Electrofuels as marine fuel: a cost-effective option for the shipping sector?

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Background

- To reduce the environmental and climate impact of shipping, in short (NO_x, SO_x, particles) and long term (CO_2), the use of alternative fuels is required.
- Expected increase in shipping demand.
- Energy efficiency measures are not enough.
- More knowledge on alternative marine fuels needed.
- Prerequisites differ between different kinds of shipping and ships.
- Range of fuel options.
- Limited biomass availability
- LNG, methanol and electricity today at limited extent.

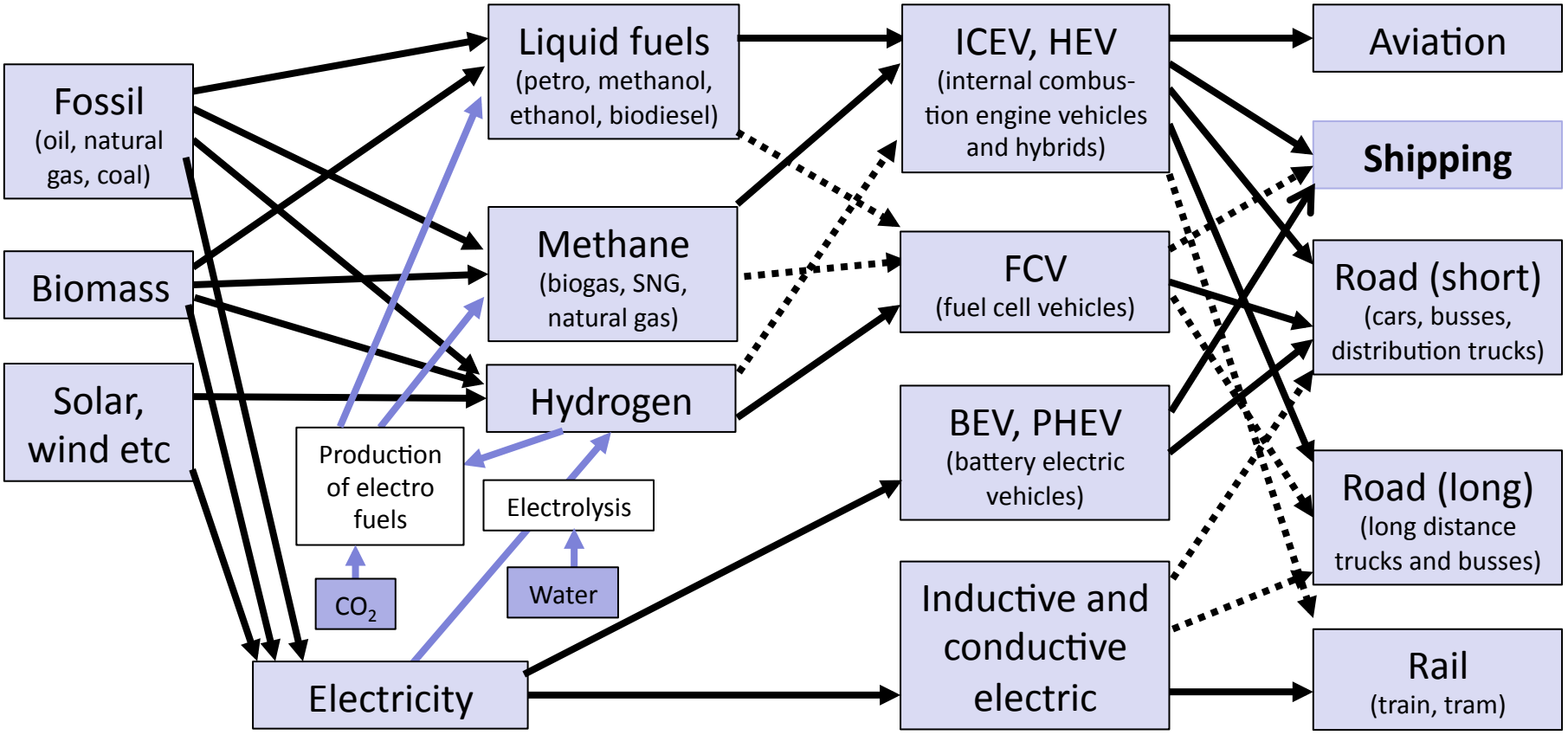
Aim

- To assess if there are conditions under which electrofuels are cost-effective compared to other alternative fuels for the shipping sector in order to reach ambitious climate targets…
- … using an energy-economic long-term global model developed to include electrofuels.

Electrofuels (also called power-to-gas/liquids/fuels or synthetic fuels) represent carbon-based fuels, e.g. methane or methanol, produced from CO_2 and water using electricity as primary energy source.

Different fuels and vehicle technology options in different transport modes?

Biofuels and electrofuels can be used in all transportation modes

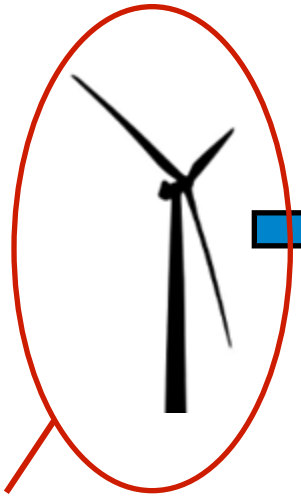


Production of electro-fuels

Water (H_2O)

Other hydrogen options (H_2)

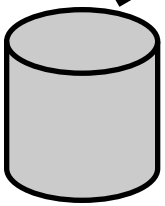
Carbon dioxide CO_2



El

Electro-lysis

Hydrogen (H_2)



CO_2 from air and seawater

CO_2 from combustion

150-1250 €/tCO_2

20-60 €/tCO_2

H_2

Heat

How to utilize or store possible future excess electricity

Synthesis reactor (e.g. Sabatier, Fischer-Tropsch)

5-10 €/tCO_2

CO_2

Biofuel production

Biomass ($C_6H_{10}O_5$)

Electrofuels

Biofuels

How to substitute fossil based fuels in the transportation sector, especially aviation and shipping face challenges utlilzing batteries and fuel cells.

Methane (CH_4)

Methanol (CH_3OH)

DME (CH_3OCH_3)

Higher alcohols, e.g., Ethanol (C_2H_5OH)

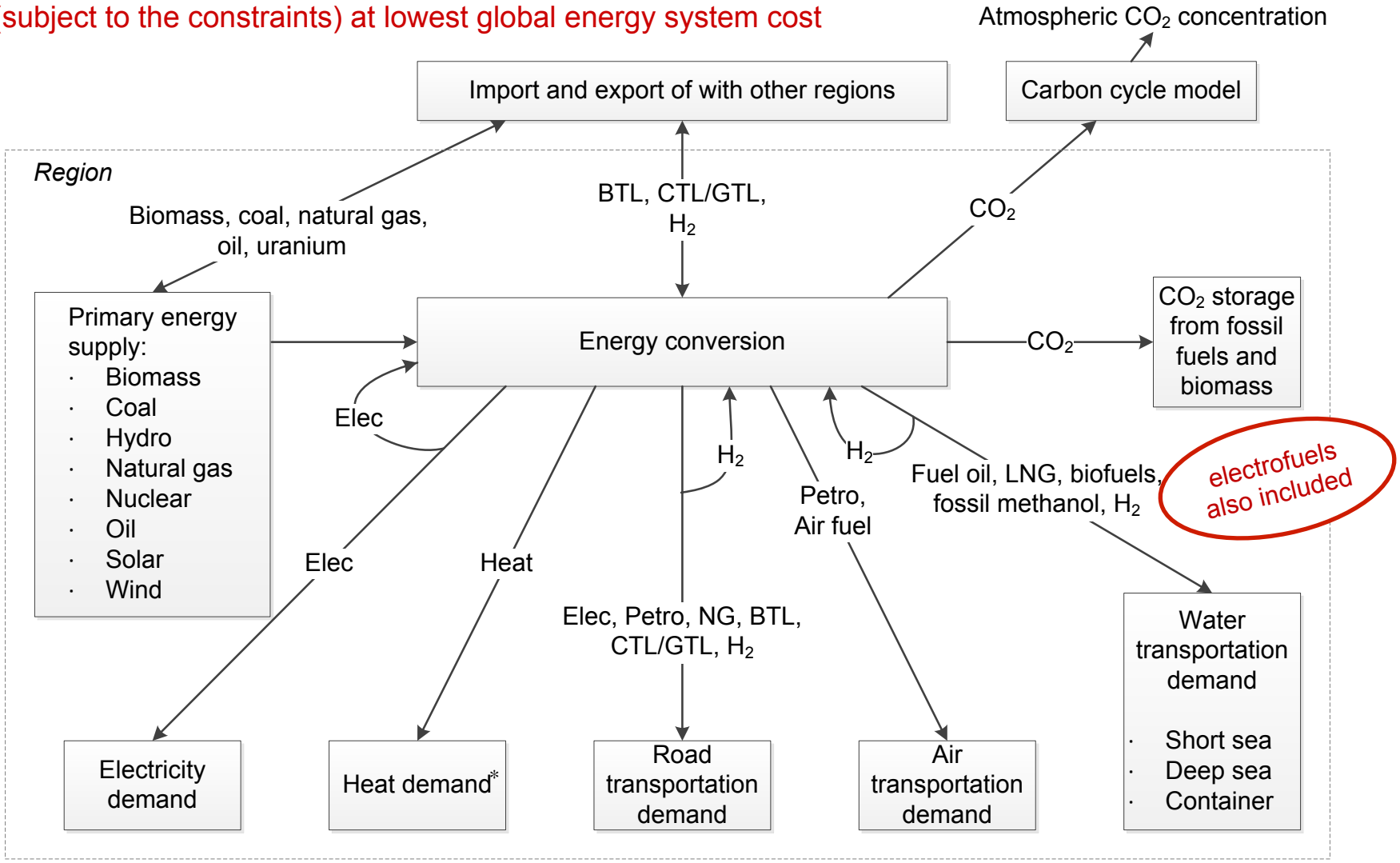
Higher hydrocarbons, e.g., Gasoline (C_8H_{18})

How to utilize the maximum of carbon in the globally limited amount of biomass

Energy-economy model Global Energy Transition (GET)

Linearly programmed energy systems cost-minimizing model

Generates the fuel and technology mix that meets the demand (subject to the constraints) at lowest global energy system cost



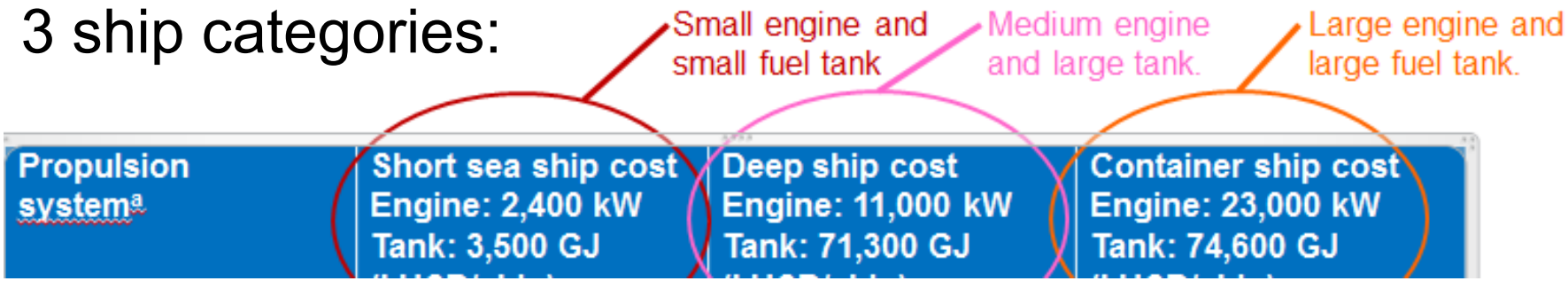
*) Heat comprises all other energy use, apart from electricity and transportation, e.g. industrial process heat, feedstock to the chemical industry.

Options for the shipping sector

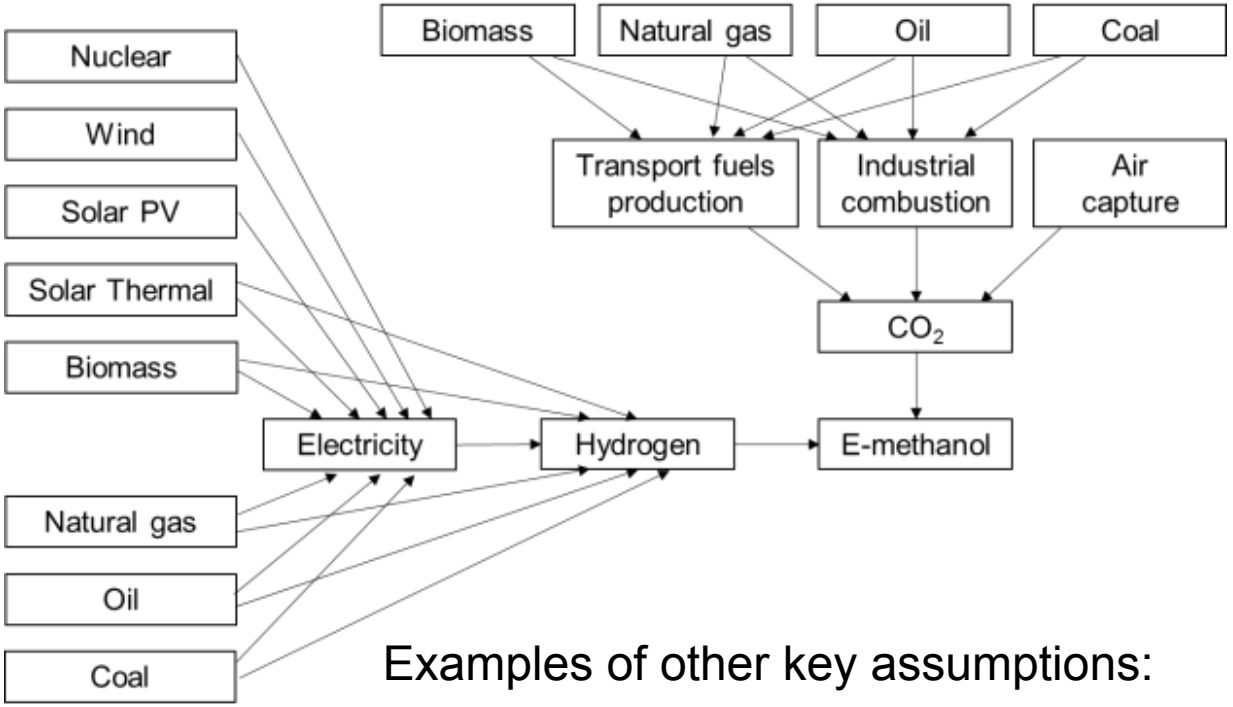
Combustion engines and fuel cells combined with

- oil-based fuels (Petro)
- liquefied natural gas (LNG)
- coal to liquid (CTL)
- biomass to liquid (BTL)
- gas to liquid (GTL)
- hydrogen (H2)
- electrofuels (E-methanol)

3 ship categories:



Electrofuel production pathways in GET



Examples of other key assumptions:

- Growth in shipping demand at a rate assumed equal to the average growth in the shipping sector during the last 20 years.
- Total primary energy resources for coal, oil, natural gas and bioenergy are set to 260 000 EJ,12 000 EJ, 10 000 EJ and 200 EJ/yr respectively.
- Methane leakage of 2% when using LNG

Scenarios

	Business as usual scenario	CO_2 reduction scenario 1	CO_2 reduction scenario 2
H2 and FC assumed large scale available for the shipping sector	Yes	Yes	No
Carbon capture and storage technology assumed available on large-scale*	No	No	No
CO_2 concentration target (400 ppm)	No	Yes	Yes

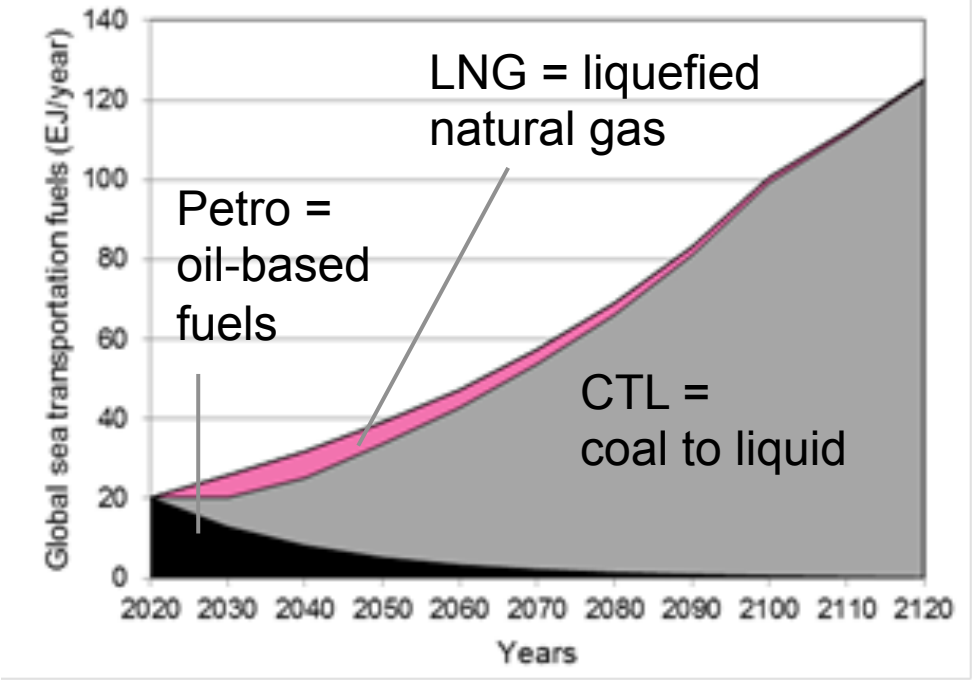
*) Electrofuels do not enter the scenarios, in this model version, if CCS is assumed available on large-scale.

H2 = hydrogen
FC = fuel cell

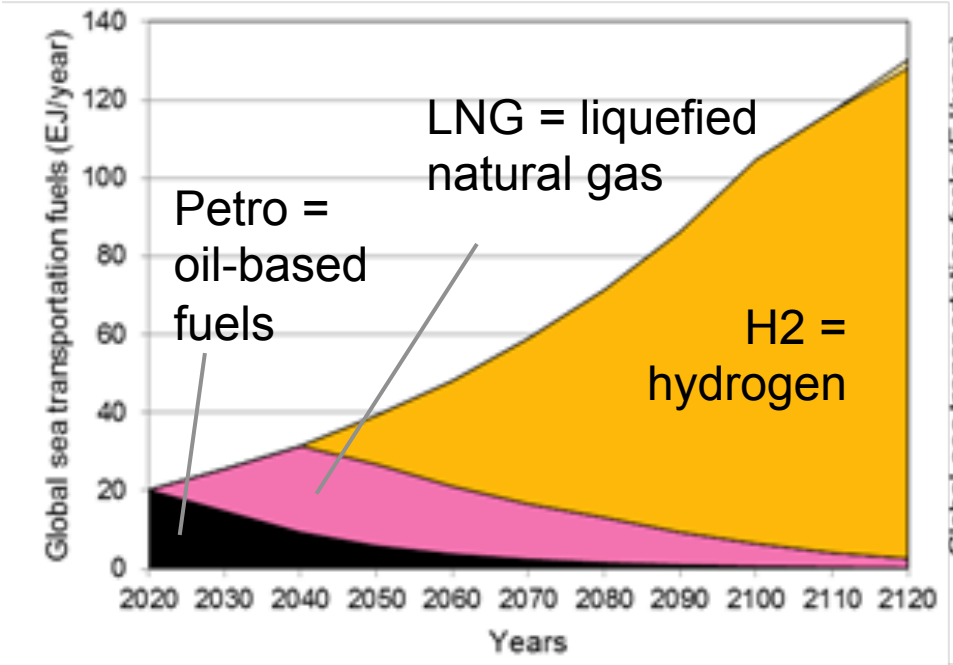
Current CO_2 level: approx. 400 ppm

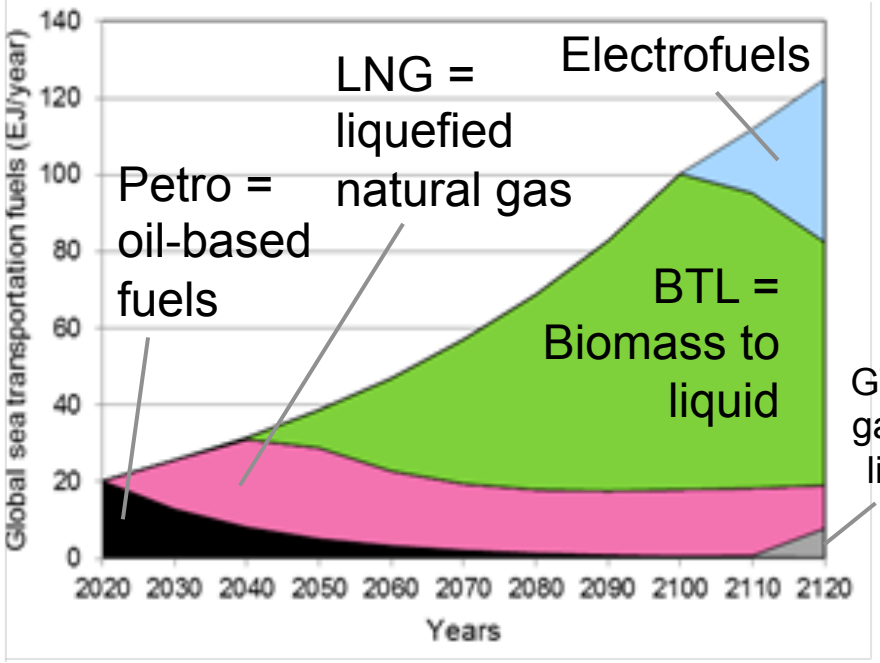
Results

Business as Usual Scenario: no CO_2 target + no CCS



Results





Scenario 1: 400 ppm + Hydrogen and fuel cells assumed available in large-scale for shipping sector + no CCS.

Scenario 2: 400 ppm + Hydrogen and fuel cells **not** available in large-scale for shipping sector + no CCS.

Initial findings

Cost-competitiveness

- In the near term unlikely that electrofuels can compete with other marine fuel options.
- However, it may become a complement to other alternatives during the end of the century if neither hydrogen nor fuel cells will be used in the shipping sector as well as CCS is not available on large scale.
- Cost-competitiveness depends on e.g., the cost and availability of other technologies.

Initial findings

Resource perspective

- Electrofuels in combustion engines demand more energy than battery electric solutions and hydrogen in fuel cells.
- With large-scale electrofuels production demand for renewable electricity may be a challenge.
- Electrofuels production is still in its infancy, many challenges need to be overcome before electrofuels can be available in large scale.

Policy implications

- The study can not point out one fuel winner, but learn how different assumptions affect cost-competitiveness between marine fuel options.
- Need for immediate action due to ships long lifetime.
- Next step: complementary analyses and sensitivity analyses will be performed, e.g., develop the model to analyze the impact of different electricity prices, improve potential for electrofuels.

Shift

Sustainable Horizons in Future Transport

Shift will inform smarter Nordic transport and energy policy

- By developing and applying tools that integrate modal shifts, fuel options, business models and consumer behaviour into scenario modelling and in-depth analysis

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