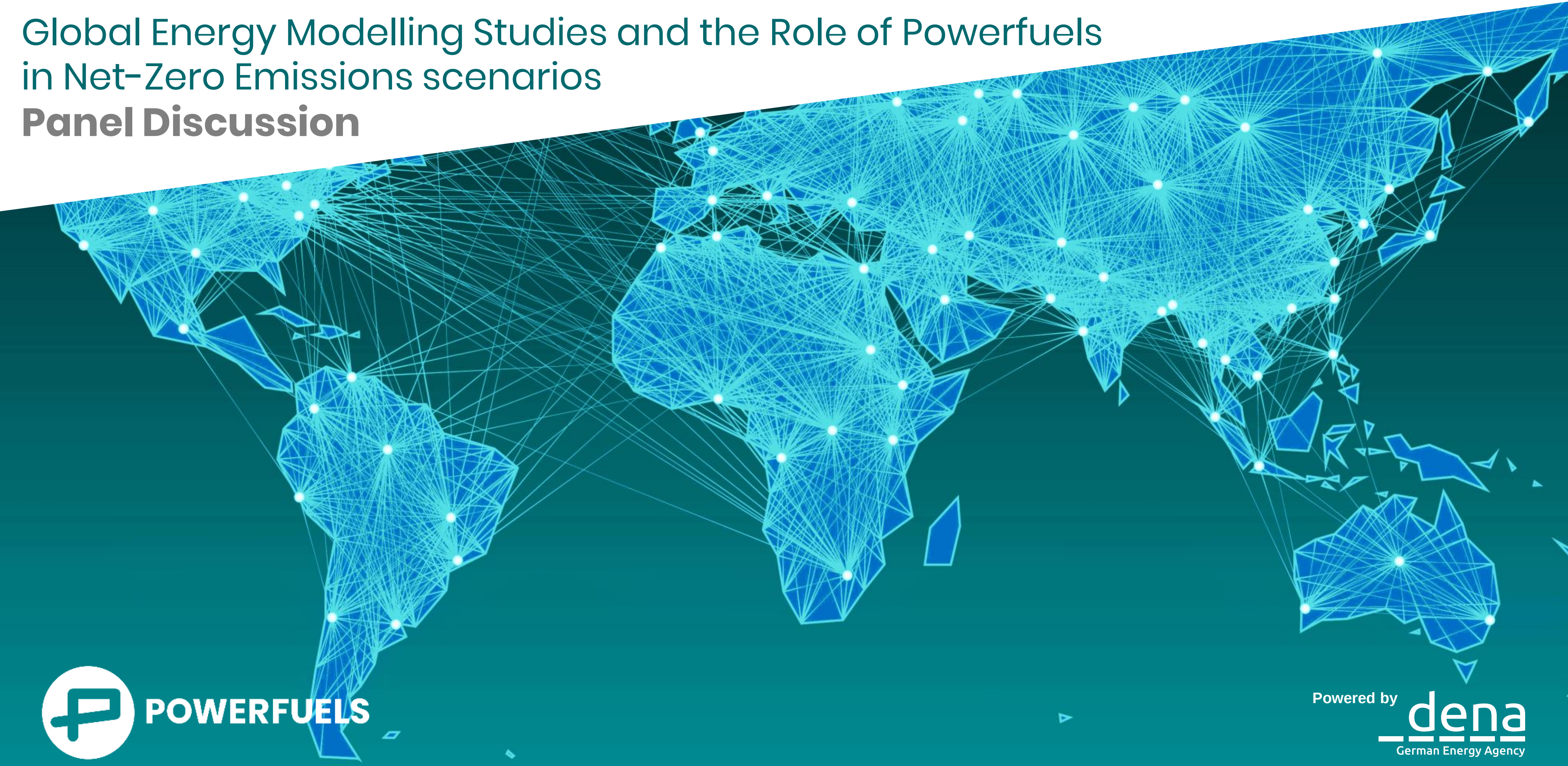
GLOBAL ALLIANCE POWERFUELS

Global Energy Modelling Studies and the Role of Powerfuels in Net-Zero Emissions scenarios

Panel Discussion



POWERFUELS

Powered by dena

German Energy Agency

AGENDA

1. **Introduction: Powerfuels in net-zero emissions (NZE) 2050 scenarios**

2. **Session 1: Assumptions and results of NZE scenarios**

3. **Session 2: Implications for global policymaking and transition pathways**

4. **Q&A and discussion**

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CEO,
German Energy Agency (dena)

Kilian Crone
Team Lead,
Global Alliance Powerfuels

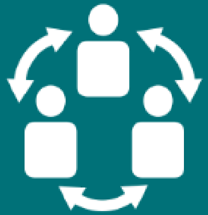
Matteo Micheli
Expert,
Global Alliance Powerfuels

Friederike Altgelt
Expert,
Global Alliance Powerfuels

Global Alliance Powerfuels – What we do

Advocacy & Communication

Raise awareness and acceptance of powerfuels as missing link to reaching global climate targets



Policy & Regulation

Support the enhancement of regulatory frameworks with a focus on Europe as demand region

Global Project Development

Stimulate project development to globally enable production capacities

Our global network

Our members

- Audi
- bp
- Deutsche Post DHL Group
- ENERTRAG – Eine Energie voraus
- ExxonMobil
- iwo – Institut für Wärme und Oeltechnik
- Lufthansa
- MEW – Mittelständische Energiewirtschaft Deutschland e.V.
- MWV – Mineralölwirtschaftsverband e.V.
- Mitsubishi International GmbH
- Shell
- Paul Wurth – SMS group
- Schaeffler
- sunfire
- uniper
- UNITI Bundesverband mittelständischer Mineralölunternehmen e.V.

Our partners

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- CO_2 Value Europe
- DECHEMA – Gesellschaft für Chemische Technik und Biotechnologie e.V.
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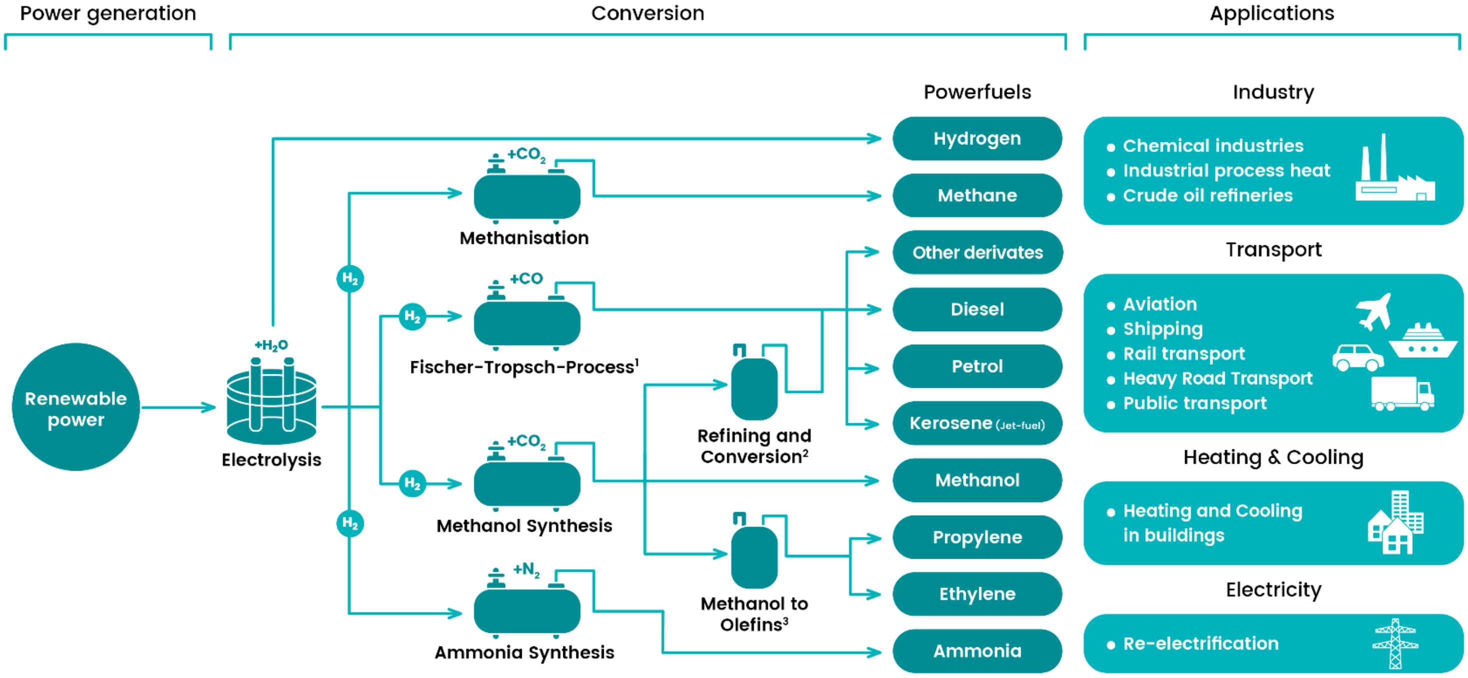
- LUT University
- CSIR
- House of Energy
- energy saxony
- Empa – Materials Science and Technology
- Skolkovo
- Sunrise
- IRESEN
- Fuel Cells and Hydrogen Joint Undertaking
- DTU
- Hydrogen Valley
- ENFRWC – Egyptian Network For Renewables and Water Cycle
- EnergieAgentur.NRW

What are powerfuels?



1 Includes: Fischer-Tropsch synthesis, hydrocracking, isomerization and distillation.

2 Includes: DME/OME synthesis, olefin synthesis, oligomerisation and hydrotrating.

3 Methanol-to-olefins process.

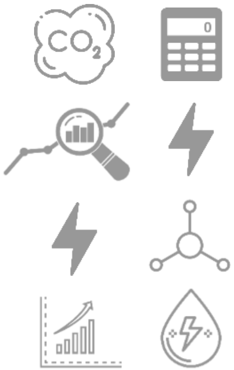
Introduction

Powerfuels in net-zero emissions 2050 scenarios

Andreas Kuhlmann
CEO,
German Energy Agency
(dena)

Prof. Christian Breyer
Professor of Solar
Economy,
LUT University

Most critical assumptions for the validity of NZE scenarios – according to the current state of research



- **Setting: Carbon-neutral** global energy system in **2050**
- **Energy demand** develops following **IEA's World Energy Outlook 2020** (Stated Policies Scenario)
- **Electrification of all sectors**, as far as **technically possible** and **cost-effective**
  - 45% of final energy demand = renewable electricity
  - 90% of primary energy = renewable electricity
- **All main powerfuels contribute** to meeting the demand (all renewable electricity (RE)-based):
  - **RE-SNG**
  - **RE-FT-Fuels**
  - **RE-Hydrogen**
  - **RE-Ammonia**
  - **RE-Methanol**

Most critical assumptions for the validity of NZE scenarios – according to the current state of research

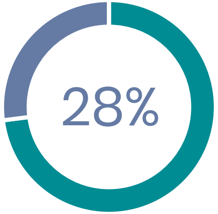
- **Some industrial processes** and specific energy uses can **only** become **carbon-neutral** by the use of **powerfuels**
- **Powerfuels** contribute to meeting the demand **both** as **energy carriers and feedstocks** (e.g., the chemical sector!)
- The use of **biofuels** other than waste, residues and by-products is **limited at 2020 levels** due to sustainability constraints
- **Technology cost reductions**:

CAPEX of main cost drivers			
Cost drivers	Unit	2020	2050
PV	[€/kW]	432 – 475	166 – 183
Wind onshore	[€/kW]	1150	900
DAC	[€/tCO2a]	730	195
Electrolyser	[€/kW]	550	< 200

Powerfuels and DAC play an important role in a carbon neutral global energy system

43,200 TWh

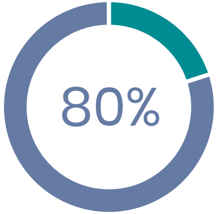
Final energy demand covered by powerfuels in 2050



of global final energy consumption 2050

6,000 Mt

CO_2 demand for powerfuels production in 2050



of which is supplied by DAC, 20% from point sources

18,000 b€

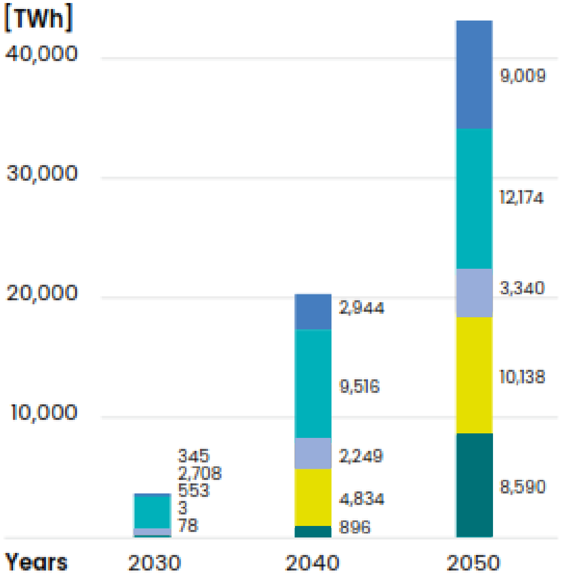
Investments required until 2050

Close to the cost of sustaining oil and natural gas demand at current levels in same timeframe.
upstream capital expenditures = approx. 17,500 b€

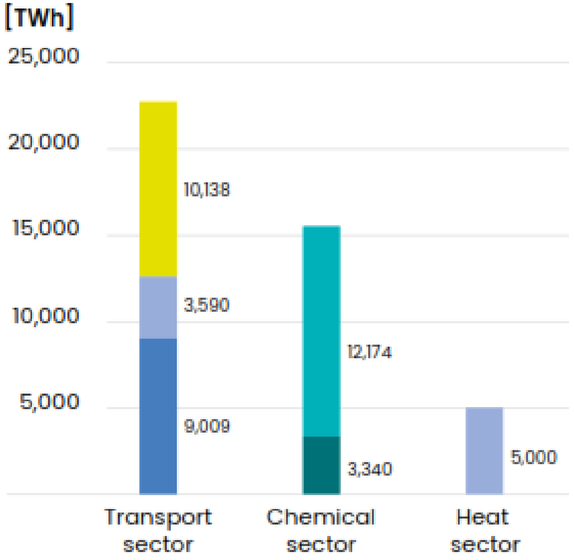
All types of powerfuels play a dominant role 2030 to 2050

With different shares in different sectors

Global powerfuels demand by year



Global powerfuels demand by sector in 2050



Legend

- SNG
- FT-fuels*
- Hydrogen
- RE-Ammonia
- RE-Methanol

Transport sector 2050	23,000 TWh
Chemical sector 2050	15,500 TWh
Heat sector 2050	5,000 TWh

*Fischer-Tropsch fuels: e-Diesel, e-Petrol, e-Kerosene and mainly e-Naphtha

Session 1
Reviewing assumptions and results of NZE scenarios

Dr. Dolf Gielen,
Director Innovation
and Technology,
IRENA

Dr. Falko Ueckerdt,
Head, National Energy
Transitions Team,
PIK

Dr. Onur Özgün,
Lead Modeller of Energy
Transition Outlook,
DNV

Prof. Christian Breyer,
Professor of Solar
Economy,
LUT University

Topics of Discussion

Electrification Rate

PtX Products

Carbon Capture Technologies

Biofuels

Scaling-Up

Cost Assumptions

IRENA
International Renewable Energy Agency

Modeling of Powerfuels
Critical assumptions

Dolf Gielen
Director, Innovation and Technology

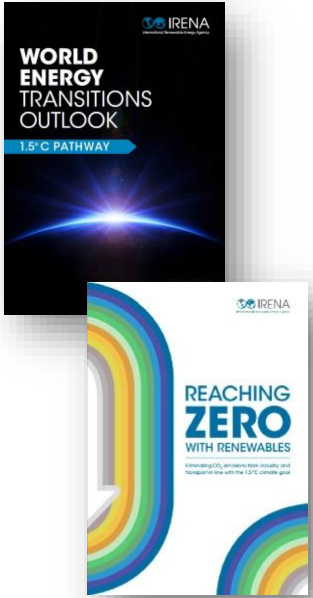
Global Alliance Powerfuels
23 March 2021

Recent relevant IRENA work

- **World Energy Transitions Outlook** (released 16 March)
  - 1.5 C scenario – net zero 2050
  - 613 Mt hydrogen in 2050 (74 EJ) – a 5-fold increase – 2/3 green 1/3 blue
    - Ammonia for shipping, mainly biofuels for aviation, electrification road transport, methanol as building block for chemicals
  - 21 000 TWh electricity is used for production of hydrogen

- **Reaching Zero with Renewables** (released September 2020, in cooperation with International Methanol Institute)
  - Outlook for hard to decarbonise industry & transport sectors incl synfuels and synthetic feedstock Innovation Outlook Renewable Methanol, five-fold demand growth
- **Innovation outlook Green Ammonia** (ongoing, with Ammonia Energy Association)
  - Three-fold demand growth

- **Biojet technology brief** (ongoing)
- **Electrification trucks event** (October 2020)
- **Greening petrochemicals** (background analysis – ongoing)



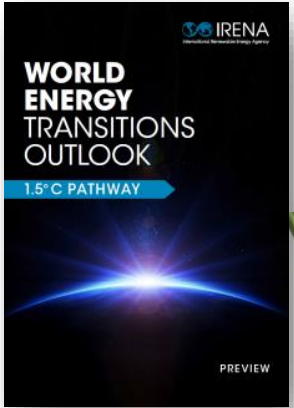
Key assumptions

IRENA
International Renewable Energy Agency

- **Transition is driven by 1.5C/net zero objectives**
- **Demand growth** – IEA SPS is not a good reference for a 1.5C scenario, too high
- **Assumptions for competing options are key** (direct electrification, biofuels)
- **No hydrogen for heating ?**
- **Carbon source for methanol in a fossil fuel free world ?**

IRENA

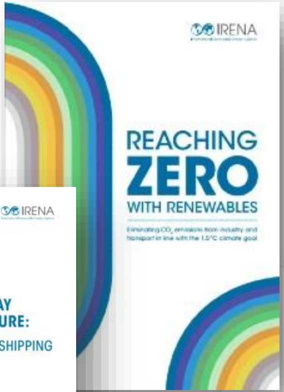
International Renewable Energy Agency

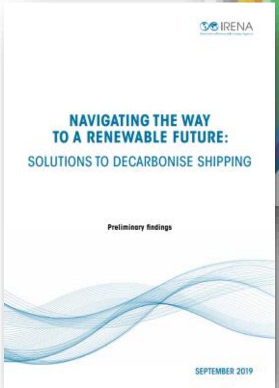


March 2021

January 2021

Thanks for your attention!





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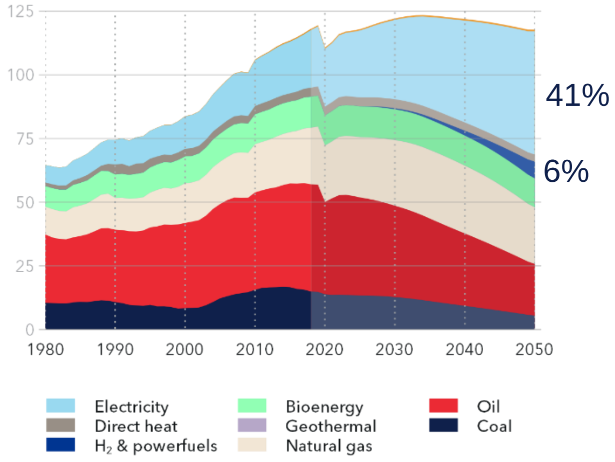
How does DNV’s Energy Transition Outlook see powerfuels?

- Not a carbon-neutral scenario
- Most likely future: ~2.3°C warming
- Total energy demand < IEA SDS

World final energy demand by carrier

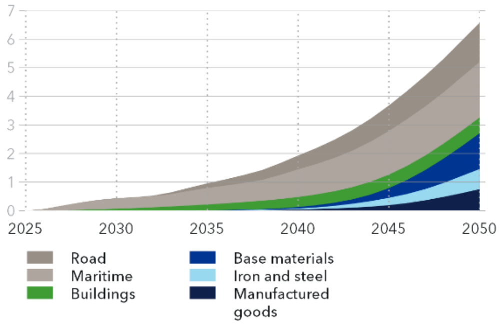
Units: thousand TWh/yr



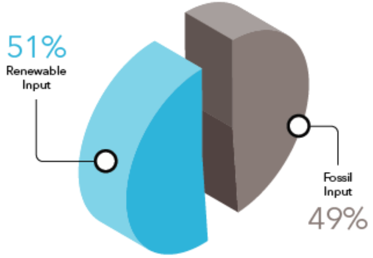
Historical data source: IEA WEB (2019)

World hydrogen & powerfuels demand as energy carrier

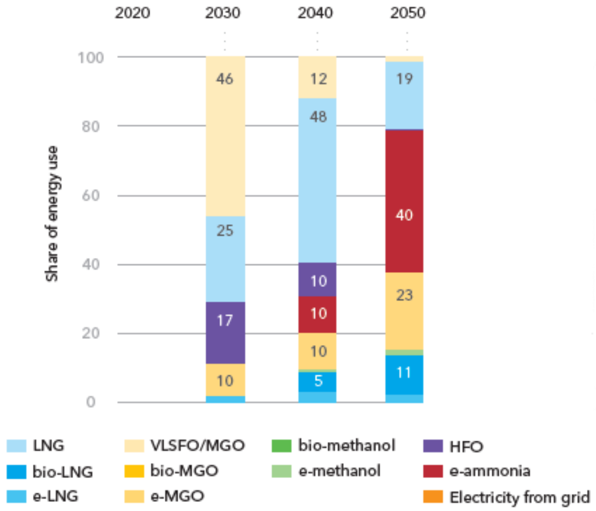
Units: thousand TWh



Hydrogen production split in 2050



Maritime fuel mix consistent with IMO targets

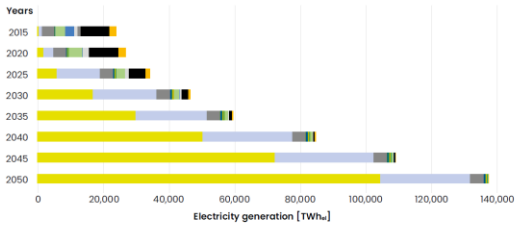


MF, mono fuel; DF, dual fuel; ICE, internal combustion engine; FC, fuel cell; EM, electric motor; HFO, heavy fuel oil; VLSFO, very low sulfur fuel oil; MGO, marine gas oil; LNG, liquefied natural gas; LPG, liquefied petroleum gas

DNV

On discussion points

- **Cost Assumptions:**
- Wind, electrolyser costs: reasonable
- 2020 PV cost: €432-475 seems too low (cheapest countries €600, average: ~€850)
- PV cost reduction: 2/3 reduction with 60x growth (11% learning rate) reasonable
- 2020 PV electricity supply = 2 x actual
- 2050 power mix:
  76% solar, 20% wind, 3% hydro, 1% others



- **Electrification rate:**
  - 38% electricity in transport: low for a net-zero?
  - Share of EV in fleet?
- How electrolysis is competitive against SMR with electricity coming from mostly solar?
- What happens to electricity price?
  - How electricity stays competitive?
  - How solar PV recovers costs?

- **Scaling-up:**
- Required investments: 18 trn € only includes powerfuel capex
- What would be the total cost of the carbon-neutral energy system?
- Are there any balancing feedback loops that will prevent mutual relationship between solar PV and powerfuels?

PIK

Potsdam Institute for Climate Impact Research

Leibniz Association

Dena/LUT - Powerfuels in NZE scenarios

Dr. Falko Ueckerdt

Head, National Energy Transitions Team
Potsdam Institute for Climate Impact Research

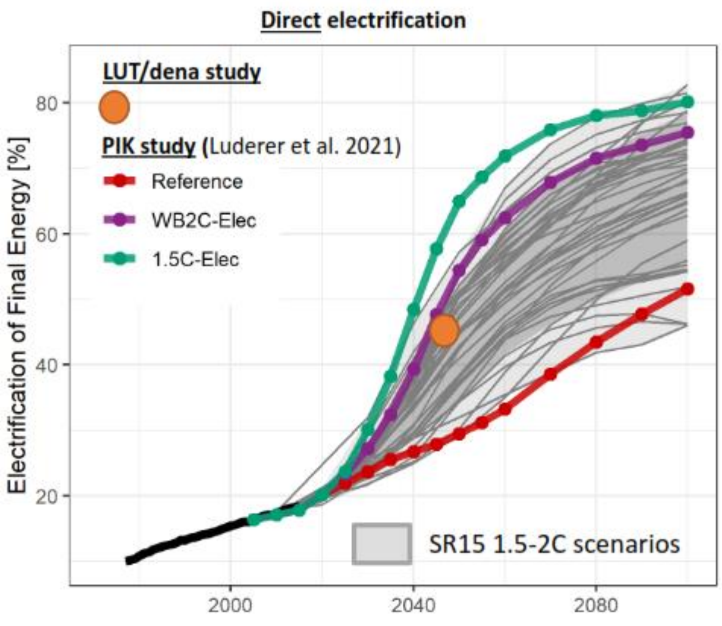
Based on:
"Potential and risks of hydrogen-based e-fuels in climate change mitigation",
Falko Ueckerdt, Christian Bauer, Alois Dirnaichner, Jordan Everall, Romain Sacchi, Gunnar Luderer (Nature Climate Change, accepted)

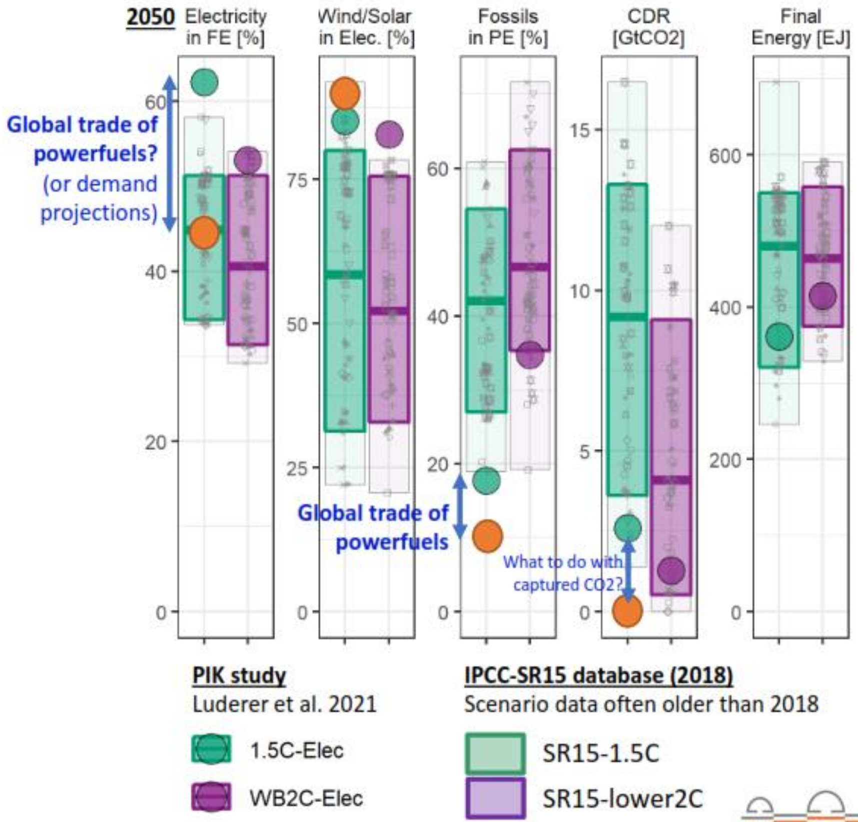
and

Luderer et al. 2021 (*Nature Energy*, in review)
„Accelerated electrification based on cheap renewables facilitates reaching Paris Climate targets"

LUT/dena and PIK explore „empty corners“ in the IPCC-SR15 2018 scenario database

IAM-scenarios with i) very-high renewables + ii) high electrification + iii) little/no CDR (BECCS) have been rare until recently





Luderer et al. 2021 (*Nature Energy*, in review)
Accelerated electrification based on cheap renewables facilitates reaching Paris Climate targets

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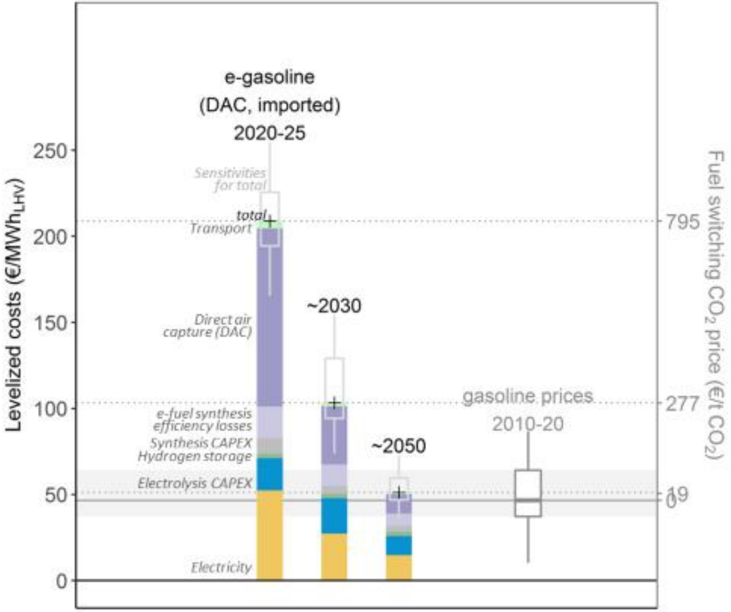
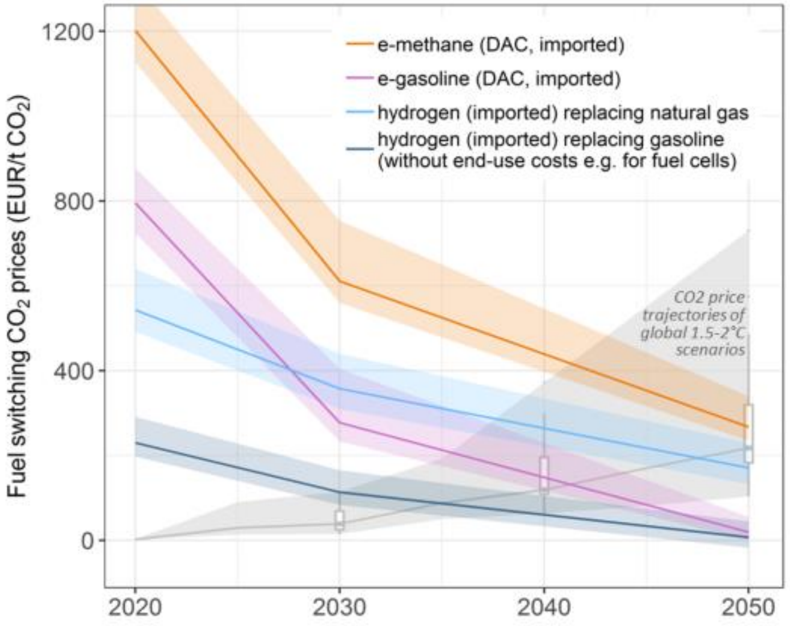
Unprecedented e-fuel scaling requires massive and continous policy support.

PIK cost estimates are similar to dena/LUT study.
Cost reductions rely on massive scaling.



Competitiveness with fossil fuels ~2030/40.
Massive policy support would be required until then.



Ueckerdt et al. 2021 (*Nature Climate Change*, accepted)
Potential and risks of hydrogen-based e-fuels in climate change mitigation

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Topics of Discussion

- Electrification Rate
- PtX Products
- Carbon Capture Technologies
- Biofuels
- Scaling-Up
- Cost Assumptions

Session 2
Implications for global policymaking and transition pathways

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Q&A and discussion

Thank you for your attention

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