Bewertung von Eisen als Energieträger für eine kohlenstofffreie Energiekreislaufwirtschaft

Einreichung zum Ideenwettbewerb **„Energie und Umwelt – Meine Idee für morgen“** der *Stiftung Energie & Klimaschutz* in 2023.

Jannik Neumann
Technische Universität Darmstadt
Fachgebiet Technische Thermodynamik
Peter-Grünberg-Straße 10
64287 Darmstadt
Telefon: +49 (0) 6151 16-22270
E-Mail: neumann@ttd.tu-darmstadt.de

Forschungsgruppenleitung:
Dr.-Ing. Frank Dammel
Technische Universität Darmstadt
Fachgebiet Technische Thermodynamik
Gruppenleitung Analyse Thermischer Energiesysteme
Peter-Grünberg-Straße 10
64287 Darmstadt
E-Mail: dammel@ttd.tu-darmstadt.de

Betreuung:
Prof. Dr.-Ing. Peter Stephan
Technische Universität Darmstadt
Fachgebiet Technische Thermodynamik
Peter-Grünberg-Straße 10
64287 Darmstadt
E-Mail: pstephan@ttd.tu-darmstadt.de

TECHNISCHE UNIVERSITÄT DARMSTADT

MASCHINENBAU We engineer future TTD

Clean Circles

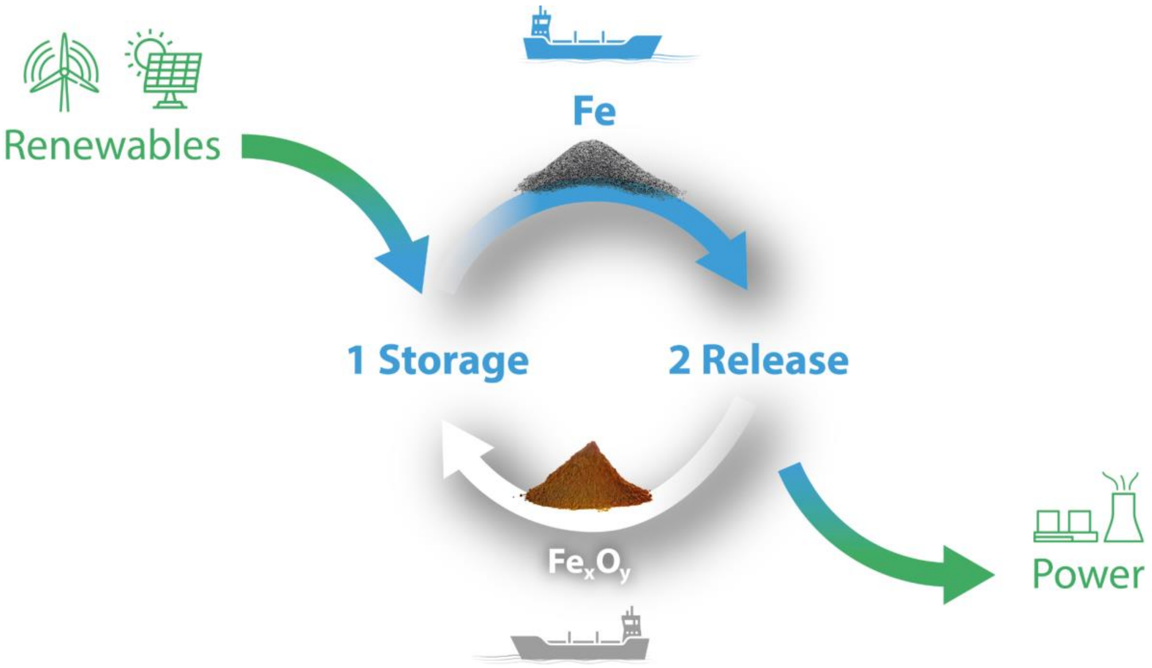
Die Promotionsmöglichkeit wird im Rahmen des Cluster Projekts *Clean Circles* geboten, welches durch das *Hessische Ministerium für Wissenschaft und Kunst* gefördert wird.

Evaluation of an Iron-based Circular Energy Economy for Carbon-free Power Supply

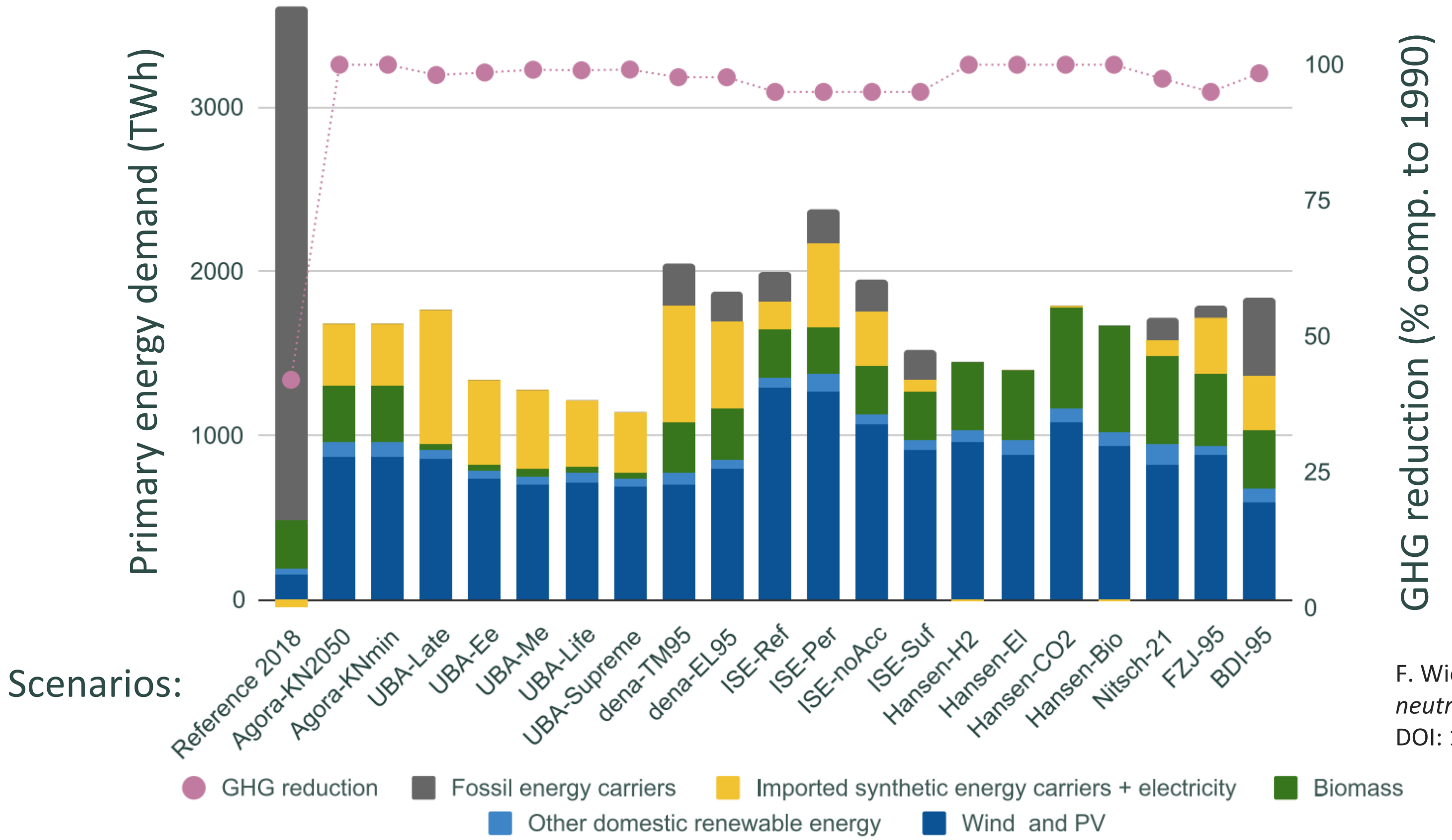
Jannik Neumann

TECHNISCHE UNIVERSITÄT DARMSTADT

Clean Circles



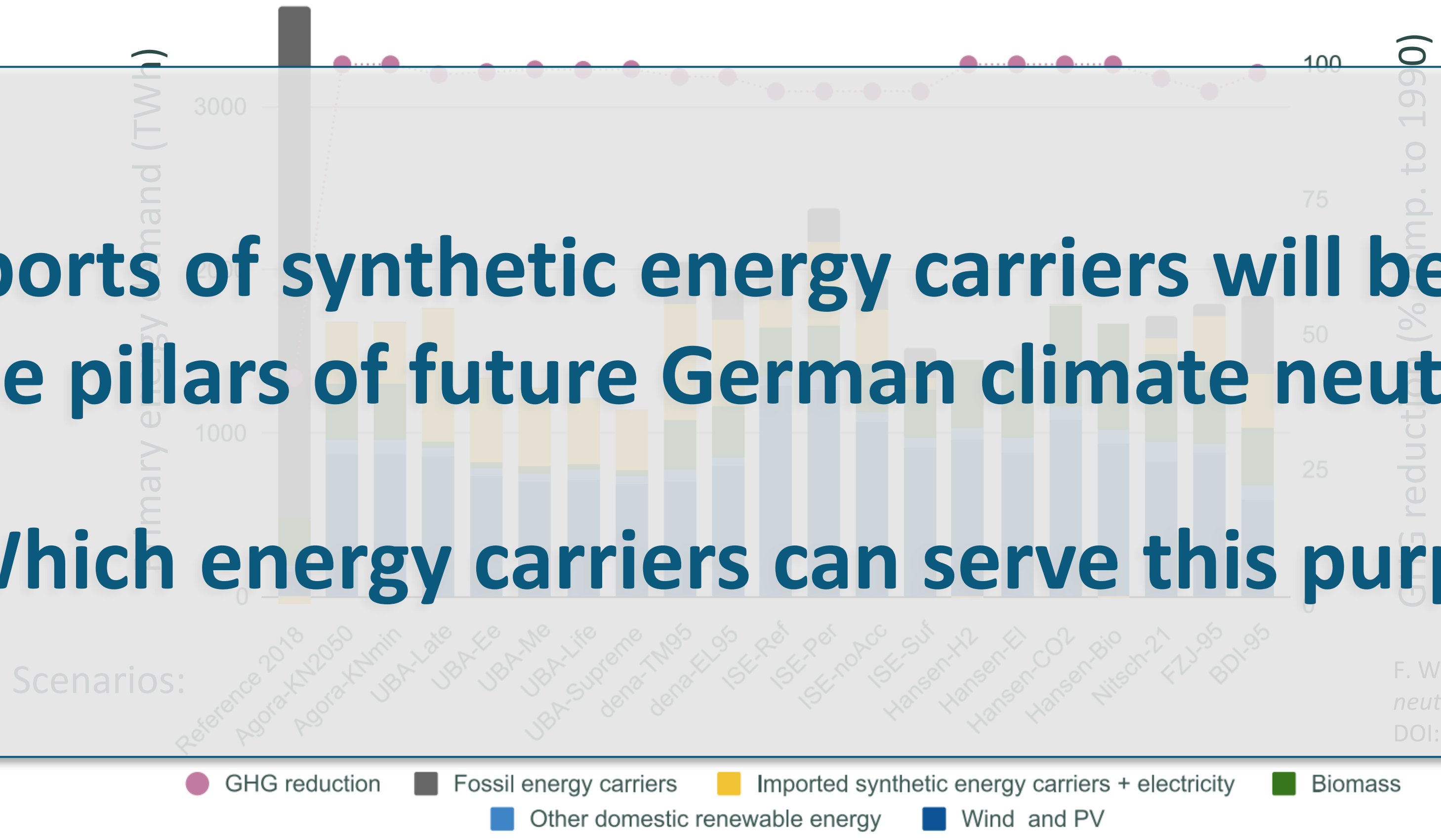
Motivation
The Need for Energy Imports – A German Perspective



F. Wiese et al.: *Strategies for climate neutrality* (2022).
DOI: 10.1016/j.rset.2021.100015.

Motivation

The Need for Energy Imports – A German Perspective

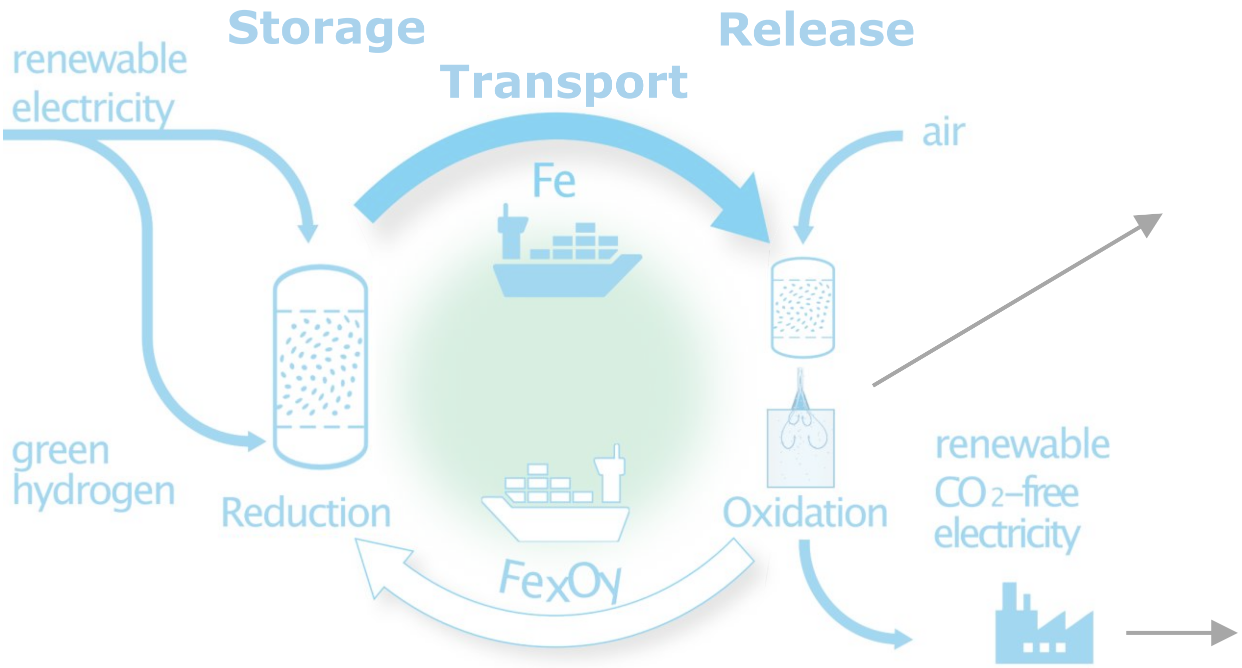


Imports of synthetic energy carriers will be one of the pillars of future German climate neutrality!

Which energy carriers can serve this purpose?

F. Wiese et al.: *Strategies for climate neutrality* (2022).
DOI: 10.1016/j.rset.2021.100015.

Iron-based Energy Cycle



$$Fe_2O_3 + 3\ H_2 \rightarrow 2\ Fe + 3\ H_2O$$

$$2\ Fe + 1{,}5\ O_2 \rightarrow Fe_2O_3$$

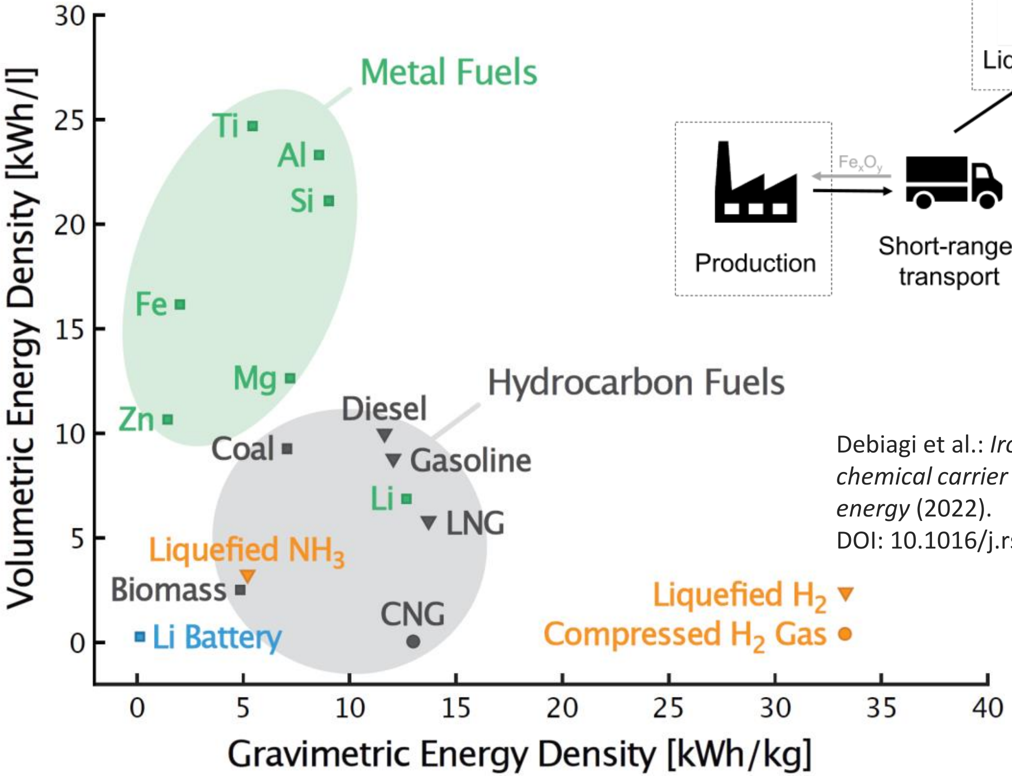
Iron combustion
Particle size ~20µm

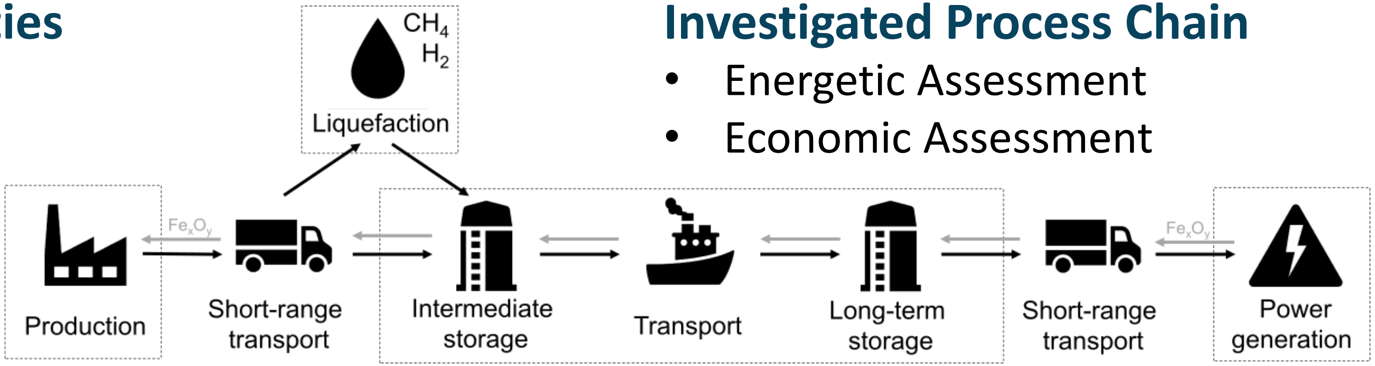
Retrofitting existing coal power plants

Techno-Economic Assessment

TECHNISCHE UNIVERSITÄT DARMSTADT

Energy Densities





Debiagi et al.: *Iron as a sustainable chemical carrier of renewable energy* (2022).
DOI: 10.1016/j.rser.2022.112579.

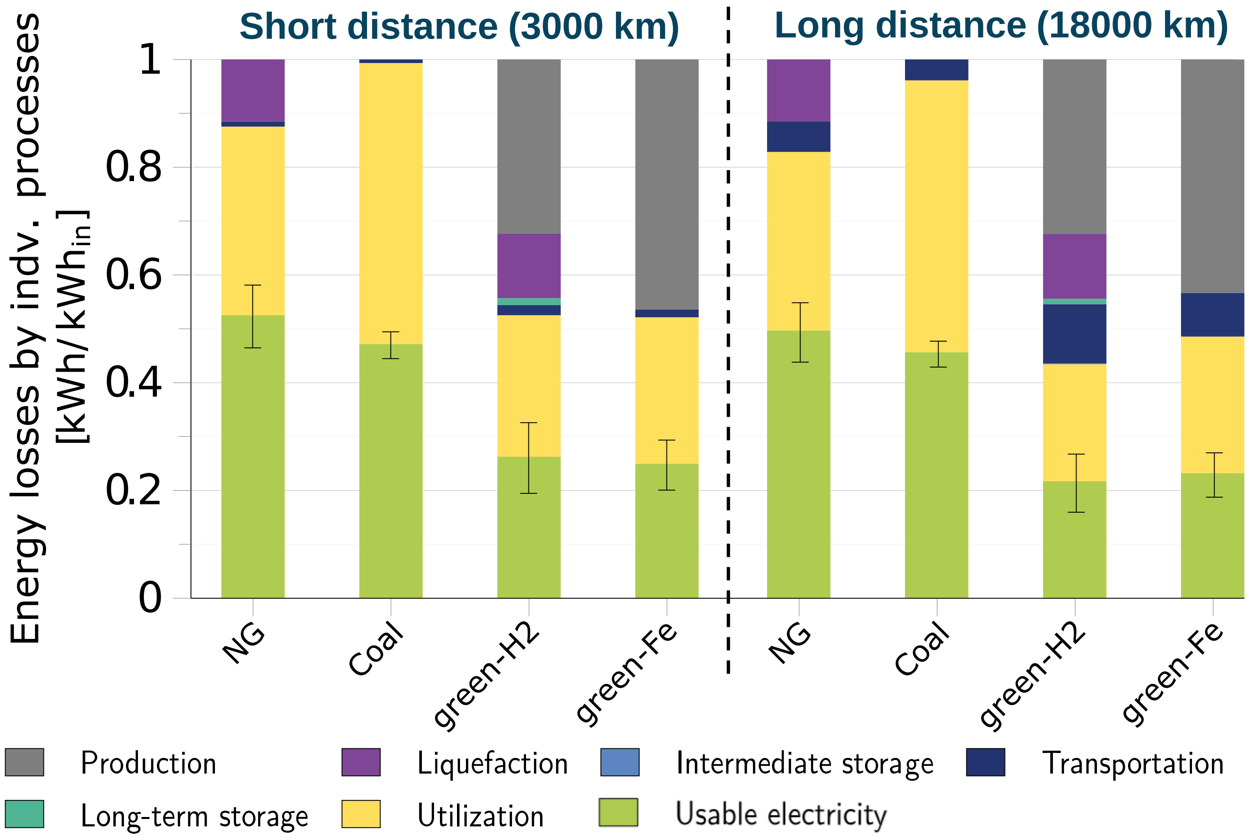
Investigated Process Chain

- Energetic Assessment
- Economic Assessment

Evaluated Energy Carriers

- Fossil Energy Carriers
  - Coal
  - (Liquified) Natural Gas
- Green Energy Carriers
  - Iron
  - (Liquified) Hydrogen

Techno-Economic Assessment
Energetic Assessment



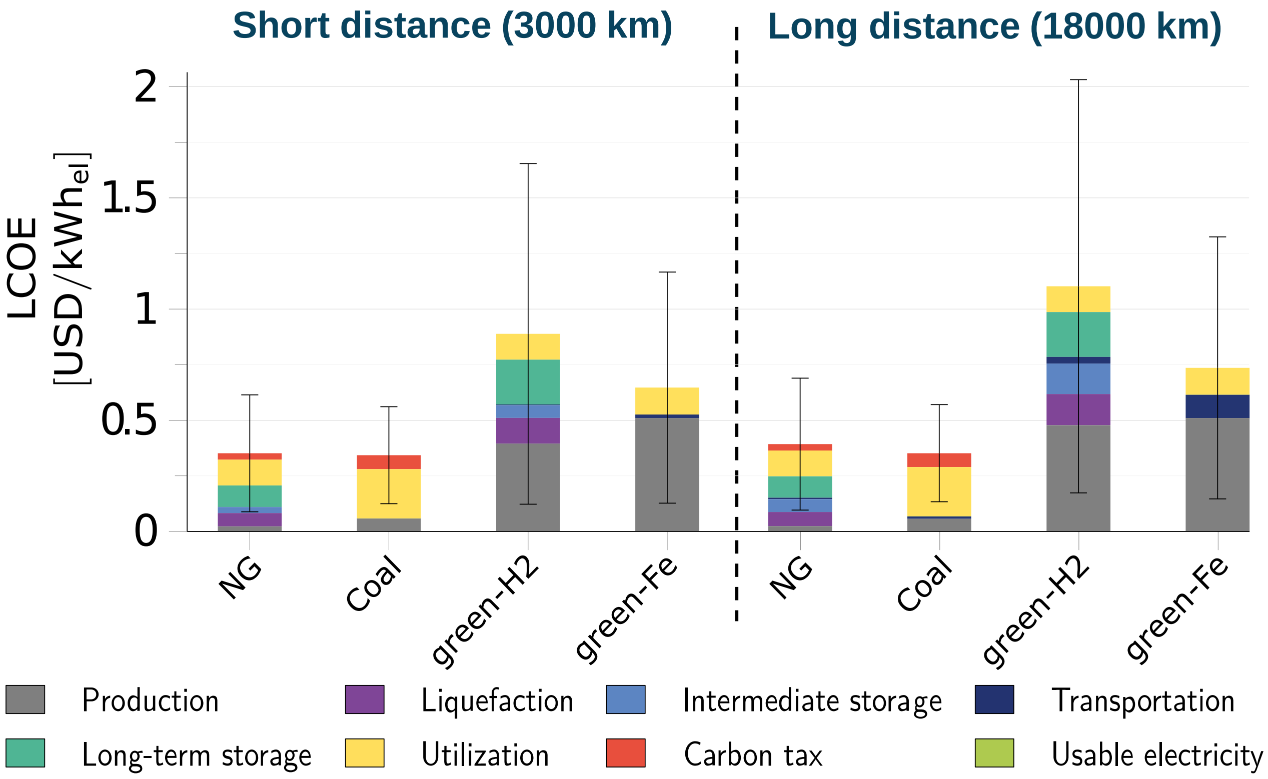
Conclusions

- Iron as an energy carrier shows competitive energetic efficiencies compared to hydrogen
- Higher energy demand for production is (over)compensated by favorable transport and storage characteristics

Neumann et al.: *Techno-economic assessment of long-distance supply chains of energy carriers* (2023).
DOI: 10.1016/j.jaecs.2023.100128.

Techno-Economic Assessment
Economic Assessment

TECHNISCHE UNIVERSITÄT DARMSTADT



Conclusions

- **Economic evaluation demonstrates advantages of iron over hydrogen**
- **Higher production costs are overcompensated by favorable storage, transport, and retrofit potential**

Neumann et al.: *Techno-economic assessment of long-distance supply chains of energy carriers* (2023). DOI: 10.1016/j.jaecs.2023.100128.

Conclusion and Outlook

Conclusion

- Crucial role of storage and transport of renewable energy for the energy transition
- Iron as an energy carrier:
  - Demonstrating competitive energetic efficiencies
  - Economic advantages over hydrogen

> Potential to play a significant role in the transition to a more sustainable, reliable energy future

Outlook

- Comprehensive assessments using exergy analyses
- Integration of ecological factors and considerations