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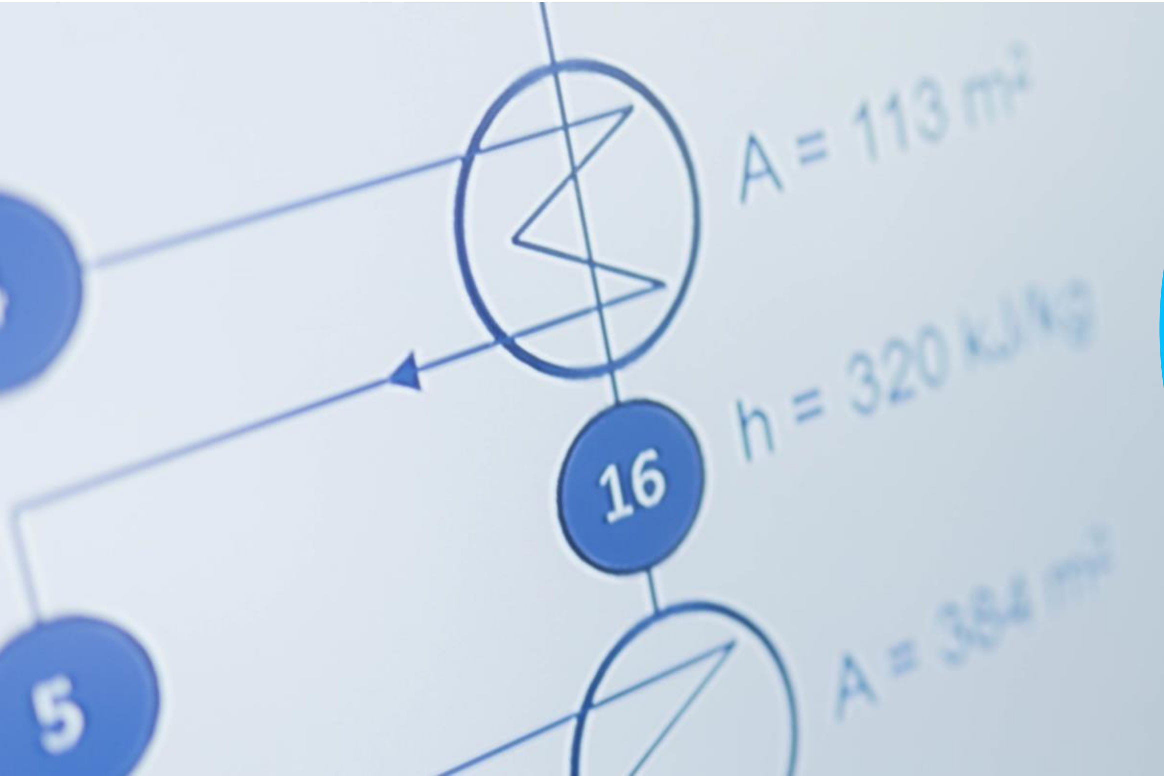

Energy Transition in global Aviation

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IER University of Stuttgart

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IER

Agenda

- Motivation
- Overview
- Results
- Discussion and limitations
- Conclusion

Motivation

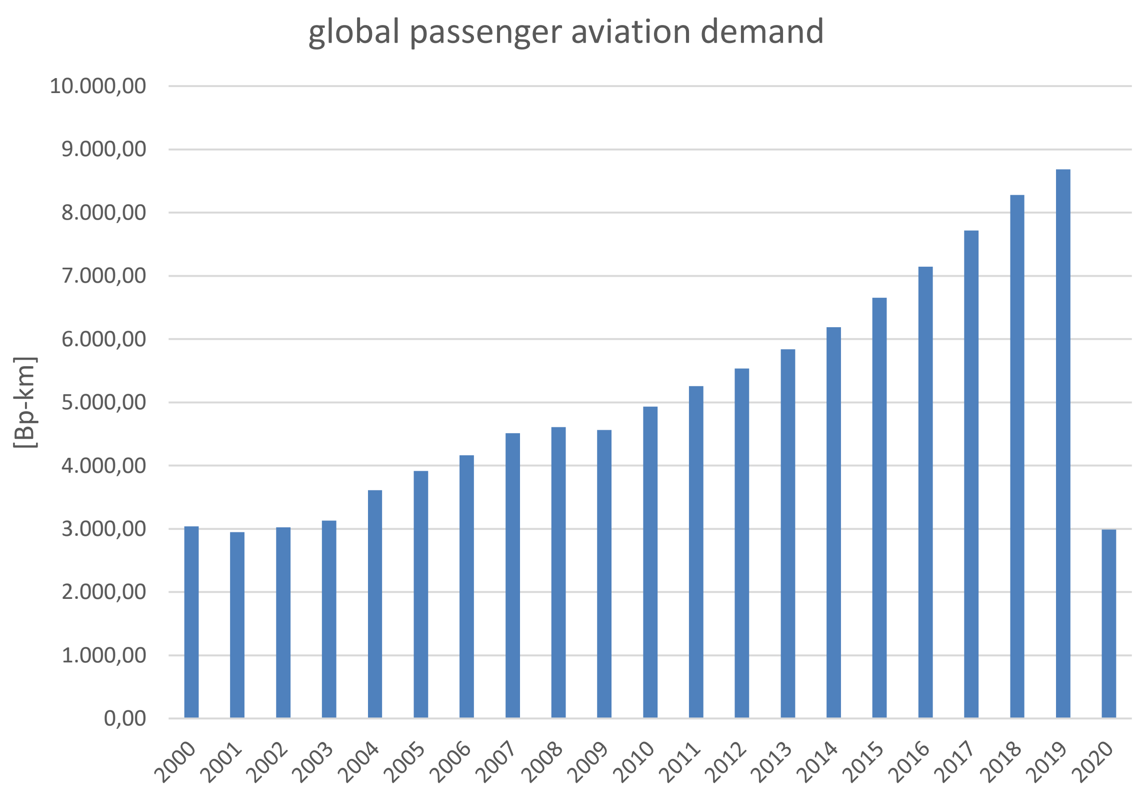
- The global aviation sector is responsible for approx. 2.5% of global CO_2 Emission
- In TIAM the aviation sector is modelled via energy input and output
  - Demand is projected in PJ
  - a-km and p-km not differentiated
  - Generic airplane process

→ different airplane types (kerosene, hydrogen and e-fuels)

→ Demand in Bp-km

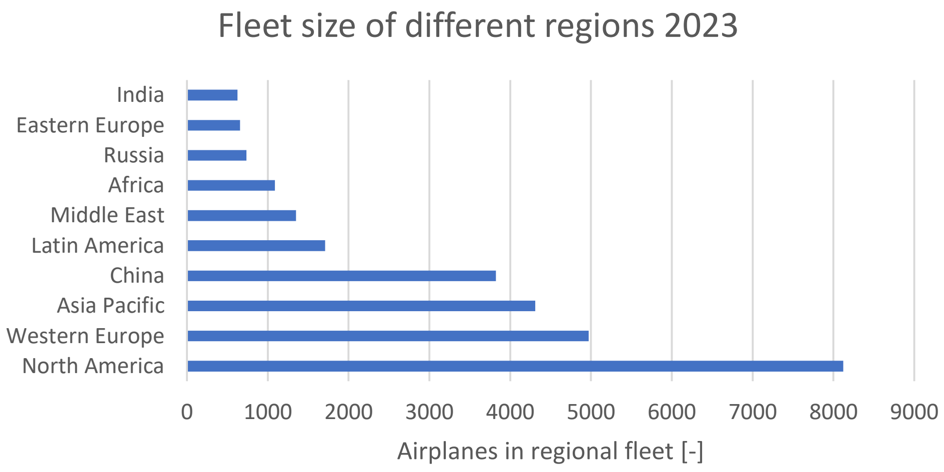
→ Interested in hydrogen and e-fuel demand

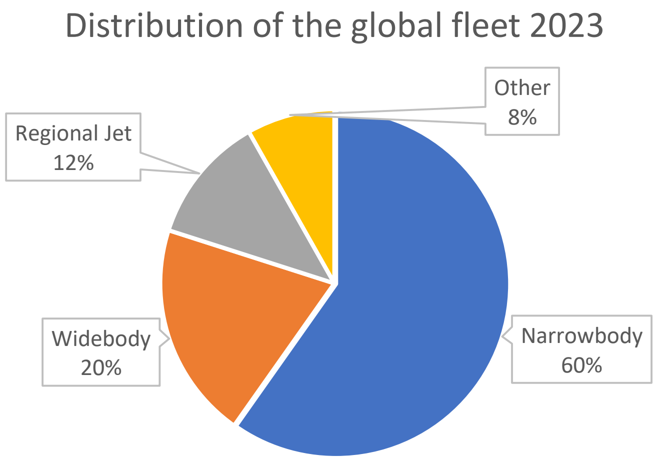
Overview of the global aviation



- 78 % passenger and 22% freight transport.
- Fuel demand decreased: 2.8 MJ/p-km in 1990 to 1.1 MJ/p-km in 2021.
- 6l/100km gasoline/diesel car has 2,11 MJ/v-km -> 2 person 1,05 MJ/p-km
- 1100 km per person a year on global average
- 2000 – 2019: 5.68% increase p.a.
- 2019 – 2020: 66% drop in demand

Global Fleet

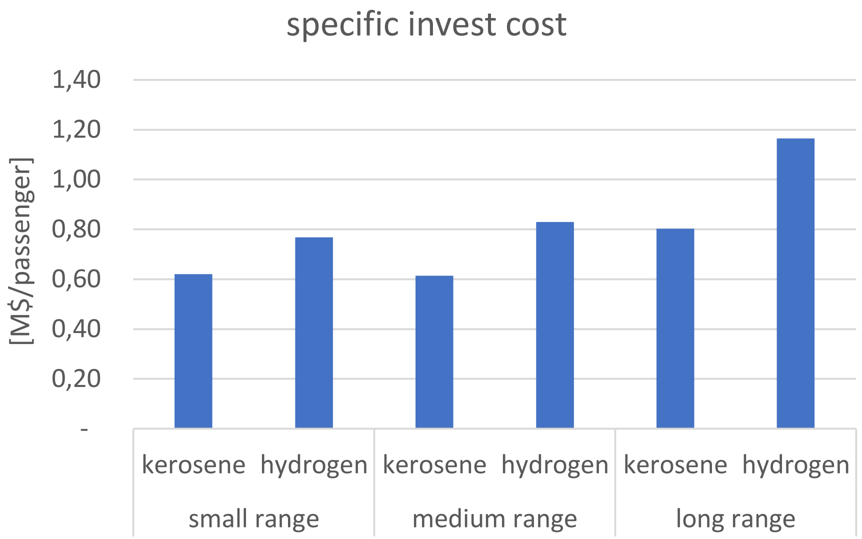


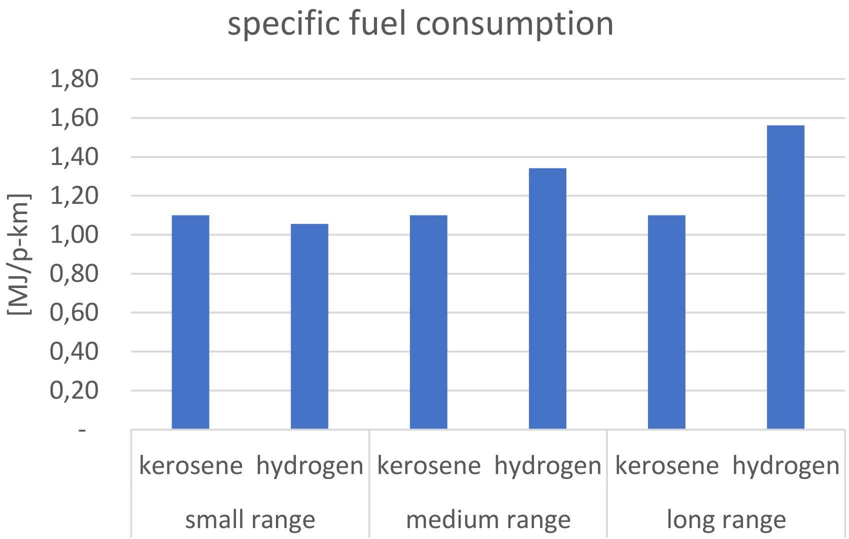


- Approx. 28000 airplanes in global fleet
- Highly populated countries/regions (e.g. India & Africa) with small fleet
- Airbus and Boeing mostly share the market for passenger aviation

Emission distribution in the global aviation

Cost and fuel assumption



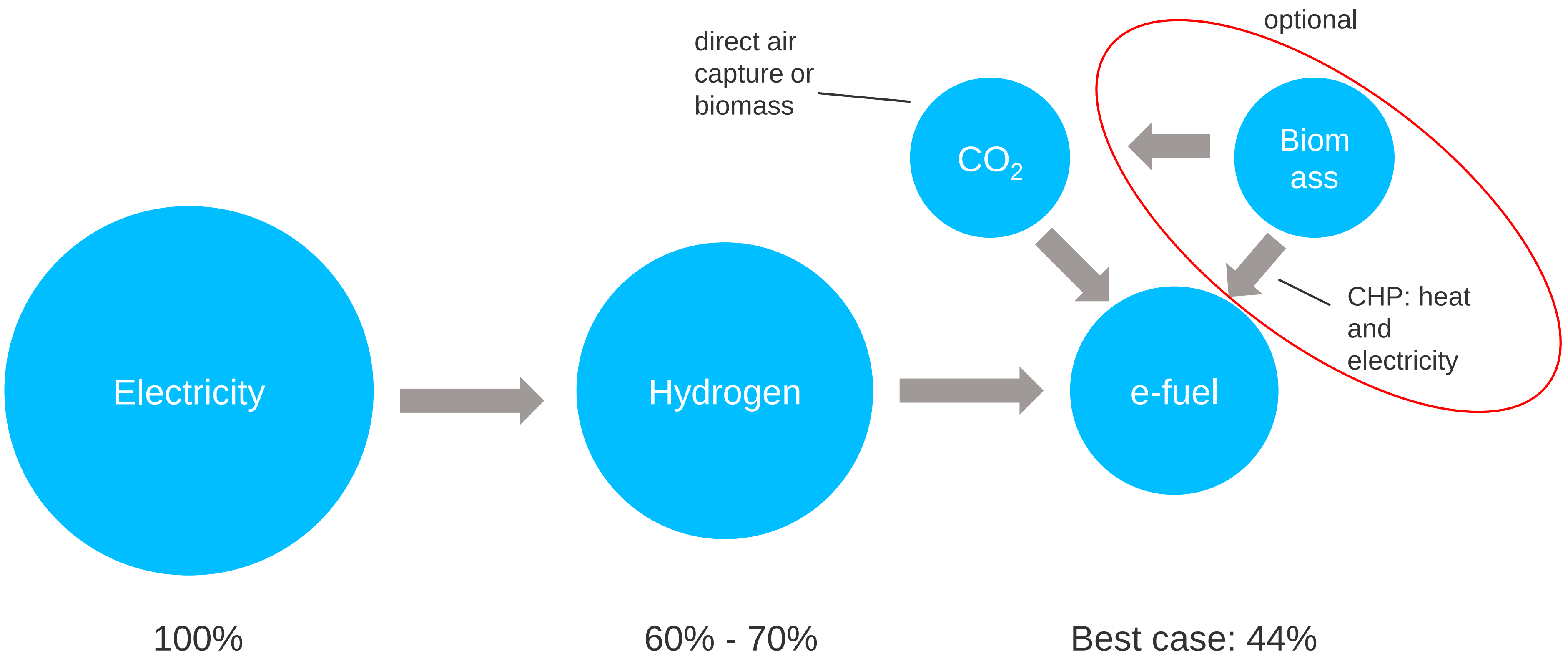


- Hydrogen planes are overall more expensive in terms of invest cost
- Starting 25% for small range and up to 45% for large range

- Small range airplanes can be 4% more efficient compared to the kerosene technology
- For large range up to 40% more fuel consumption is possible

Energy carrier in global aviation

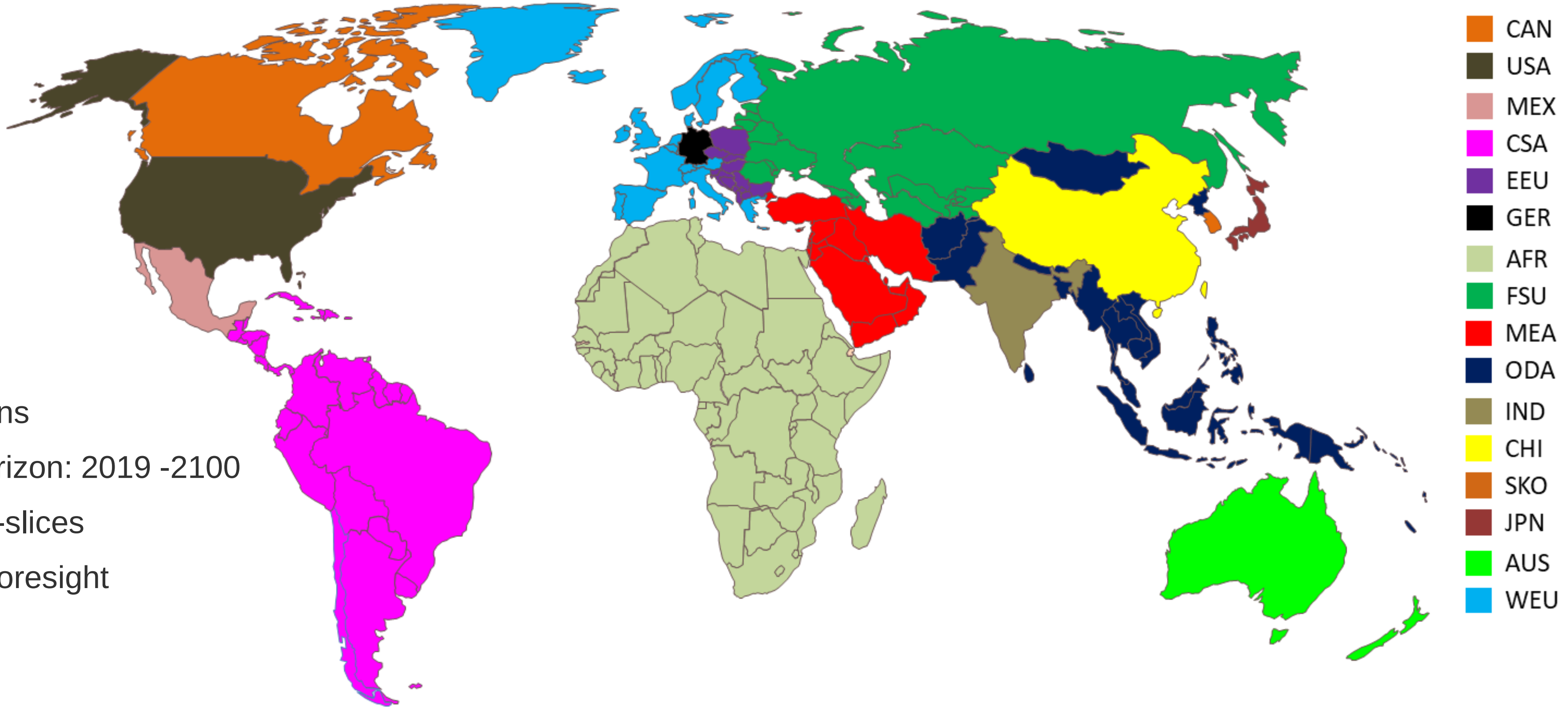
Process chain for sustainable aviation fuels



Results

Aviation Model

Based on TIAM properties



- 16 regions
- Time horizon: 2019 -2100
- 12 Time-slices
- perfect foresight

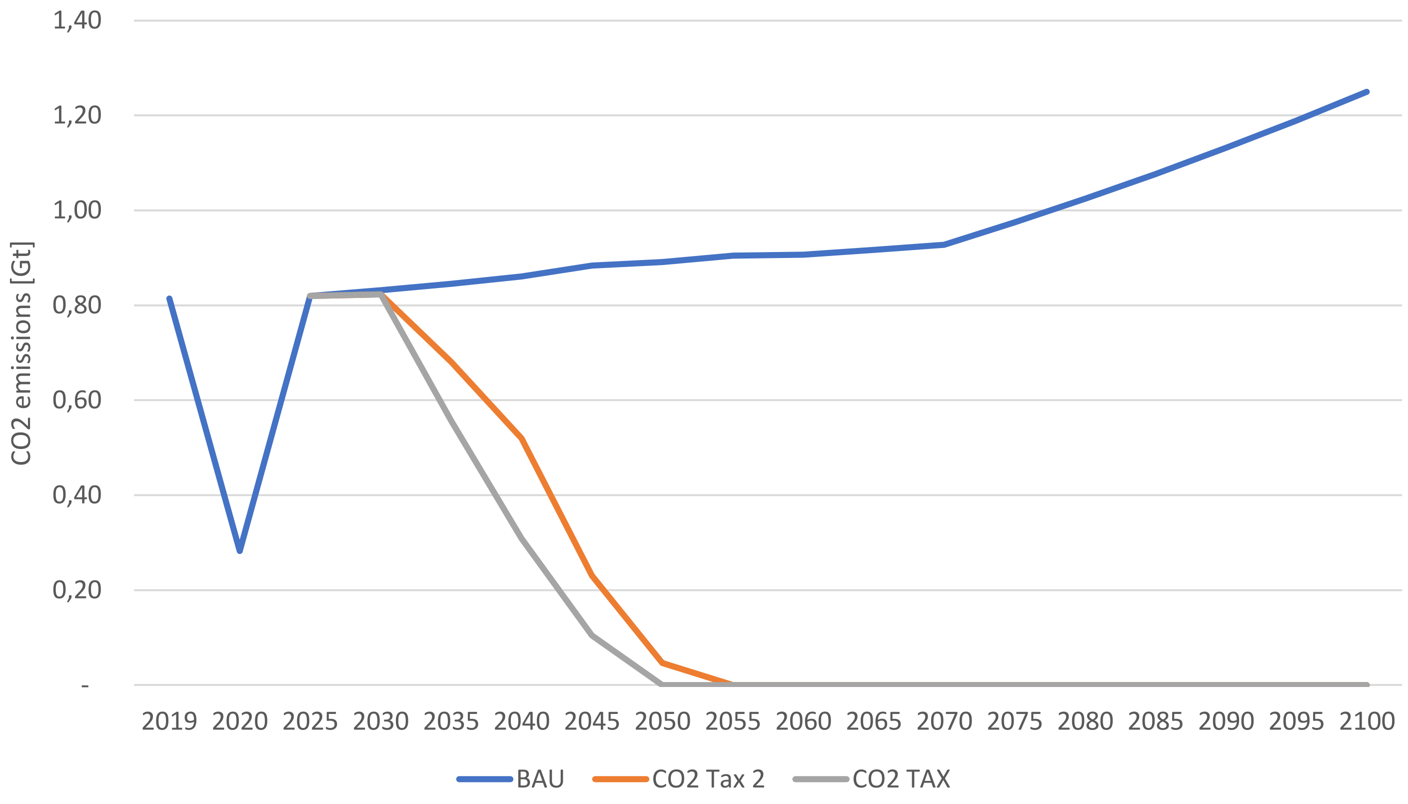
Results

Scenario description

Scenario	Description	Demand	Efficiency increase
BAU	No climate policy	1% rise in demand p.a.	20% in 2050
CO2 Tax	Climate policy via CO_2 tax Hydrogen and e-fuels are available starting 2030		
CO2 Tax 2	Climate policy via CO_2 tax Hydrogen is not considered. E-fuels available starting 2030		

Results

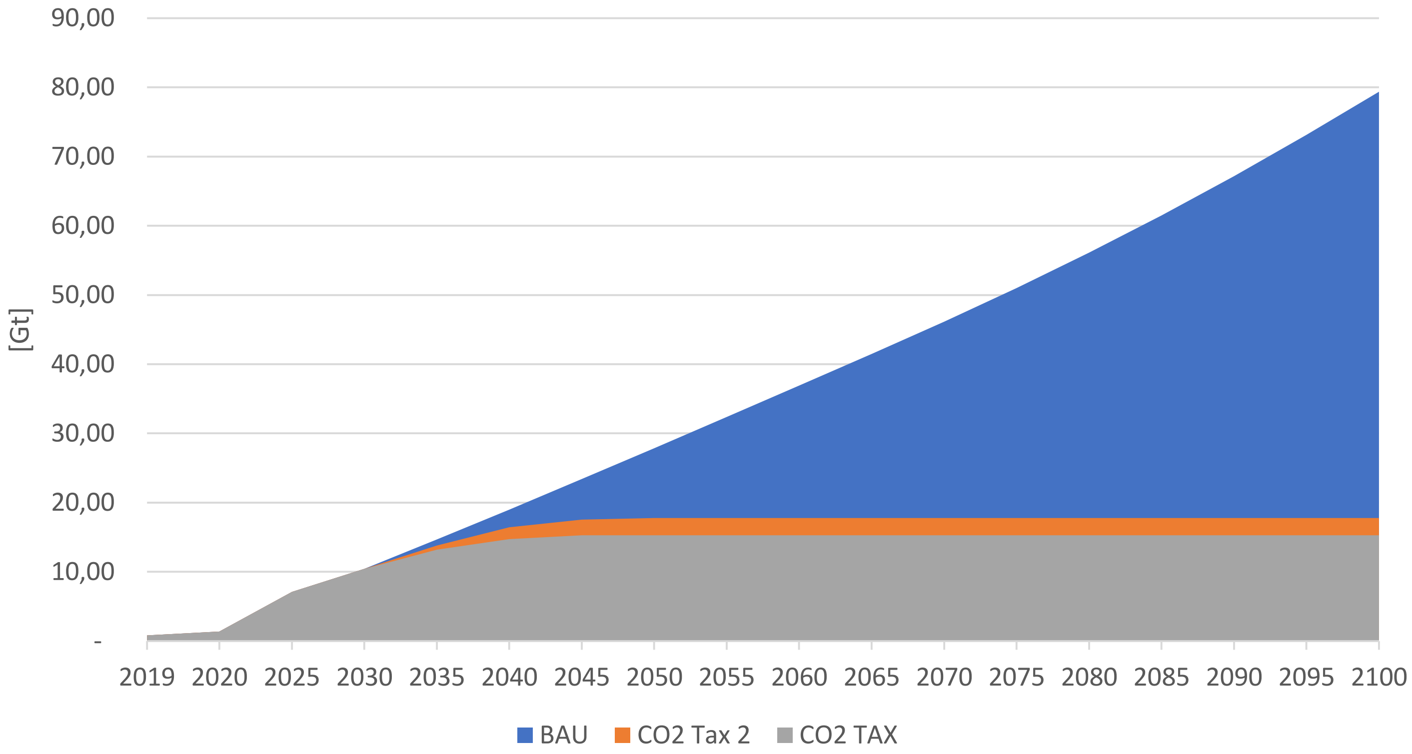
CO_2 Emissions related to global aviation



- Net Zero 2050 with CO_2 Tax
- In BAU the CO_2 emission rise to over 1,2 Gt
- e-fuels need an adjusted price path

Results

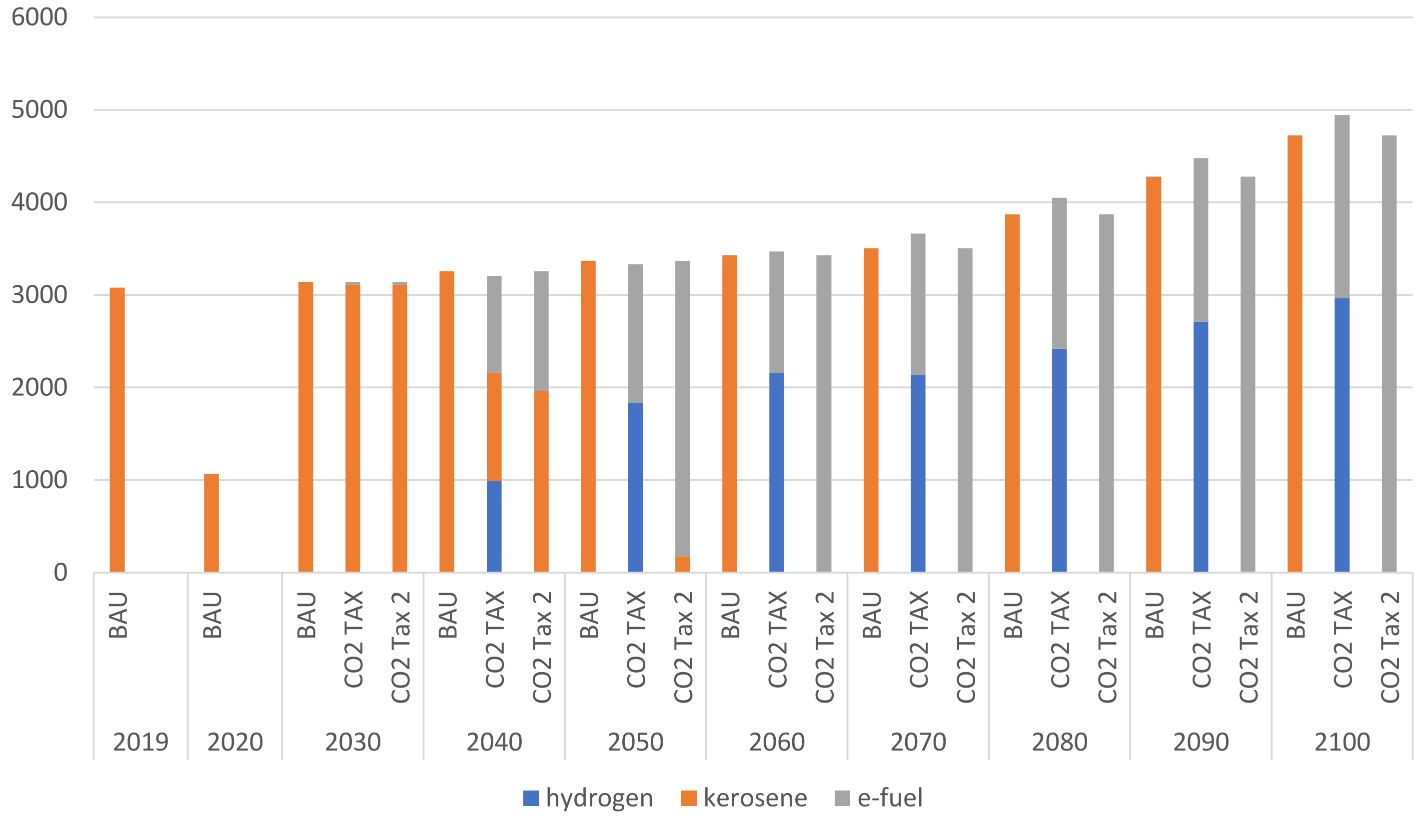
Global commulative CO_2 Emissions



- Cumulative CO_2 of BAU 80 Gt in 2100.
- 420 Gt CO_2 Emission available according to the IPCC
- 19% of CO_2 Budget for BAU 4,2% for CO2 Tax 2 and 3,6% for CO2 Tax

Results

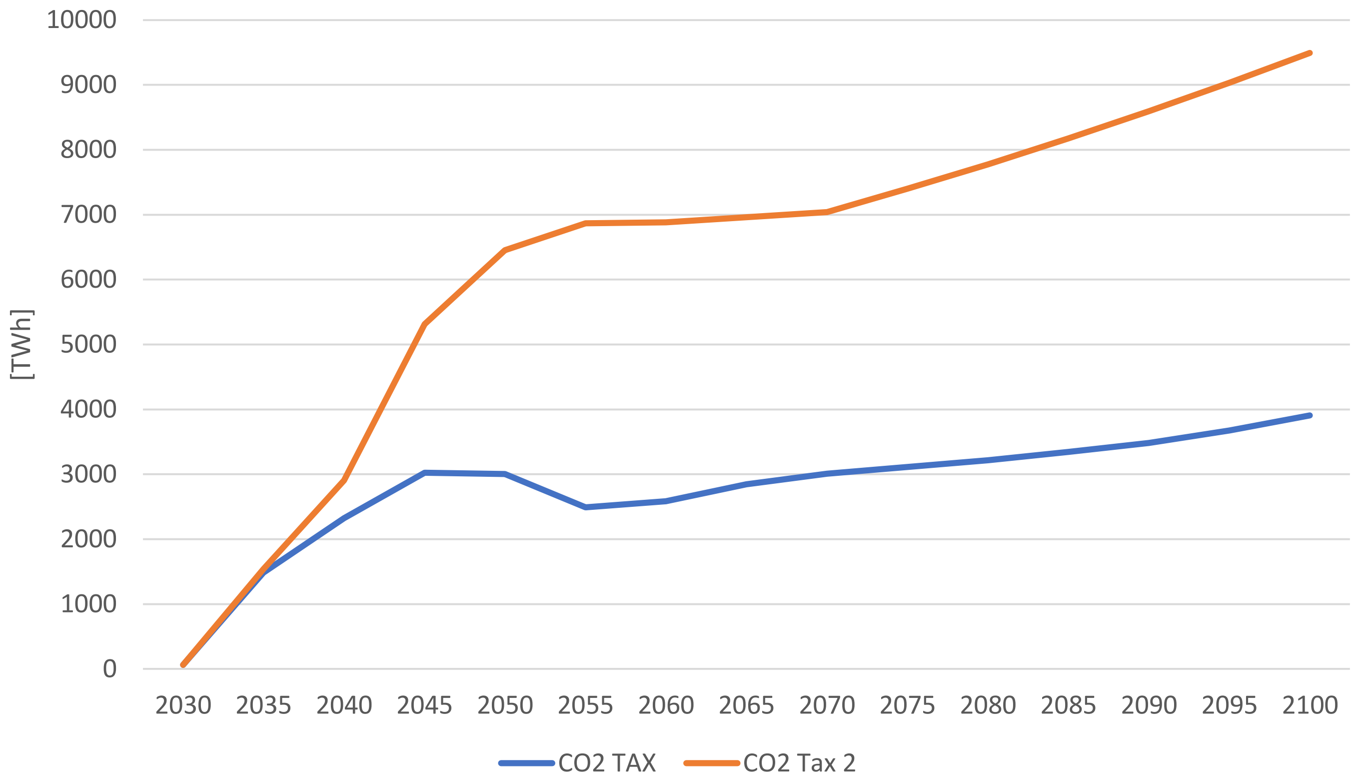
Global fuel demand for aviation



- Fuel demand can rise to roughly 5000 TWh in 2100
- 60% increase in overall fuel demand for CO2 Tax
- 53% increase in overall fuel demand for CO2 Tax 2
- 60/40 hydrogen to e-fuels in 2100 for CO2 Tax

Results

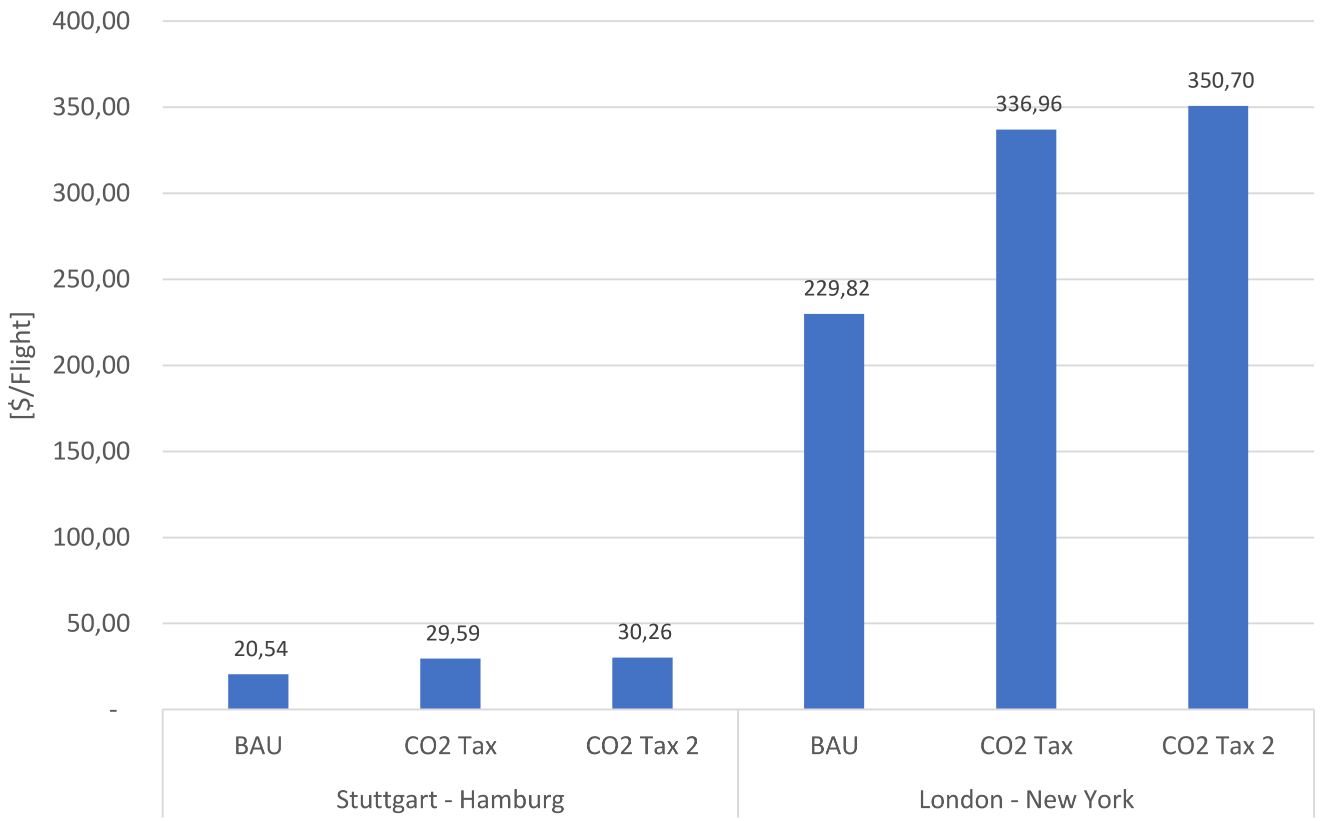
Global electricity demand for aviation



- Over 9000 TWh demand in 2100 for CO2 Tax 2
- Approx. 4000 TWh demand in 2100 for CO2 Tax
- Germany 2100
  - CO2 Tax: 174 TWh
  - CO2 Tax 2: 255 TWh
  - Electricity production 2022: 510 TWh

Results

Cost comparison



- Stuttgart – Hamburg
  - 550 km
  - CO_2 Tax + 44%
  - CO_2 Tax 2 + 47%
- London – New York
  - 5500 km
  - CO_2 Tax + 46%
  - CO_2 Tax 2 + 52%

Discussion & Conclusion

Discussion and limitations

- Only direct CO_2 emissions are considered for now
  - Emission factor of 73,5 g CO2/MJ considered (135 g CO2/MJ)
  - Cloud building not been considered so far
- Hydrogen airplanes uncertain
  - Data availability is uncertain and infrastructure costs as well
- Standalone model for now
  - No competition with other sectors
- Behavioral change is possible but not considered
- A demand increase of 1 % p.a. is the lowest estimate in recent literature (often 4% or even more)
- No consideration of battery electric or fuel cell airplanes and biofuels

Conclusion

- Net zero possible for both hydrogen and e-fuels
- Hydrogen planes will require a new infrastructure which will cause additional costs
- e-fuels are more flexible
  - No change in technology is necessary
  - Shares with fossil kerosene possible
- Due to climate policy flights increased by 40% in cost at a minimum
- At least 5000 TWh of sustainable aviation fuels are required in 2100
- The decision of e-fuels or hydrogen will increase the energy dependency for certain countries/regions
- Global coordination necessary
- Behavioral change would be beneficial

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Thanks!

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