Carbon footprint of ammonia as marine fuel and costs

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GreenShipping Niedersachsen

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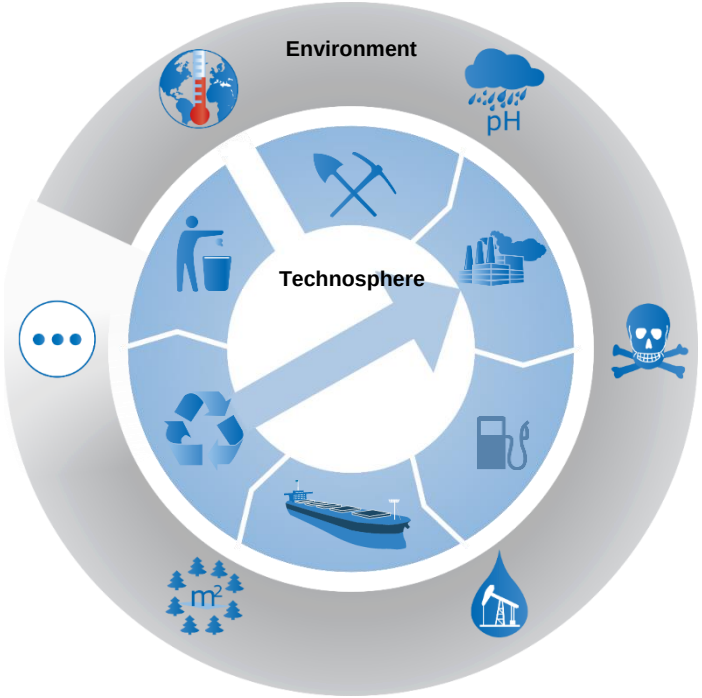
Life Cycle Assessment (LCA)



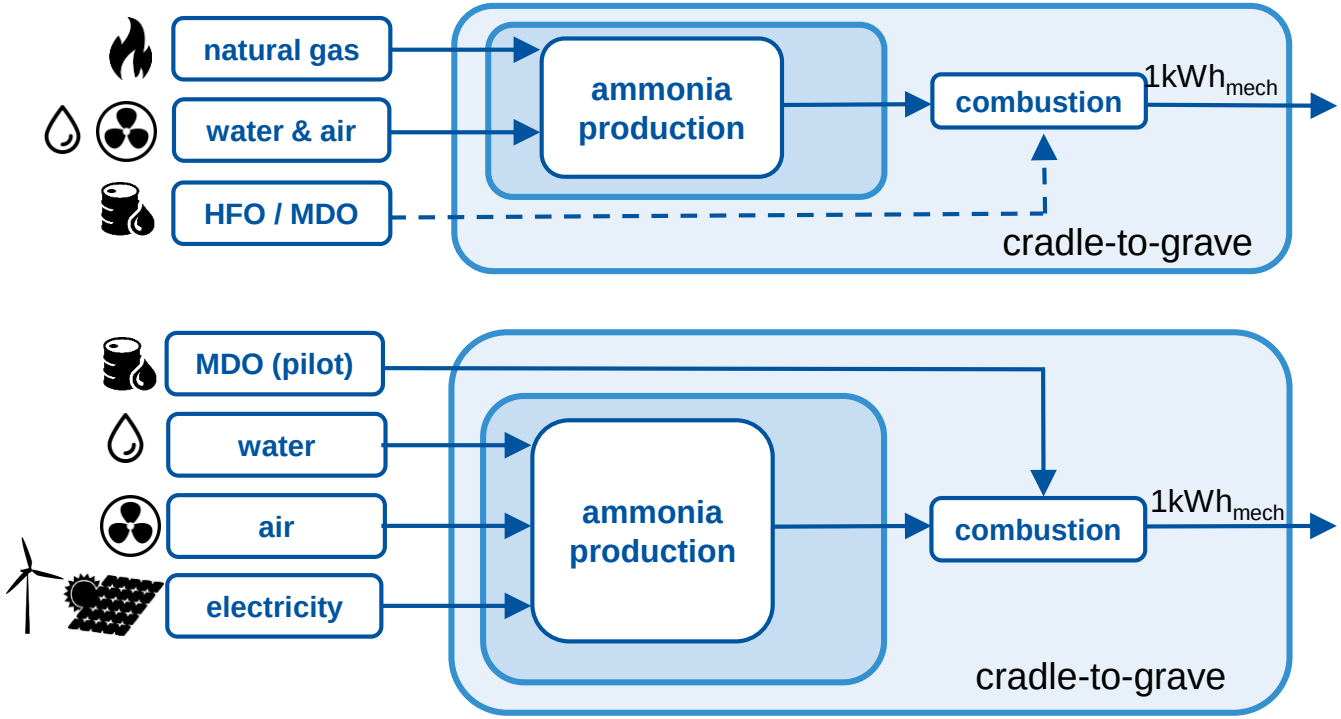
- Holistic evaluation
  - From cradle to grave
  - Variety of environmental impact categories
- Standardized methodology
  - ISO 14040 / 14044

Goal and scope

GHG reductions

Global scale

Fuel costs

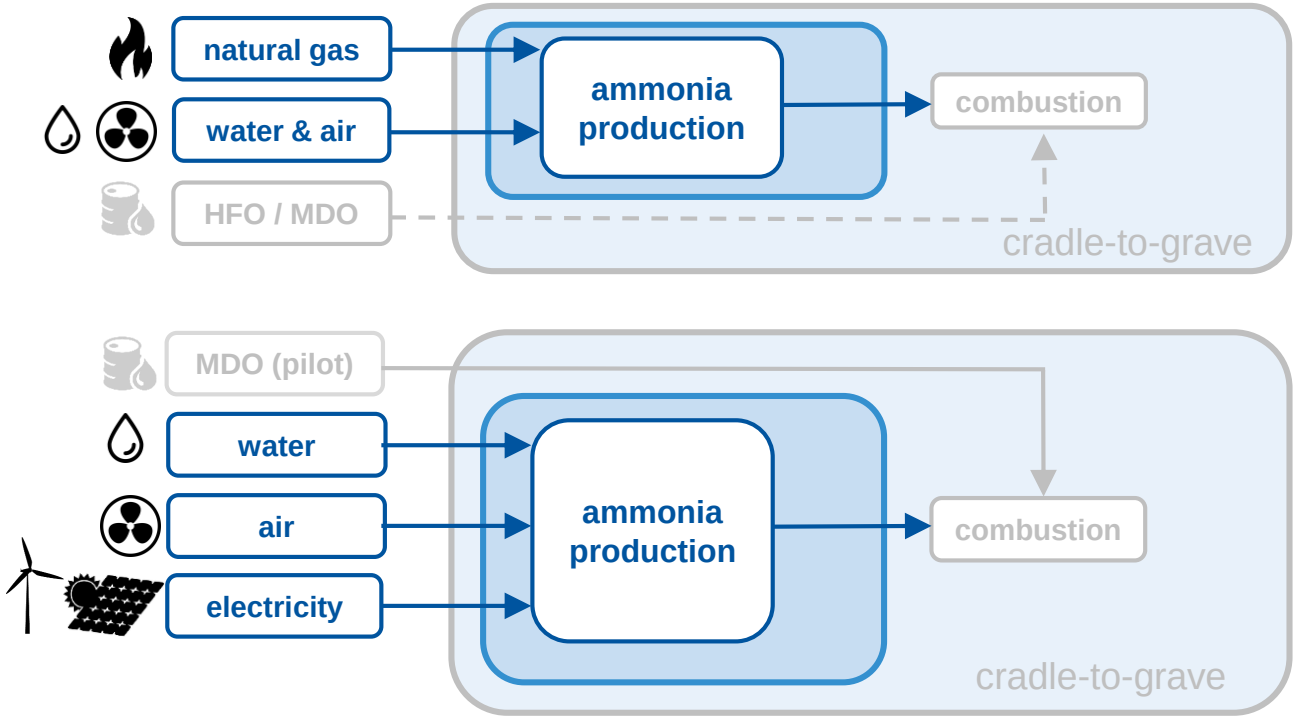


Ammonia from cradle-to-gate

GHG reductions

Global scale

Fuel costs



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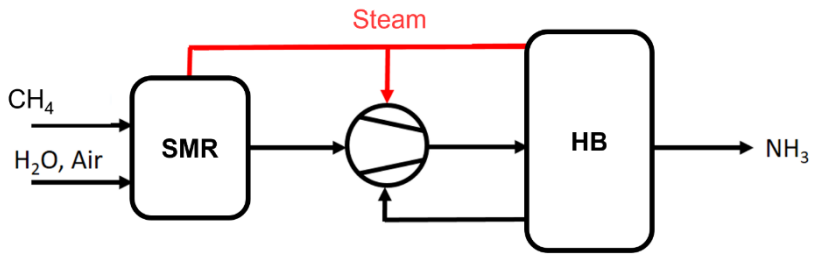
Ammonia production pathways

Technology readiness level

Conventional Haber Bosch



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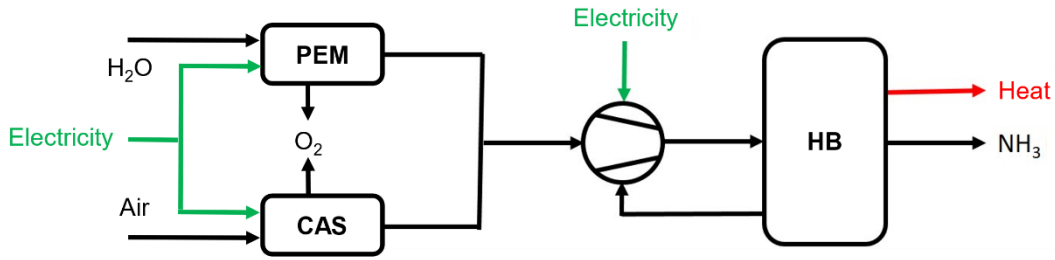
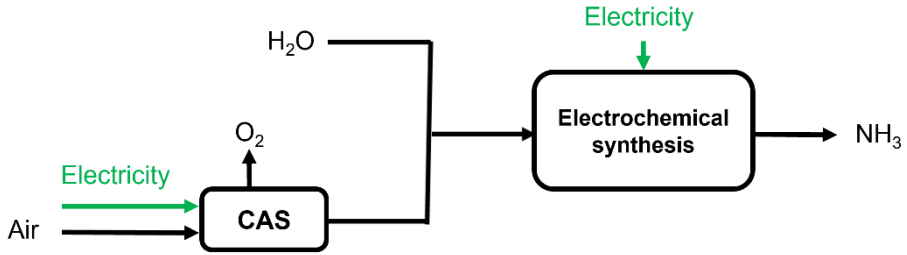
Electrified Haber Bosch



6 - 9

Electrochemical synthesis



1 - 3

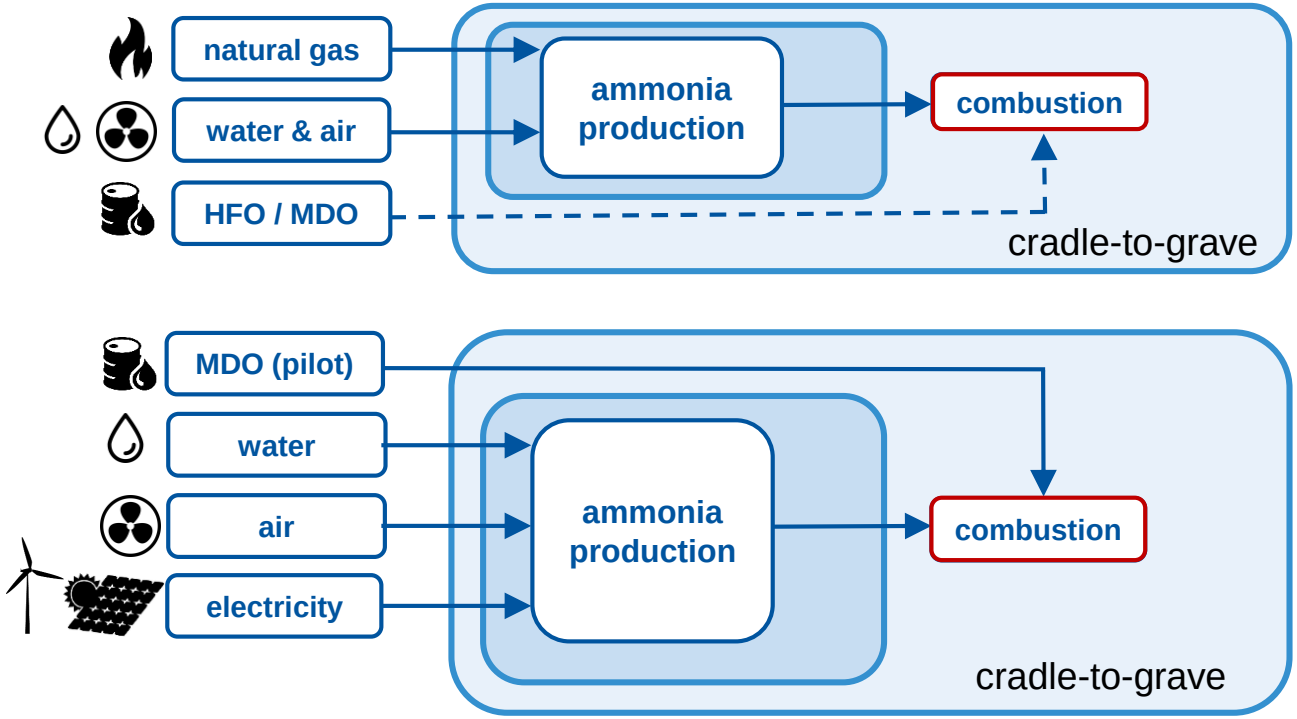
SMR steam methane reforming
PEM PEM-electrolysis
CAS cryogenic air separation

Ammonia from cradle-to-grave

GHG reductions

Global scale

Fuel costs



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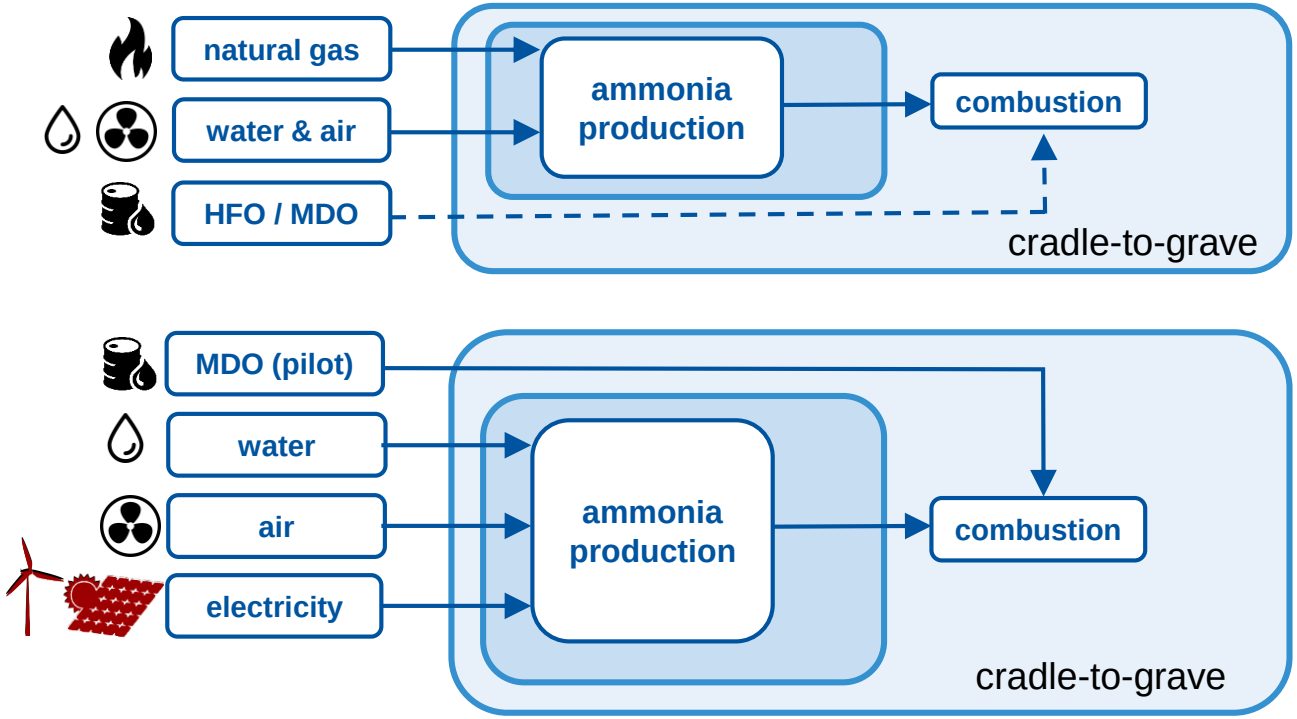
Ammonia from cradle-to-grave

GHG reductions

Global scale

Fuel costs



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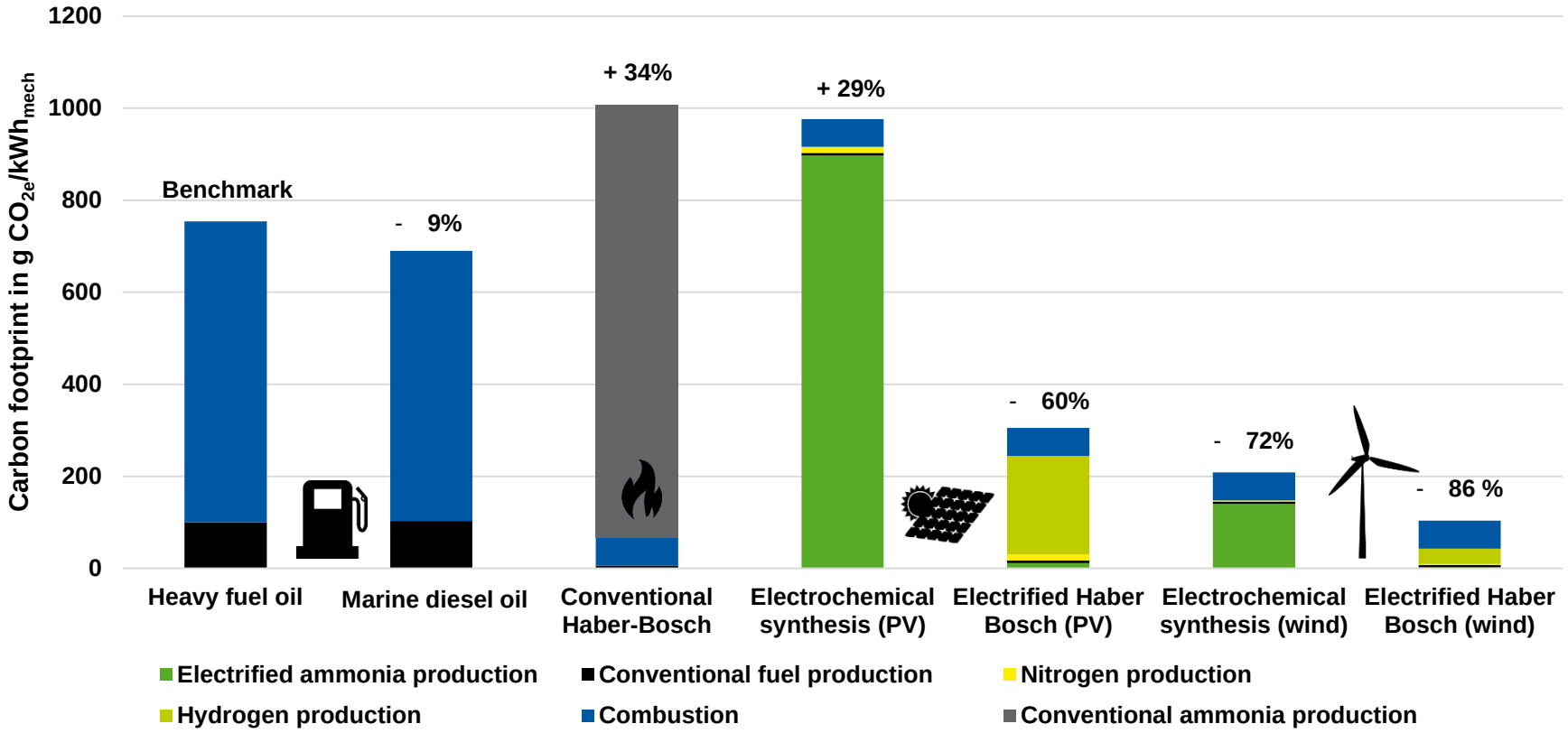
Carbon footprint of conventional and ammonia marine fuel



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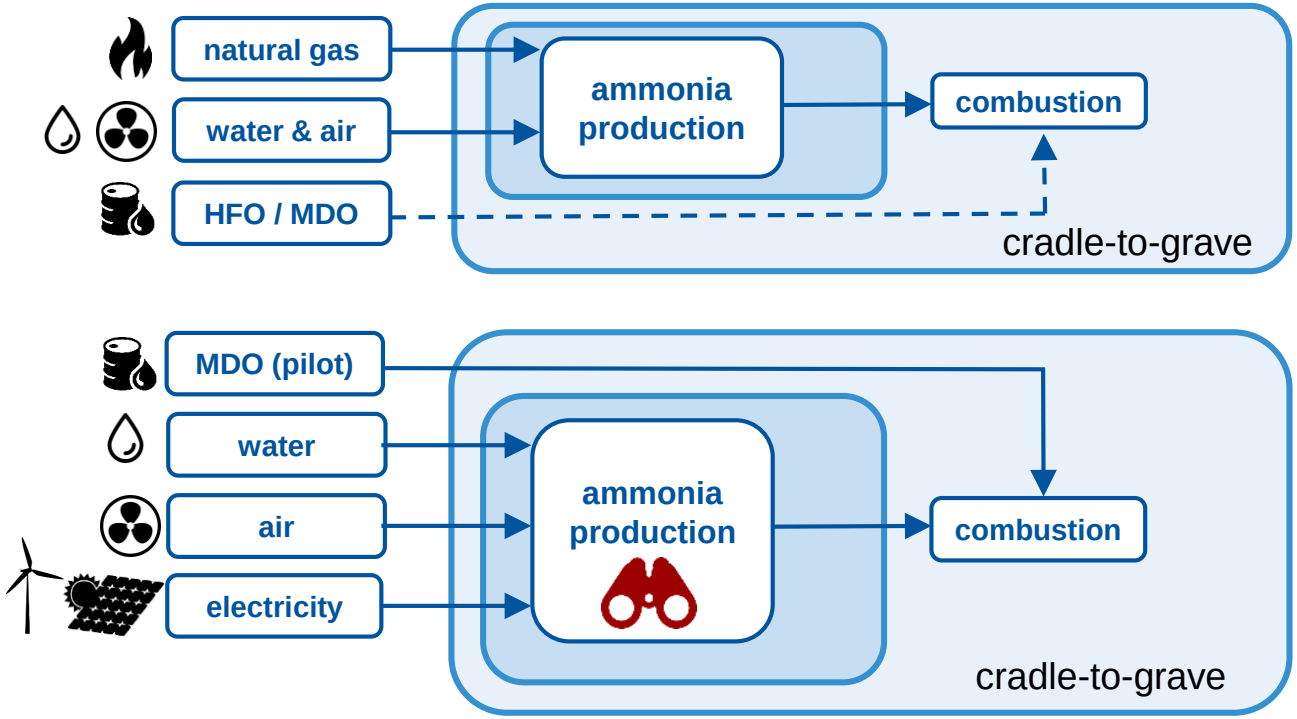
Future potential for ammonia marine fuel

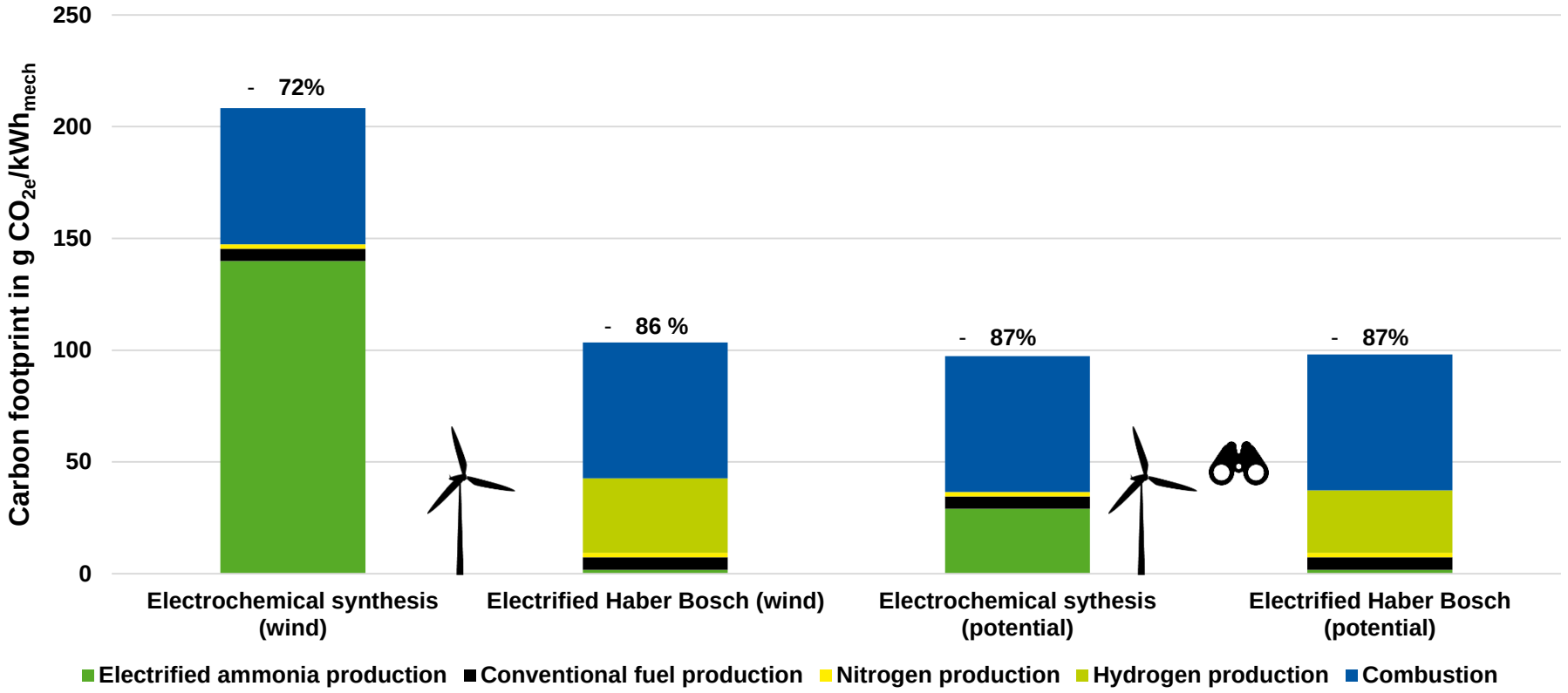
GHG reductions

Global scale

Fuel costs



Carbon footprint of ammonia marine fuel – future potential



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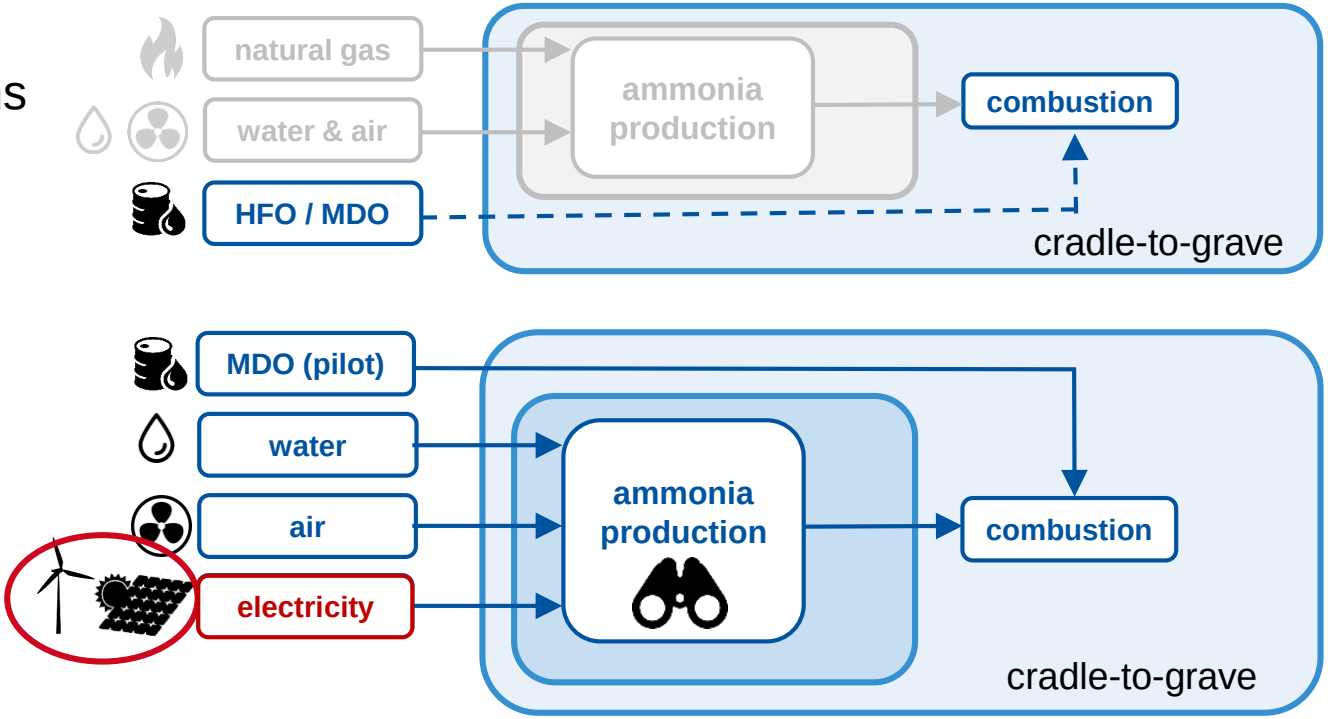
Carbon footprint sensitivity study of the electricity supply

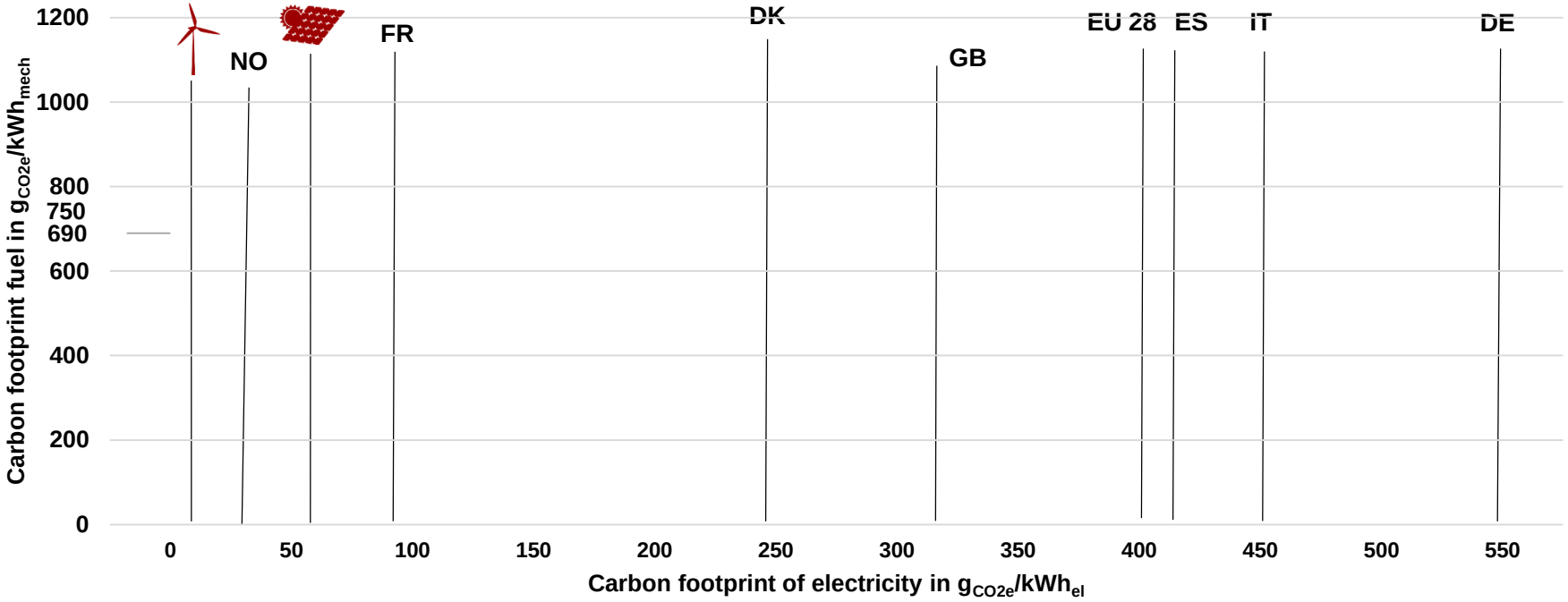
GHG reductions

Global scale

Fuel costs



Carbon footprint sensitivity study of the electricity supply



Marine diesel oil

heavy fuel oil

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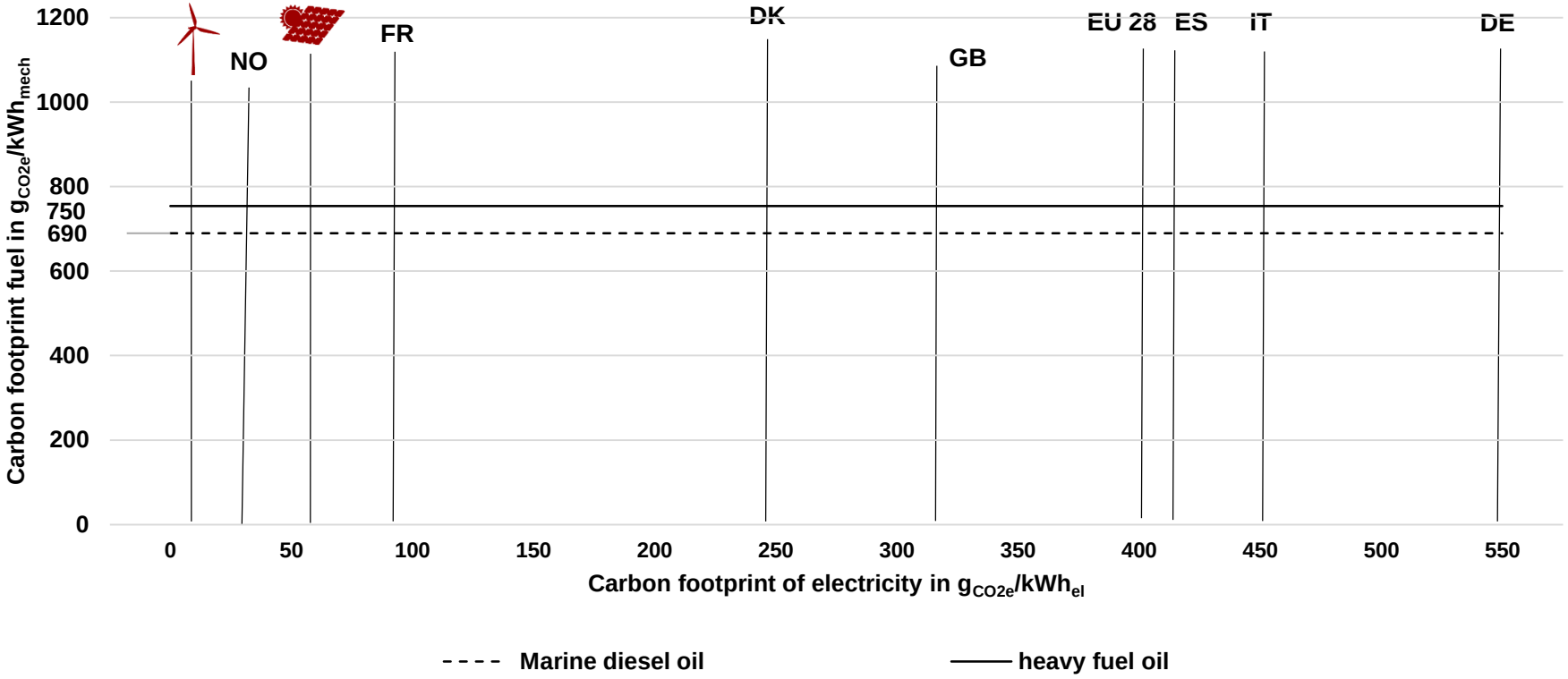
Carbon footprint sensitivity study of the electricity supply



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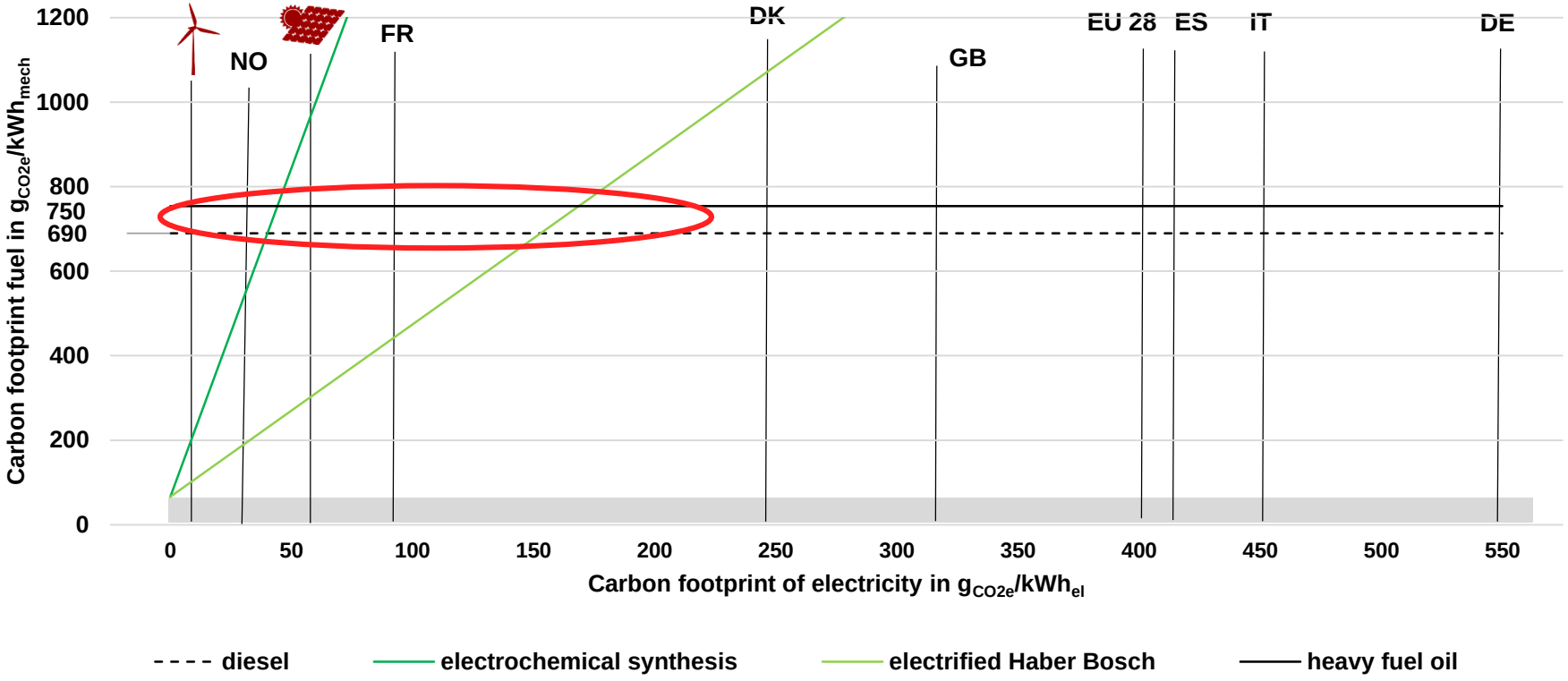
Carbon footprint sensitivity study of the electricity supply



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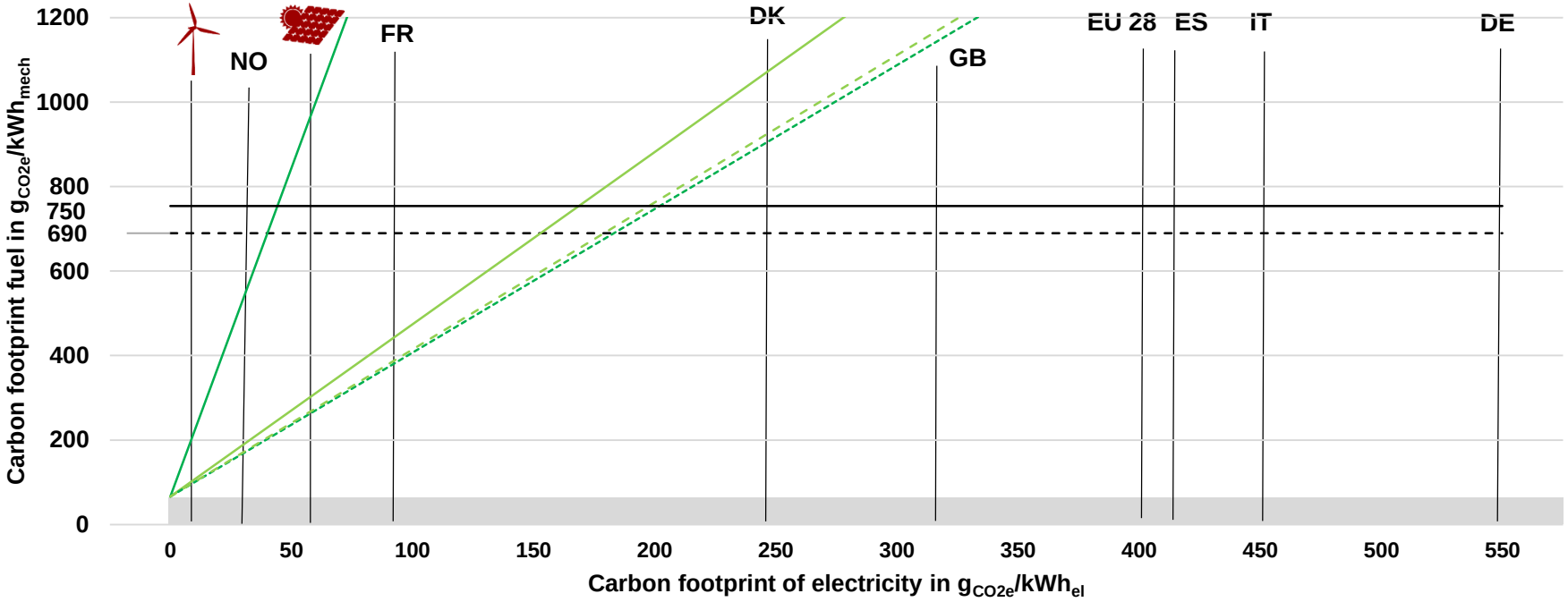
Energy from where ? Impact on Carbon footprint



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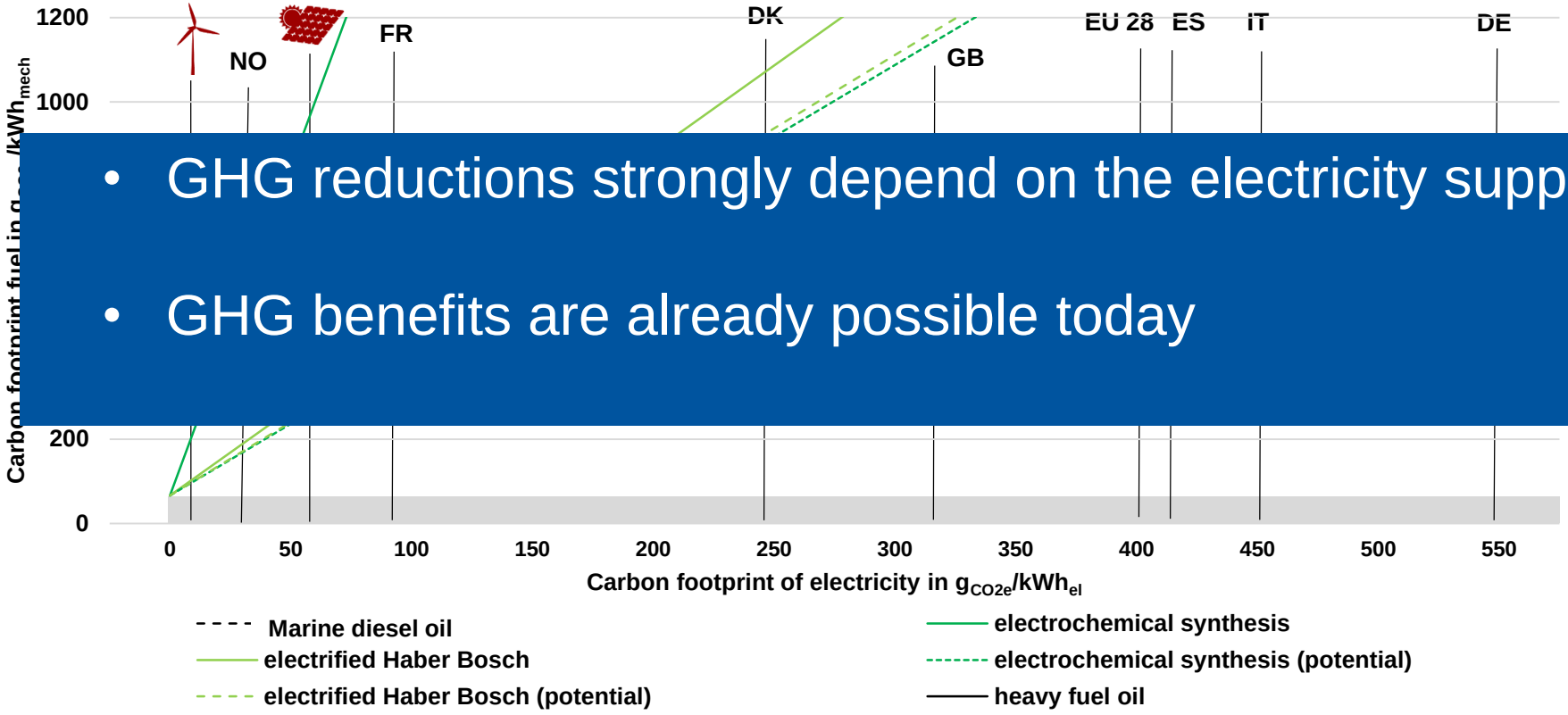

- GHG reductions strongly depend on the electricity supply
- GHG benefits are already possible today

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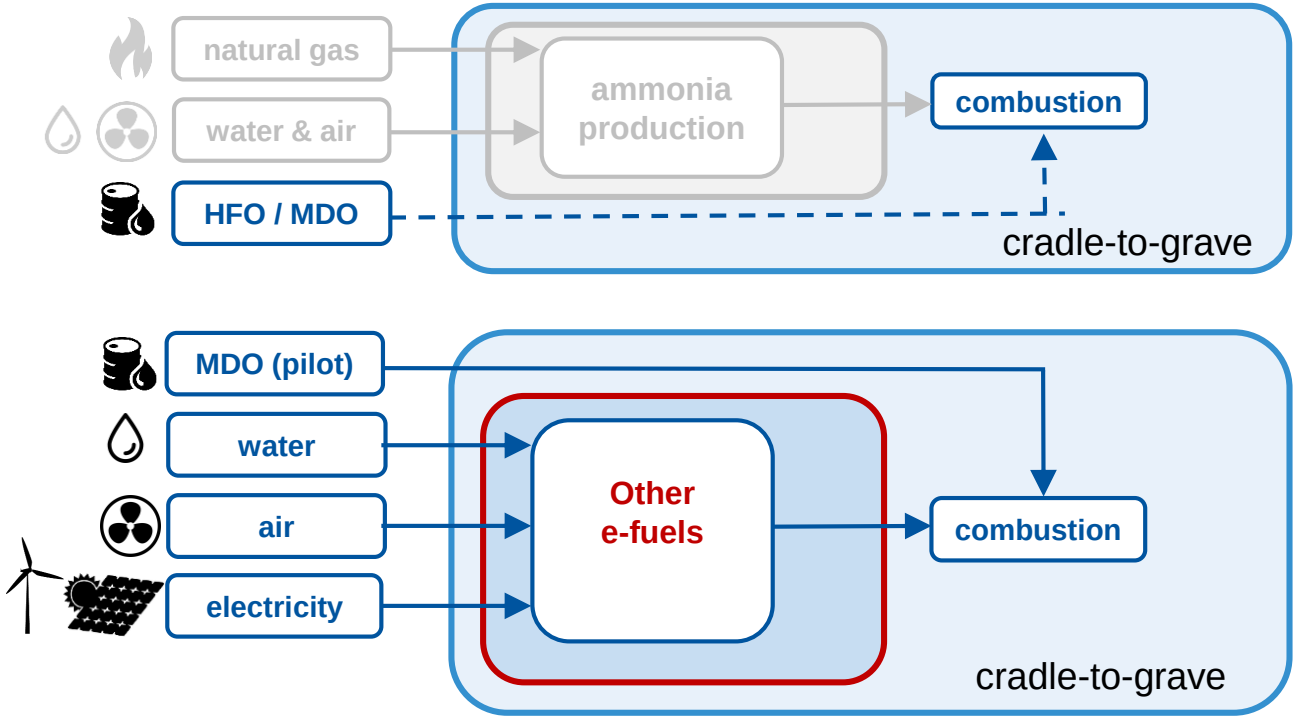
Carbon footprint of other e-fuels

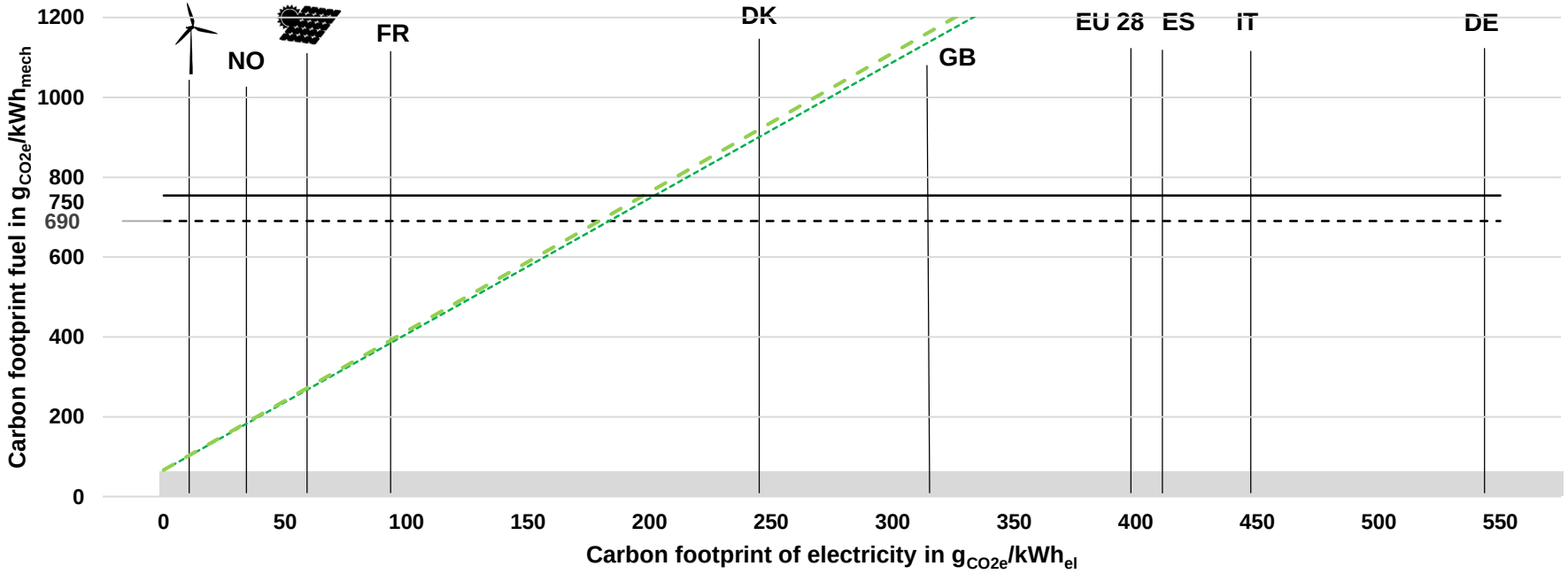
GHG reductions

Global scale

Fuel costs



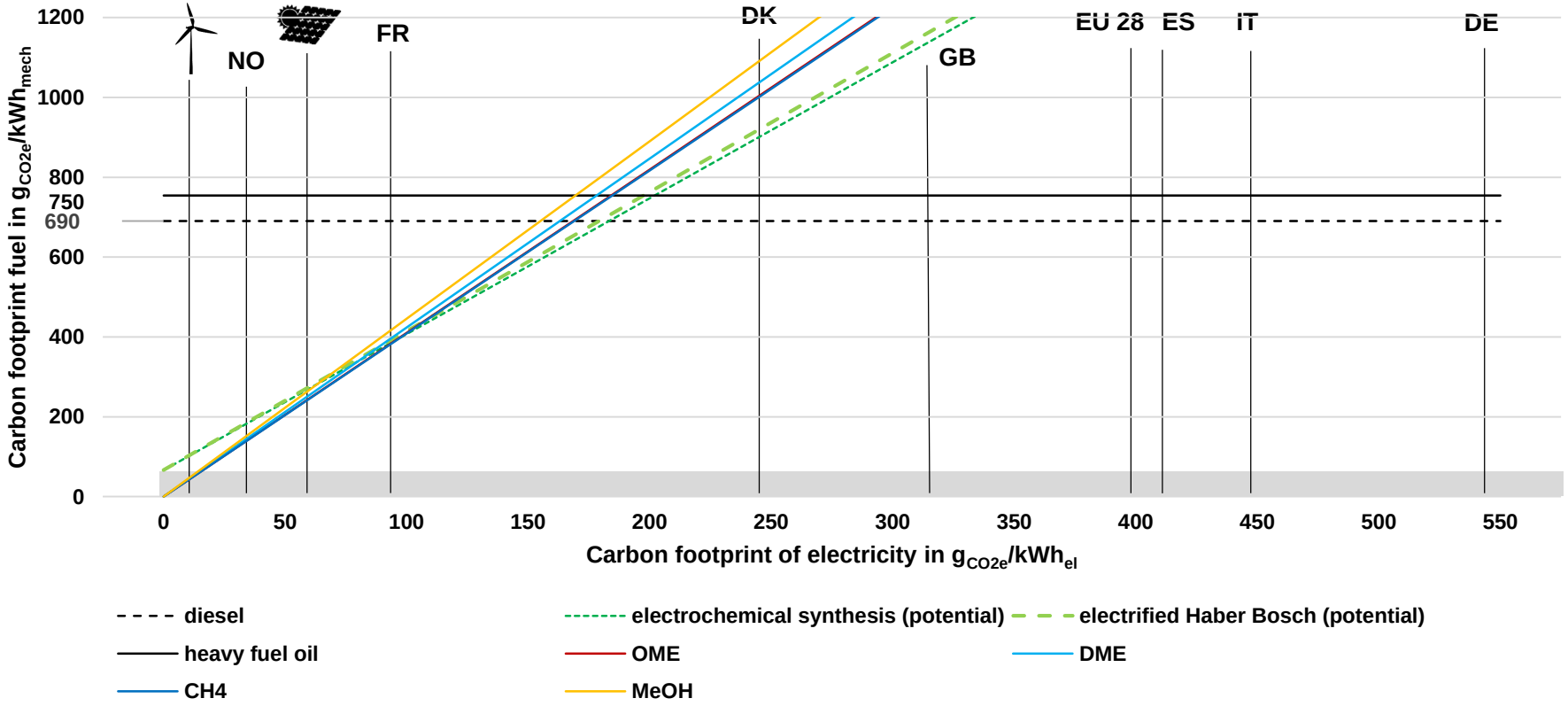
Carbon footprint of other e-fuels



diesel
heavy fuel oil
CH4
electrochemical synthesis (potential)
OME
MeOH
electrified Haber Bosch (potential)
DME

Deutz et al., *Energy Environ. Sci.*, 2018, **11**, 331-343.
2. Roadmap Kopernikus Projekt “Power-to-X”.
Bongartz et al., *Appl. Energy,* 2018, 231, 757-767.
Artz et al., *Chem. Rev.*, 2018, 118, 2, 434-504

Carbon footprint of other e-fuels



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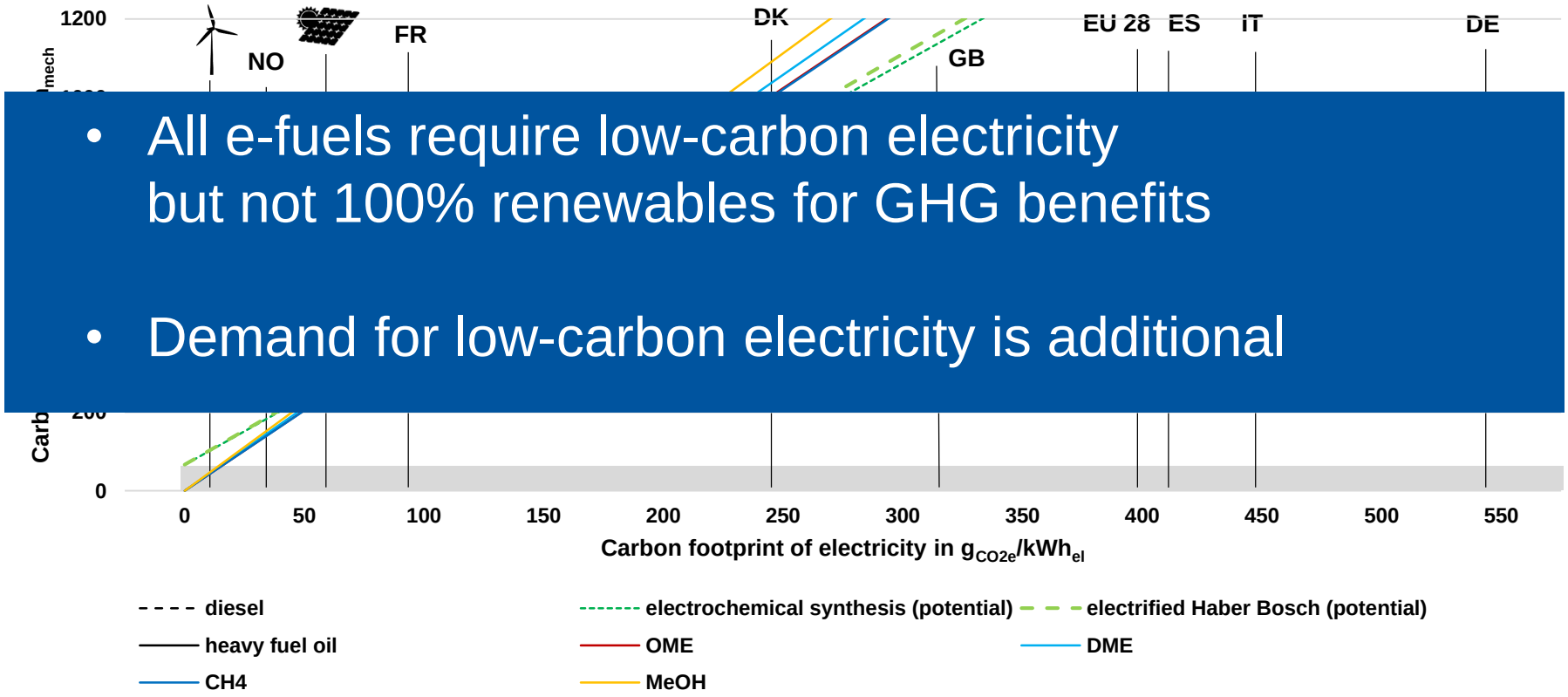
Carbon footprint of other e-fuels



- All e-fuels require low-carbon electricity but not 100% renewables for GHG benefits
- Demand for low-carbon electricity is additional

Deutz et al., *Energy Environ. Sci.*, 2018, **11**, 331-343.
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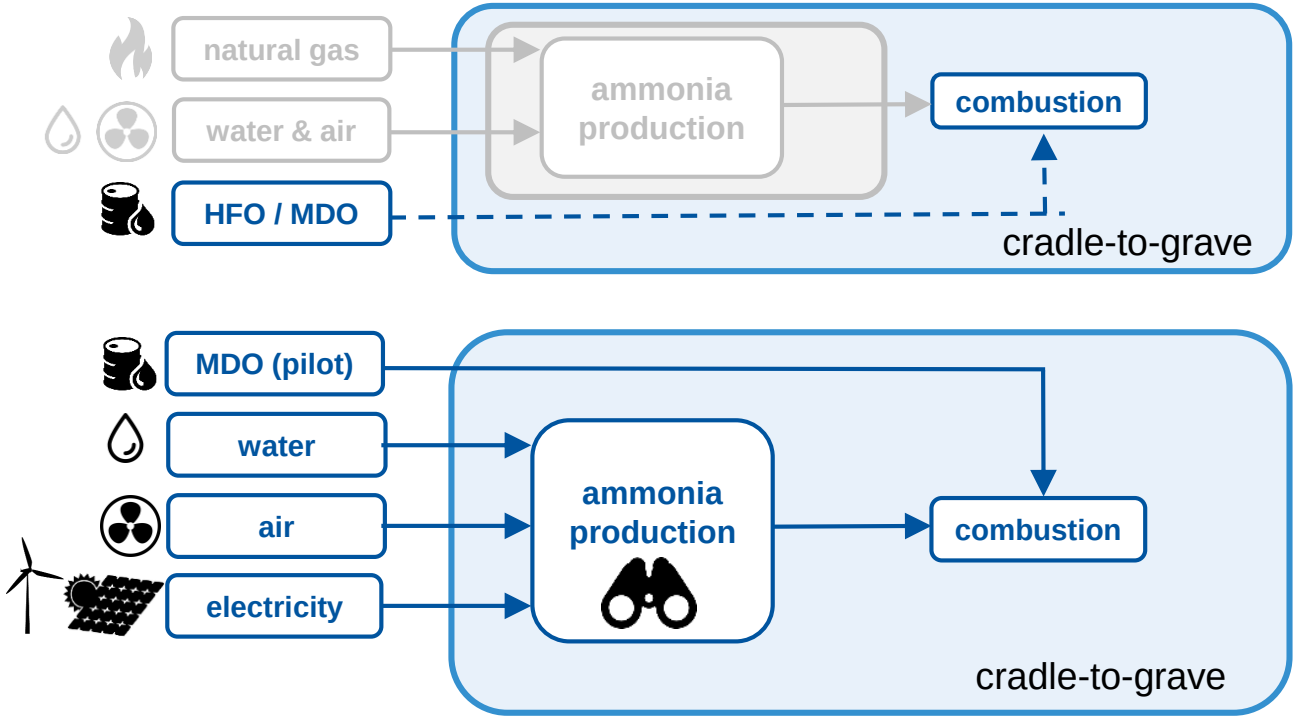
Ammonia as marine fuel on a global scale

GHG reductions

Global scale

Fuel costs



Ammonia as marine fuel on a global scale

Global demand marine fuel ≈ 250 $Mt_{HFO\text{-}eq.}/y$[1,2]

Substitution with green ammonia from electrified Haber Bosch:

3700 TWh ≙ 14% of global generation (2018)[3]

GHG reduction of 700 $MtCO_{2e}$ ≙ 2% of global GHG emisisons (2018)[4]

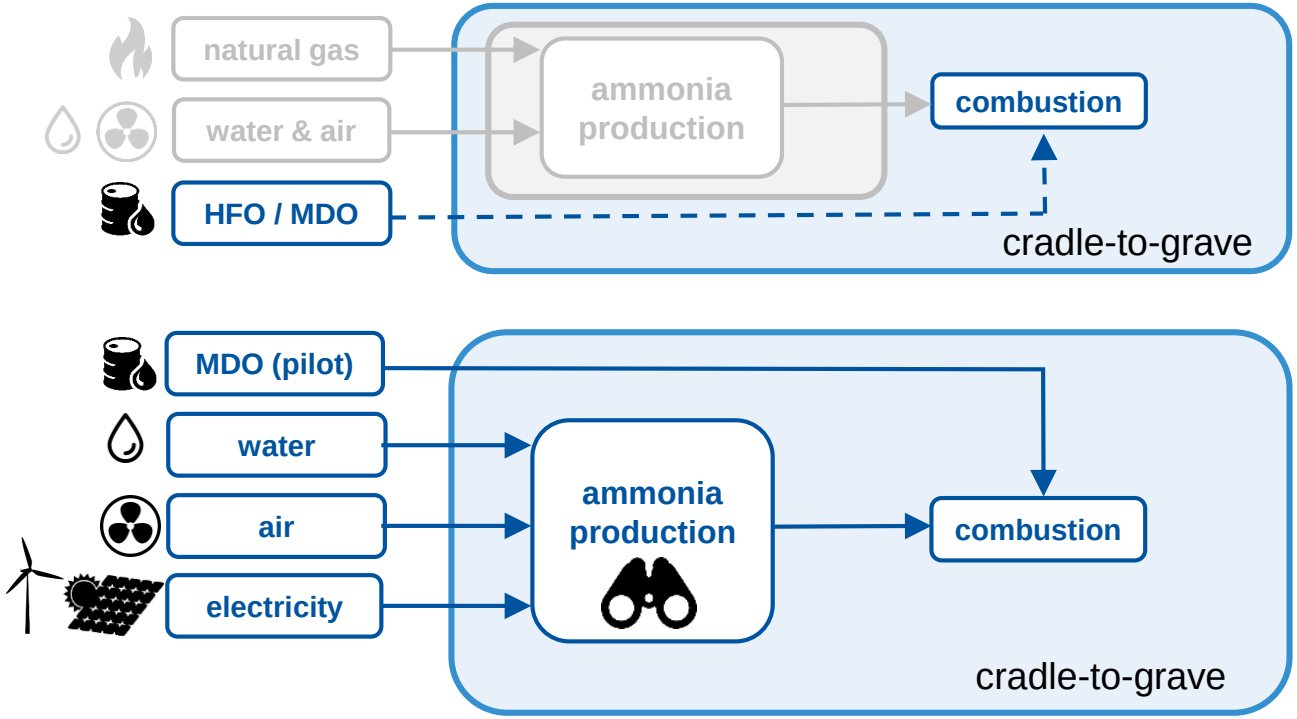
1) Assumption: fuel = HFO
2) IEA 2019 – The Future of Hydrogen
3) IEA 2019 – World Energy Outlook 2019
4) https://ourworldindata.org/co2-emissions?country=

Fuels costs – impact of the hydrogen supply

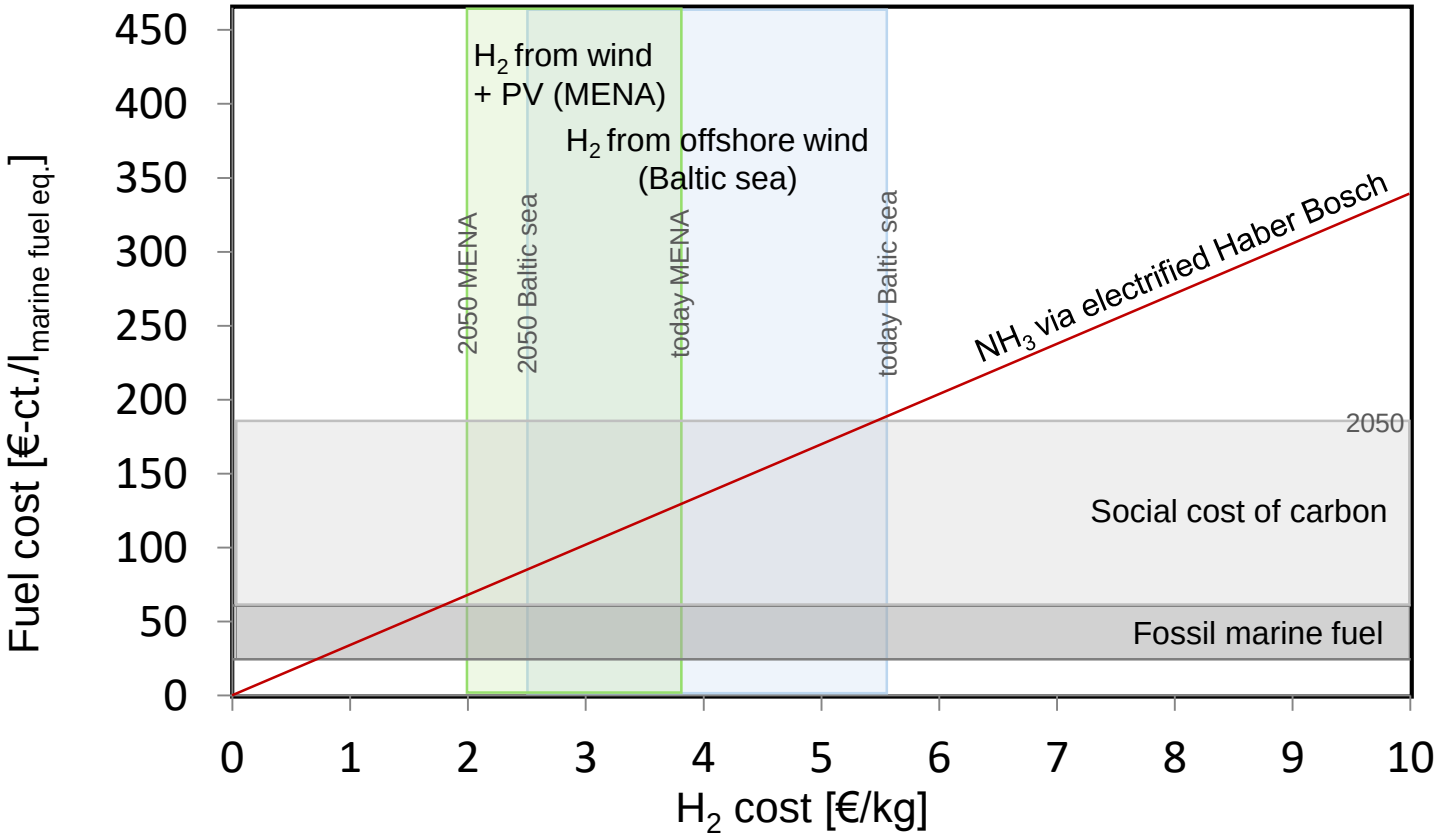
GHG reductions

Global scale

Fuel costs

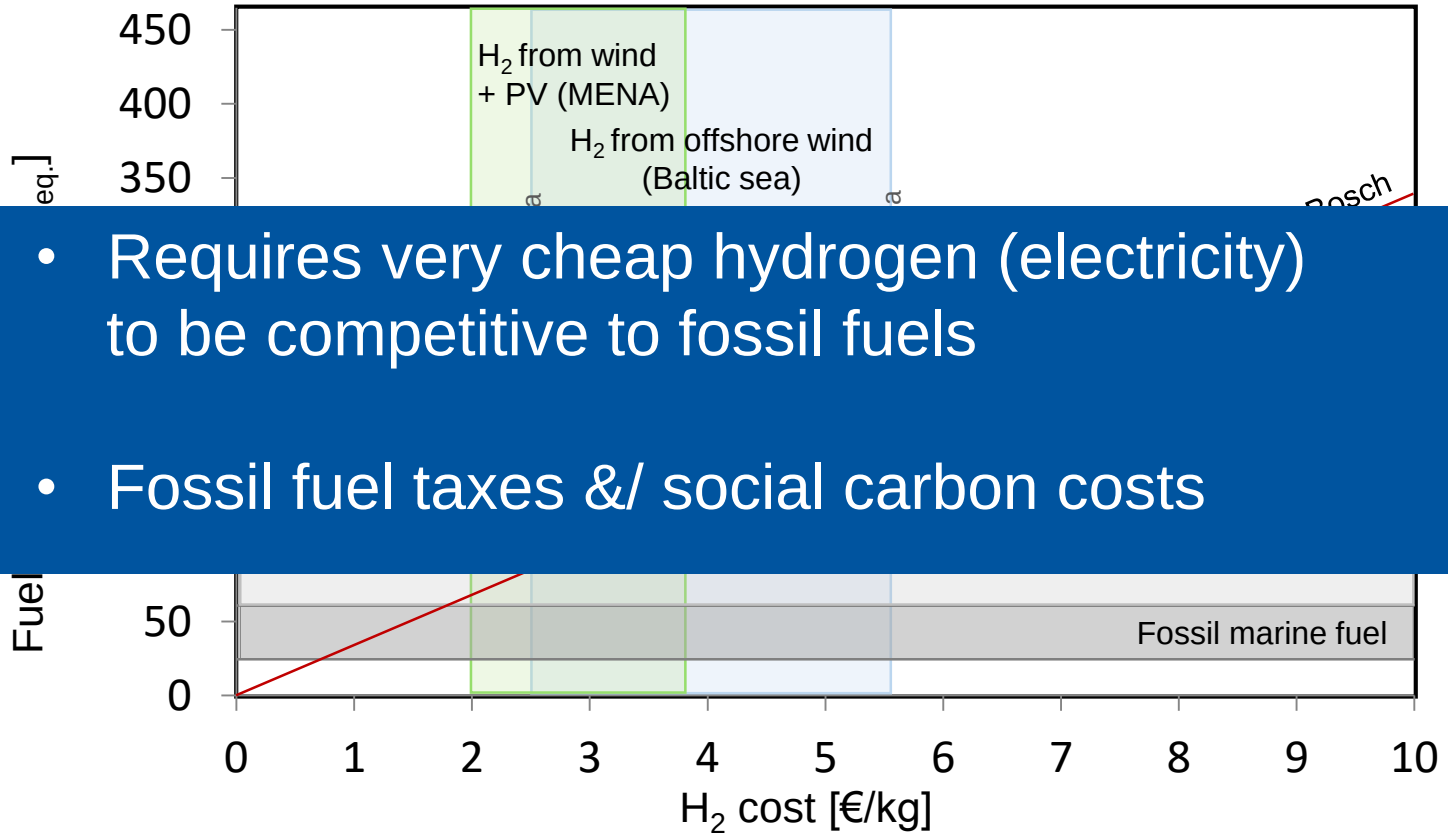


Fuels costs – impact of the hydrogen supply



https://shipandbunker.com/prices/emea/nwe/nl-rtm-rotterdam#ULSFO
AGORA, 2018, The Future Cost of Electricity-Based Synthetic Fuels
UBA, 2020, Empfehlung zu den Klimakosten

Fuels costs – impact of the hydrogen supply



- Requires very cheap hydrogen (electricity) to be competitive to fossil fuels
- Fossil fuel taxes &/ social carbon costs

https://shipandbunker.com/prices/emea/nwe/nl-rtm-rotterdam#ULSFO
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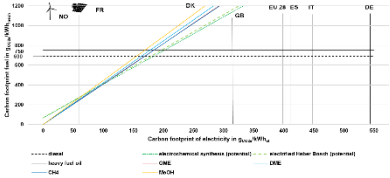
Summary

- GHG benefits require low-carbon energy but are already possible today
- As GHG emission efficient as other e-fuels



- Additional electricity demand implies a massive expansion of the electricity sector

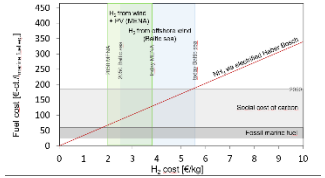
Global demand marine fuel ≈ 250 Mt_{LFO}/y[1,2]

Electricity demand for substitution with green ammonia from electrified Haber Bosch:

3700 TWh ≙ 14% of global generation (2018)[3]

GHG reduction 700 $MtCO_{2e}$ ≙ 2% of global GHG emisisons (2018)[4]

- Requires very cheap electricity and additional tax



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Thank you for your attention!

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