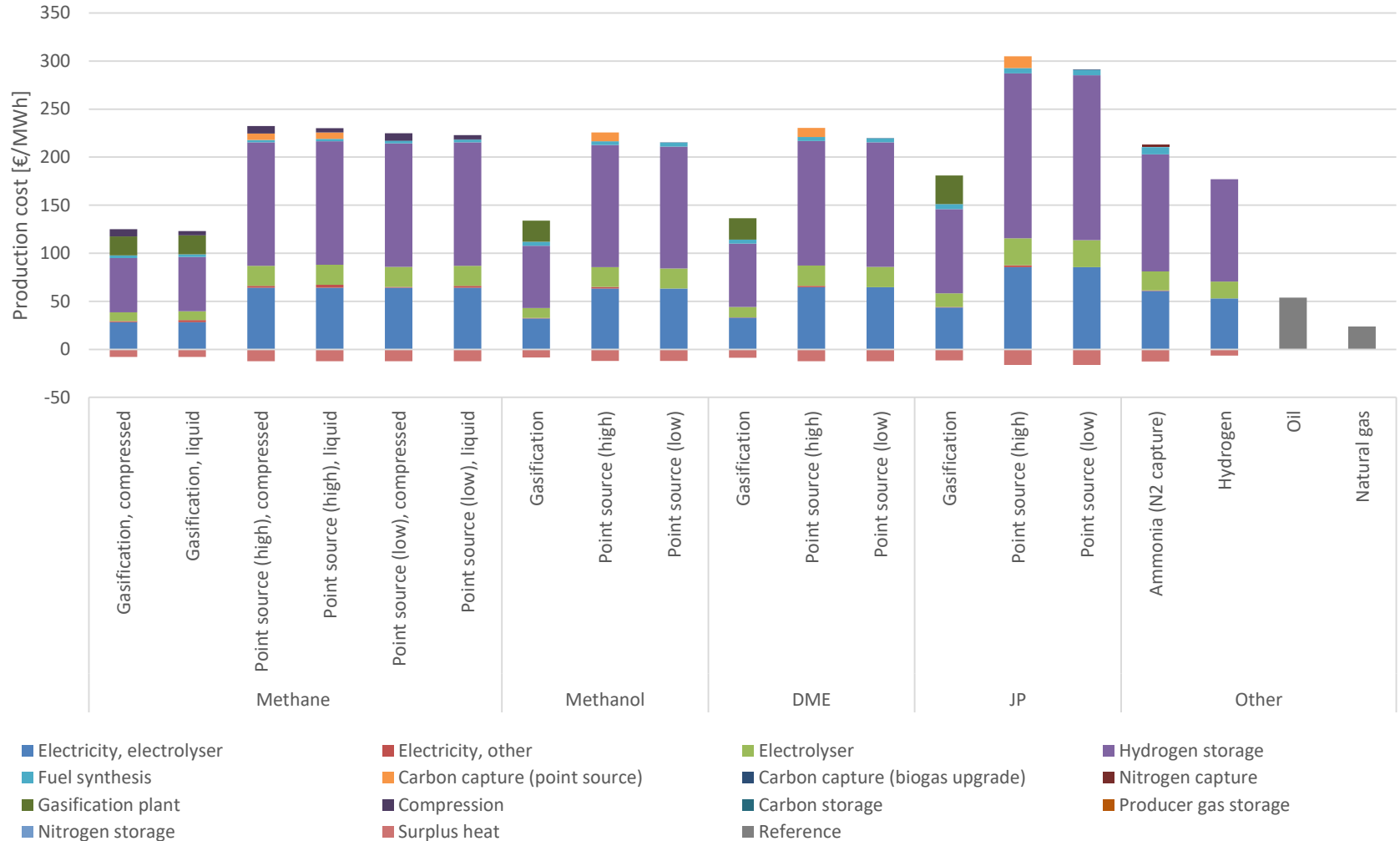
<sup>1</sup> Technology Data – Energy Storage (2018),  
Danish Energy Agency

<sup>2</sup> Shipping CO<sub>2</sub> - UK Cost Estimation Study (2018),  
Element Energy

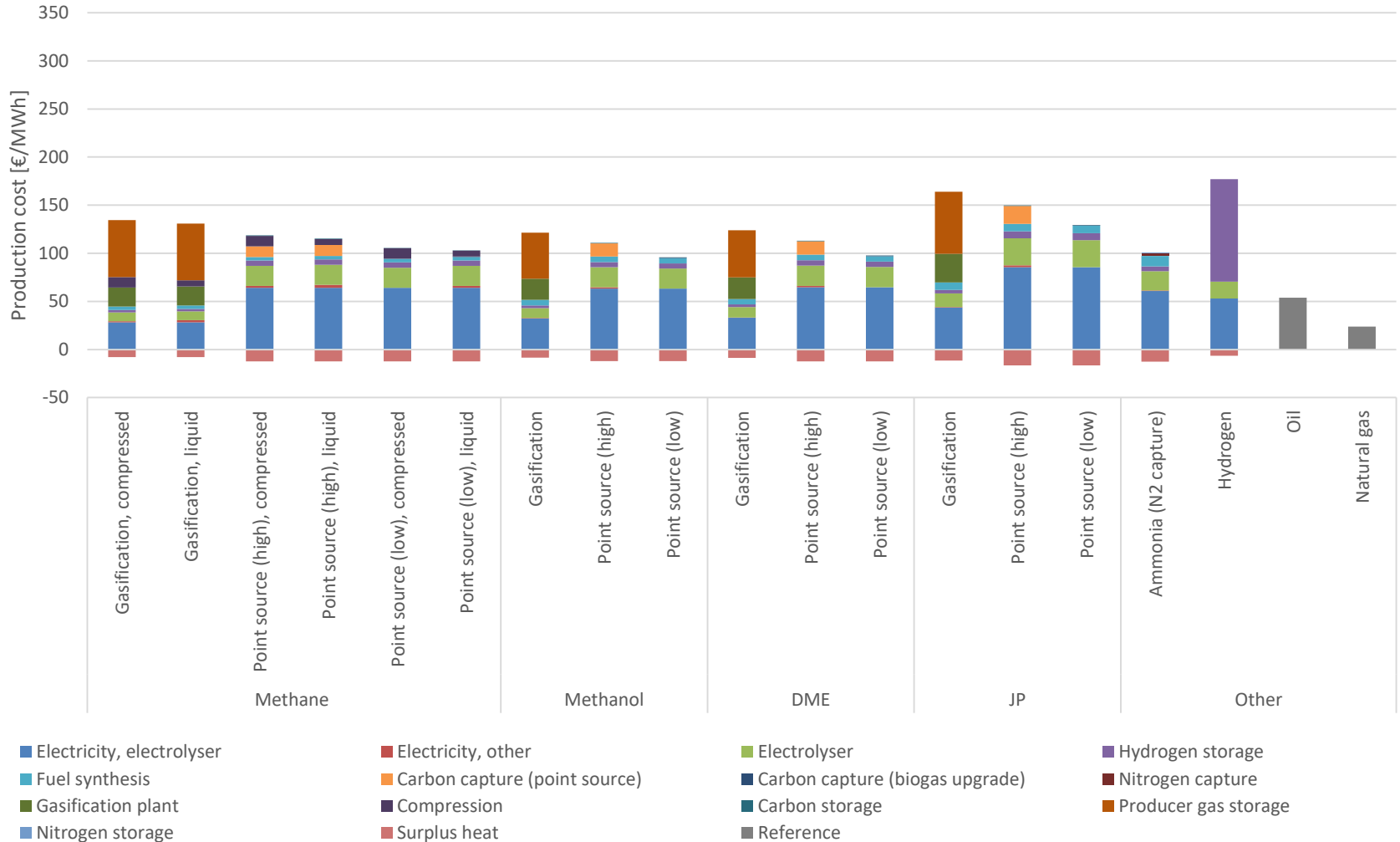
# Buffer capacity and storage

- Flexibility by hydrogen storage
  - Electrolysis: 70 % buffer capacity (5.153 FLH)
  - 5 days of hydrogen storage (half of the technical optimum)
- Flexibility by buffer capacity of CO<sub>2</sub>/N<sub>2</sub> capture and CO<sub>2</sub>/N<sub>2</sub> storage
  - Electrolysis: 70 % buffer capacity (5.153 FLH)
  - CO<sub>2</sub>/N<sub>2</sub> capture:
    - Methane: 70 % buffer capacity
    - Methanol (incl. DME and JP): 50 % buffer capacity
    - Ammonia: 50 % buffer capacity
  - 5 hours of hydrogen storage
  - 7 days of CO<sub>2</sub>/N<sub>2</sub> storage

# Flexibility by hydrogen storage\*

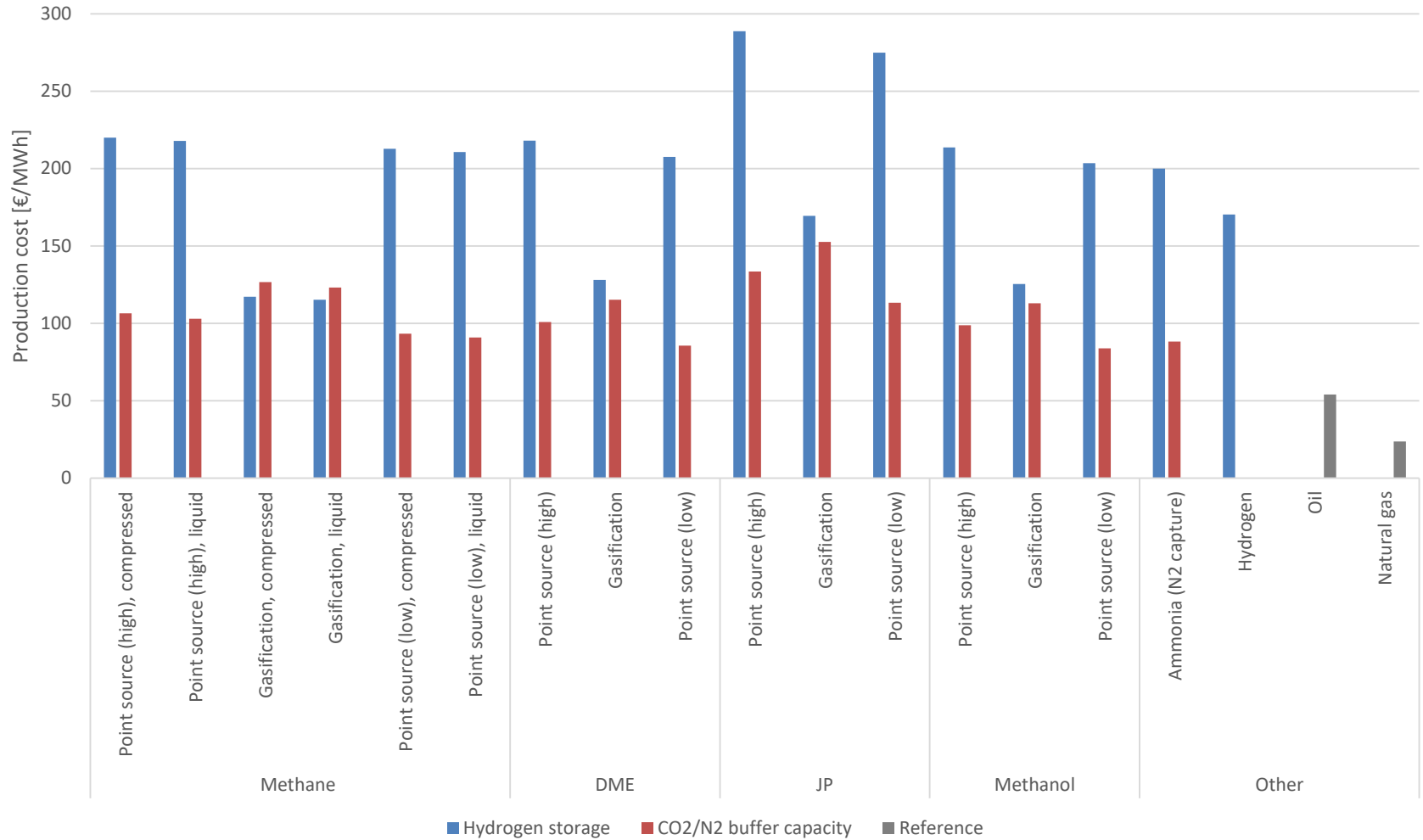


# Flexibility by buffer capacity of CO<sub>2</sub>/N<sub>2</sub> capture\*





# Comparison\*



# CO<sub>2</sub> shadow price

- The CO<sub>2</sub> shadow price for CCU depends on the application and alternatives
- A high price of the substituted fossil fuels lowers the CO<sub>2</sub> shadow price
- High CO<sub>2</sub> emissions of substituted fossil fuels lowers the CO<sub>2</sub> shadow price
  
- CCU<sup>3</sup> production cost as estimated with CO<sub>2</sub>/N<sub>2</sub> capture buffer capacity
- CCS<sup>4</sup> of 141 €/ton as estimated by The Danish Council on Climate Change<sup>5</sup>

<sup>3</sup> CCU = Carbon capture and utilisation

<sup>4</sup> CCS = Carbon capture and storage

<sup>5</sup> Kendte veje og nye spor til 70 procents reduction (2020), The Danish Council on Climate Change

# Assumptions for substituted fuel

Type of transport	Type of fuel	Price (2030) [€/GJ] <sup>6</sup>	CO <sub>2</sub> (combustion) [kg CO <sub>2</sub> / GJ] <sup>7</sup>	CO <sub>2</sub> (upstream) [kg CO <sub>2</sub> / GJ] <sup>8</sup>
Heavy road transportation	Diesel	15,0	74,0	11,5
Aviation	JP1	14,6	72,0	11,5
Shipping	HFO	10,5	78,9	13,5

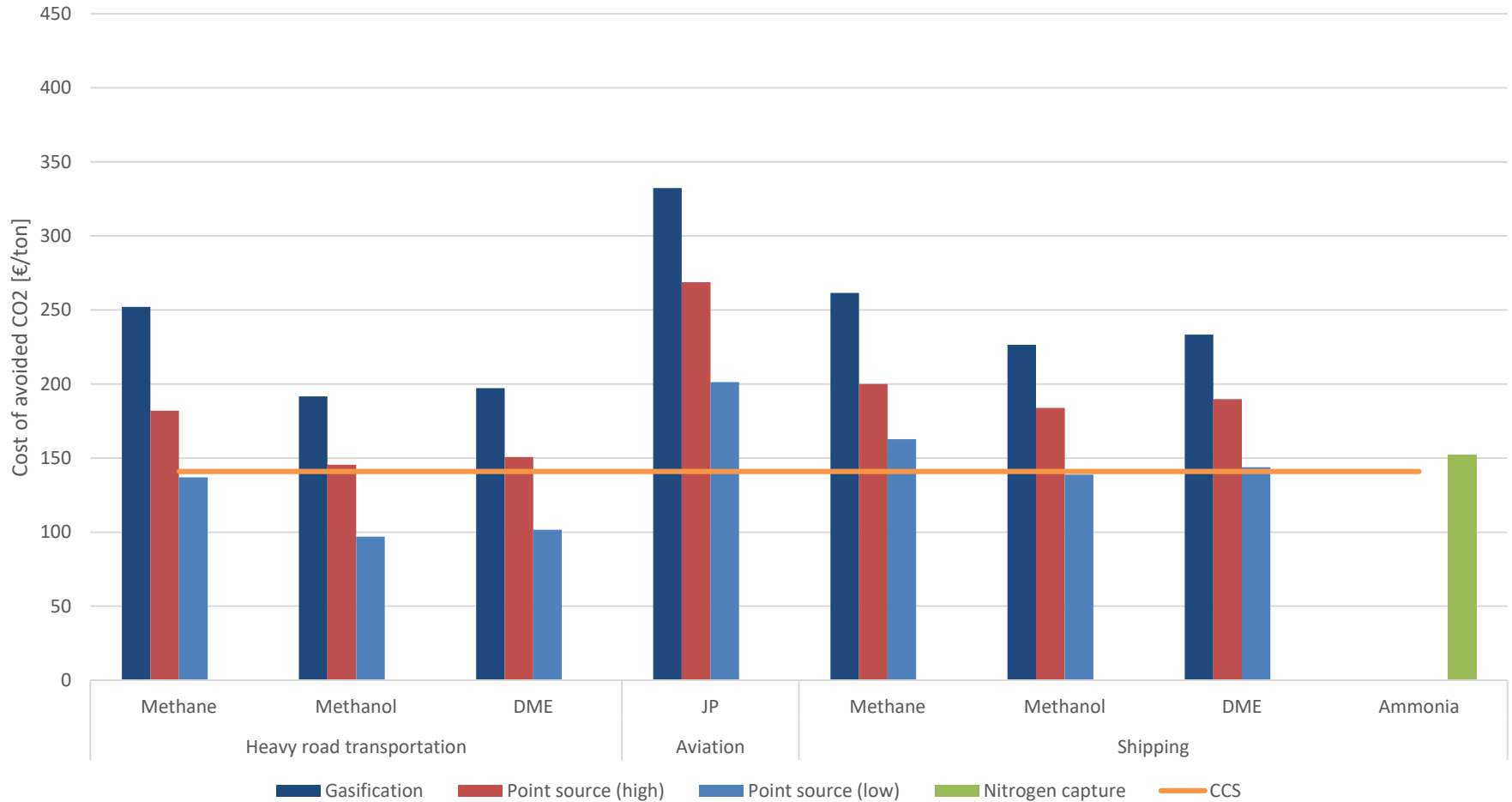
<sup>6</sup> Samfundsøkonomiske beregningsforudsætninger for energipriser og emissioner (2019), Danish Energy Agency

<sup>7</sup> Energy statistics 2018 (2020), Danish Energy Agency

<sup>8</sup> Fastlæggelse af energidata til brug i CO<sub>2</sub>-opgørelser (2011), Thomas Astrup, Ole Dall, and Henrik Wenzel

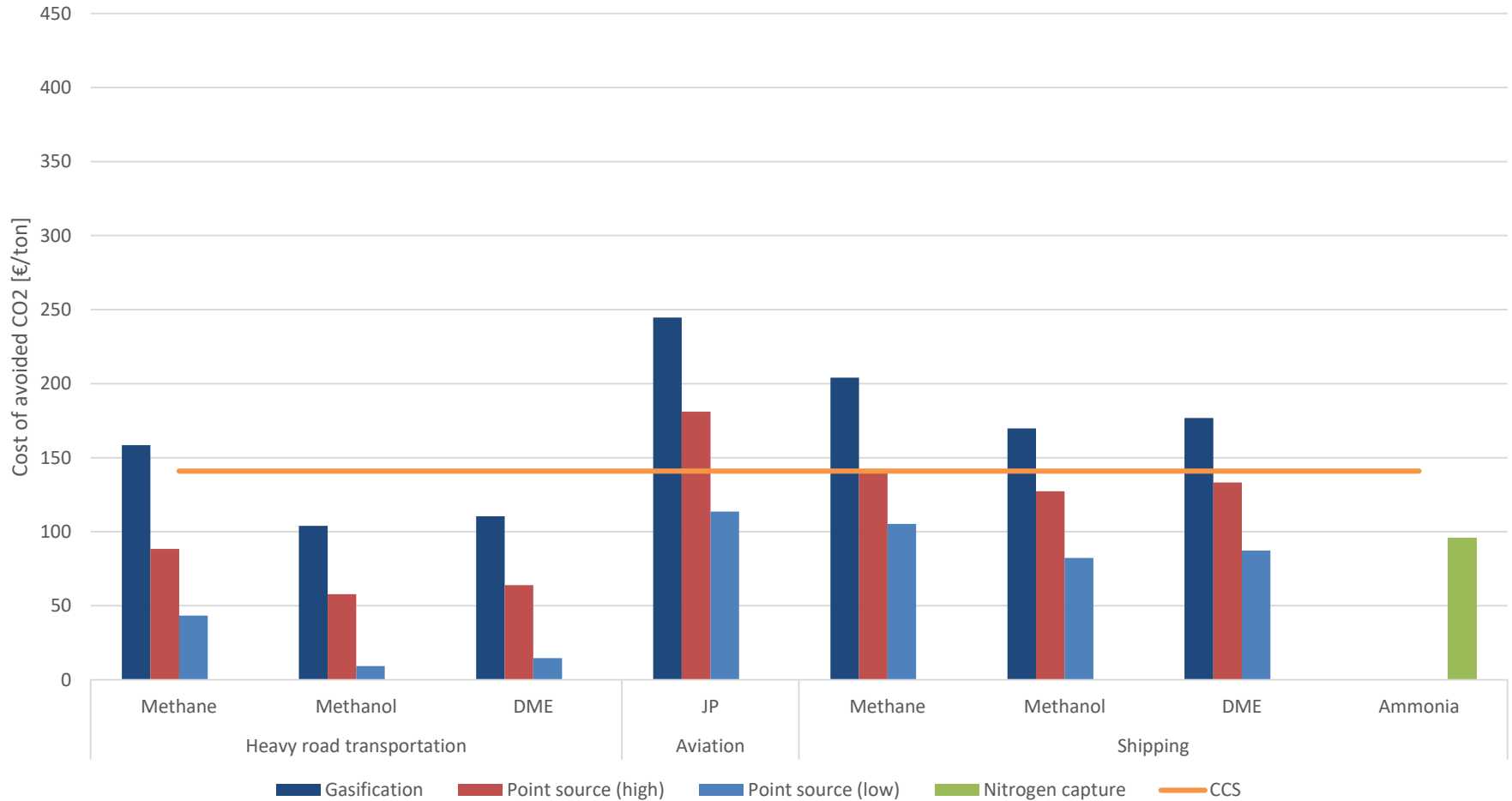
# CO<sub>2</sub> shadow price\*

Price of fossil fuels: 100 % of reference value



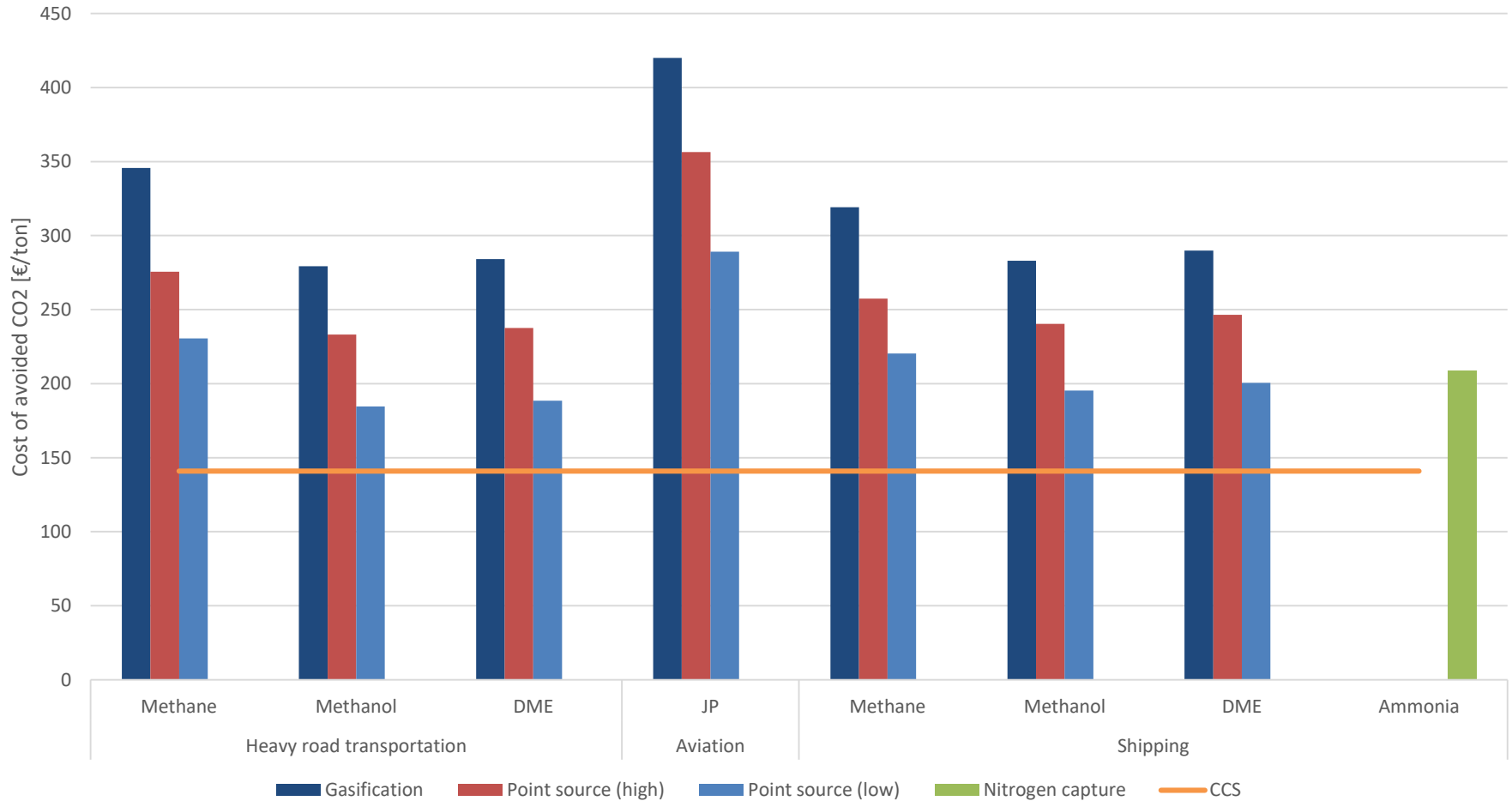
# CO<sub>2</sub> shadow price\*

Price of fossil fuels: 150 % of reference value



# CO<sub>2</sub> shadow price\*

Price of fossil fuels: 50 % of reference value



# Thank you for your attention!

## Questions?

Brian Vad Mathiesen & Christian Bundgaard  
Sustainable energy planning group, Aalborg University  
[christianb@plan.aau.dk](mailto:christianb@plan.aau.dk)

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