Renewable Energy – Potentials and Implications for Mobility

Gordon Witham

Institute for Automotive Engineering (ika)
RWTH Aachen University

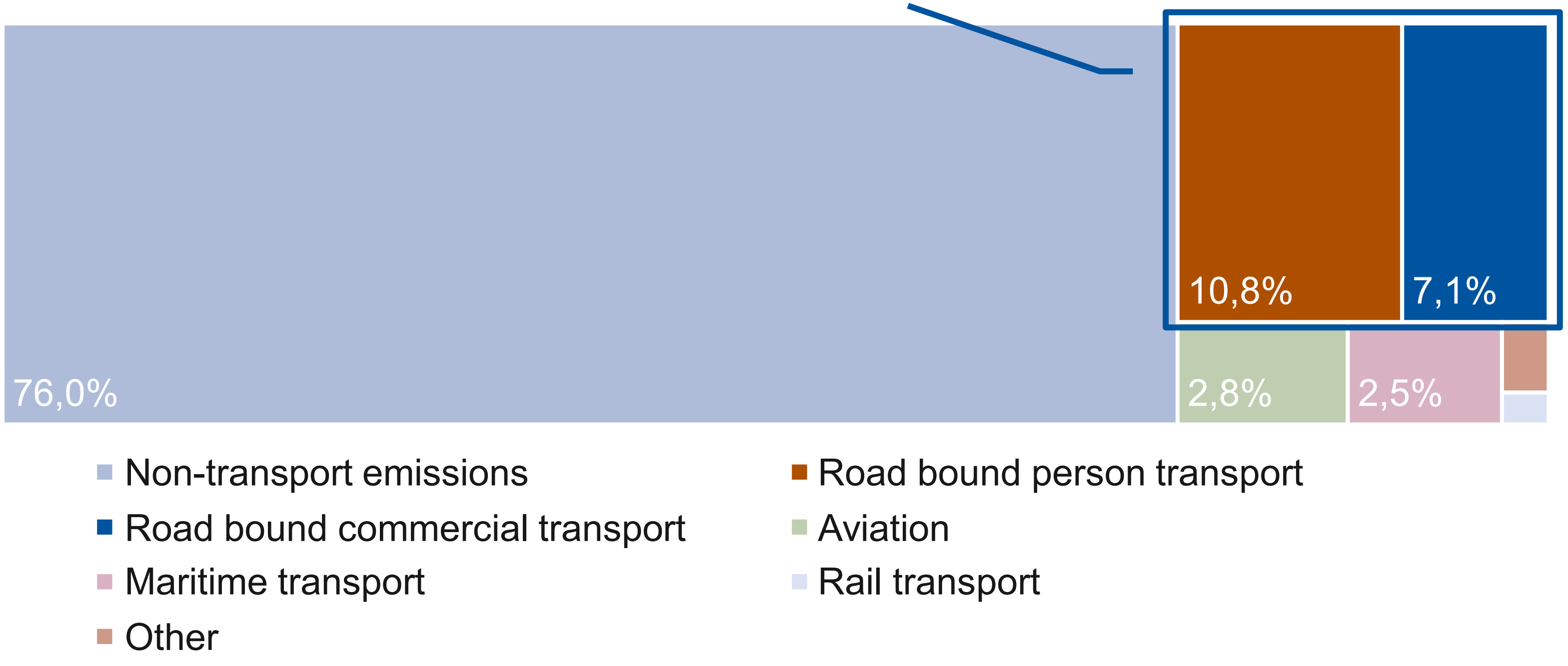
Eco-Mobility Conference
Vienna, 14. November 2025

Renewable Energy – Potentials and Implications for Mobility

Motivation

Emissions in transportation

Road bound mobility causes approx. 18 % of global CO_2 emissions

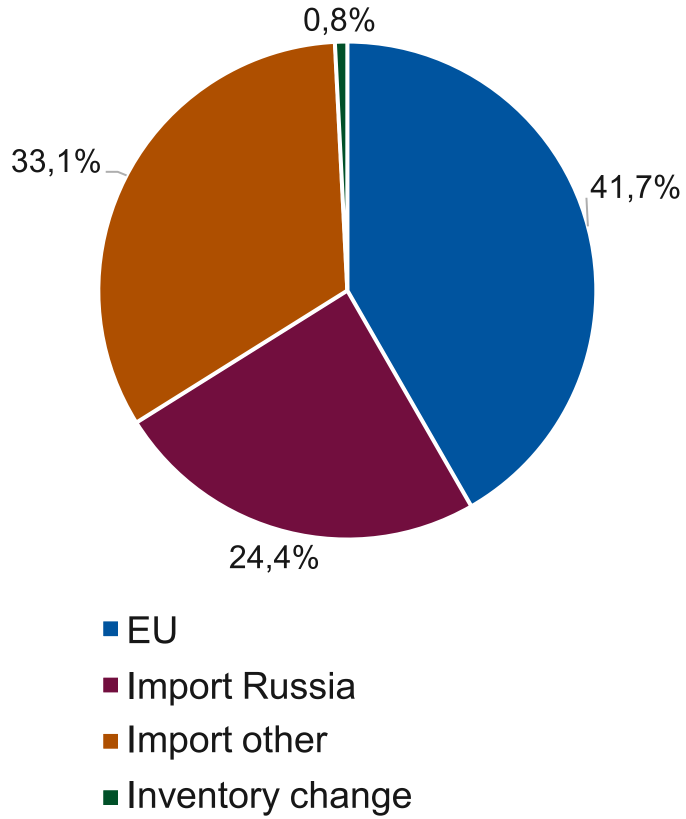


Questions:

- ➢ What is the potential for energy production from renewable sources in the EU?
- ➢ How can mobility contribute to the increased use of renewable energies?

Primary energy

- Primary energy demand in EU: 15.000 TWh (2020)

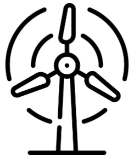


[RIT20], [EUC23a]

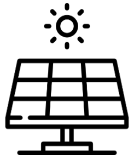
Renewable Energy – Potentials and Implications for Mobility
Energy Conversion

Energy sources

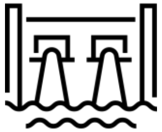
- Wind energy



- Solar energy

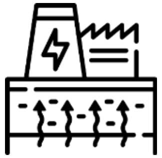


- Hydro- & tidal energy



- Biomass

- Geothermal energy



- Other discussed options:
  - Nuclear (fission & fusion)
  - Fossil energy carriers with *Carbon Capture and Storage* or *Carbon Capture and Usage*

Variable power

- Availability and utilization of power plants via capacity factor *k*

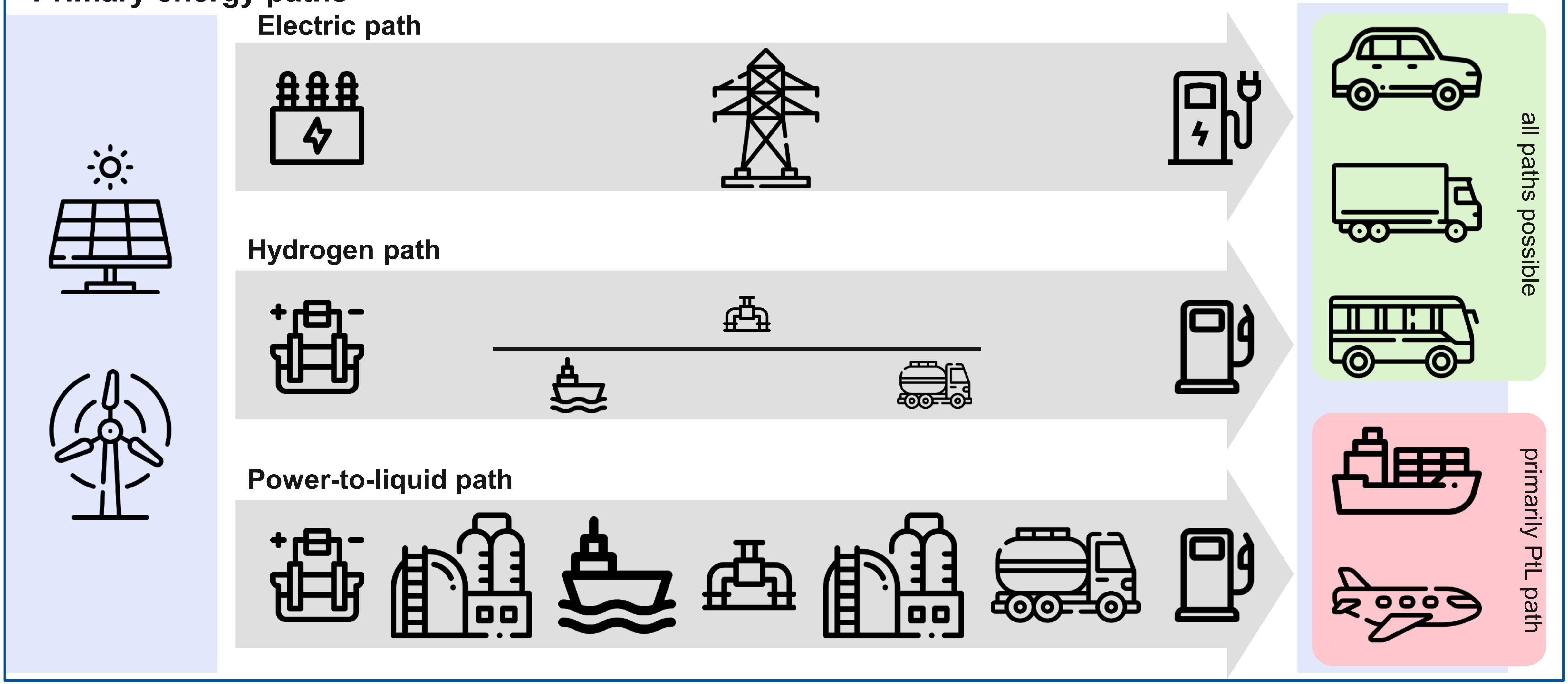
$$k = \frac{Energy\ supply}{Rated\ power \cdot Time}$$

- Influences
  - Environmental
  - Maintenance and servicing
  - Electricity demand

Energy carrier	Capacity factor
Nuclear	50 – 92 %
Coal	39 – 67 %
Gas	16 – 60 %
Wind	19 – 41 %
Photovoltaics	10 – 20 %

[EIA24], [GOV23], [BDE22]

Primary energy paths



[EFU23], [HIM24], [DAH21], [STA18], [BON18], [LES20], [KOR21], [GRA21], [BAK23], [PIS23], [TOR24]

Renewable Energy – Potentials and Implications for Mobility

What is possible in Europe?

Energetic Potential

- **ENSPRESO dataset**
  - Study examining the technical potential for generation of renewable electricity under regulatory constraints in the EU (+ UK)
    - 3 scenarios (low, medium, high) considering technical advancements and regulatory changes
  - ➢ Conclusion: Most conservative assumption provides sufficient electricity to meet today's primary energy demand.

But ENSPRESO only addresses annual energetic potential, not availability of power.

Power Potential

- **Model Development**
  - Installed capacities based on ENSPRESO scenarios low and medium
  - Resolution of installed capacities on national levels
  - Usage of capacity factors from C3 data service
  - Usage of electricity demand from eurostat (as reference)

Model to determine seasonal and daily average availabilities of renewable electricity.

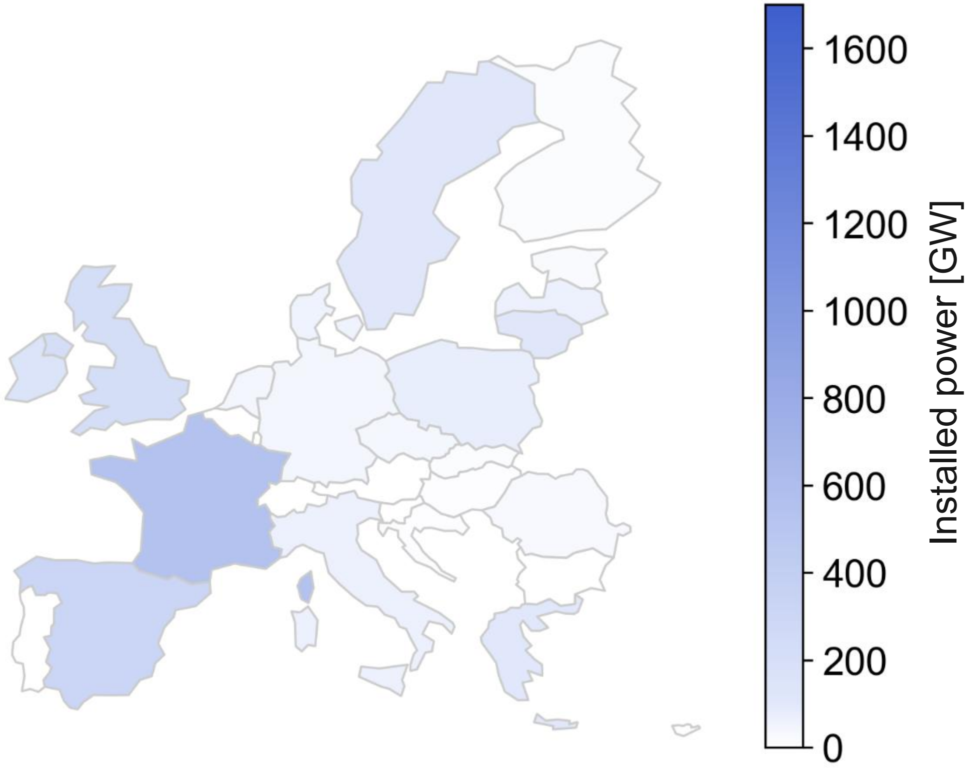
[JRC21], [C3S21]

Energy Potentials – Wind

Assumptions

- **Available areas and choice of locations**
  - **onshore**
    - Current national distance regulations
    - Inclination < 2.1°
  - **offshore**
    - Distance to coast > 22 km
    - Ocean depth 0-100 m
    - Distance to infrastructure > 3.7 km
  - **general**
    - Capacity factor *k* > 25 %
- **Power**
  - Power density: 5 MW/km²

Wind onshore



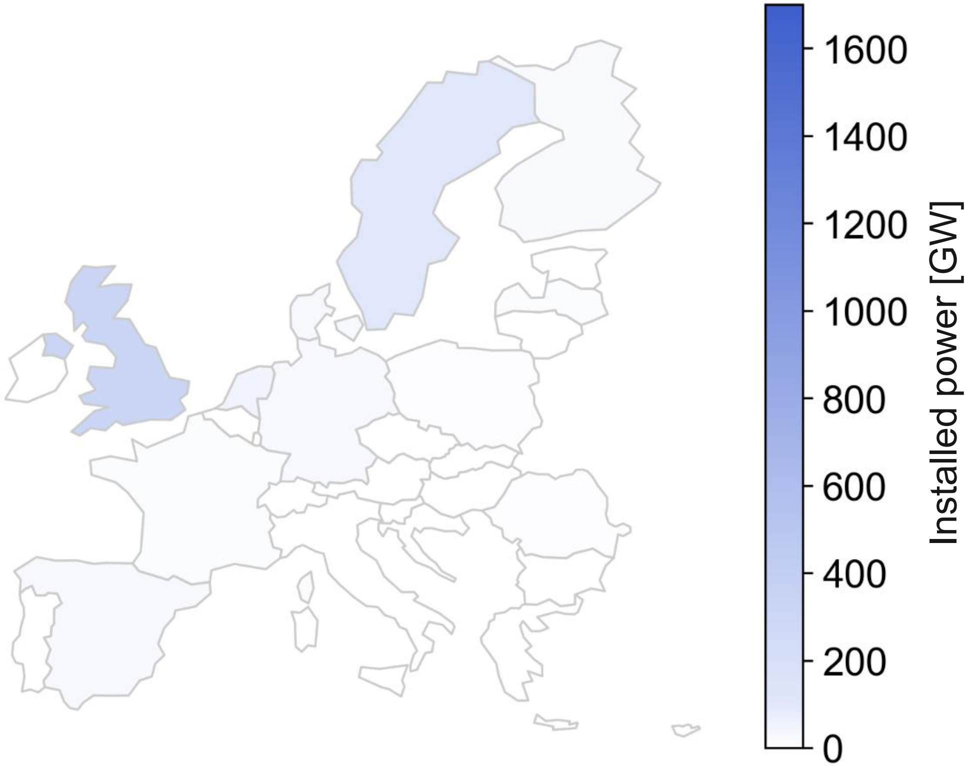
[DBA24]

Energy Potentials – Wind

Assumptions

- **Available areas and choice of locations**
  - **onshore**
    - Current national distance regulations
    - Inclination < 2.1°
  - **offshore**
    - Distance to coast > 22 km
    - Ocean depth 0-100 m
    - Distance to infrastructure > 3.7 km
  - **general**
    - Capacity factor k > 25 %
- **Power**
  - Power density: 5 MW/km²

Wind offshore



[DBA24]

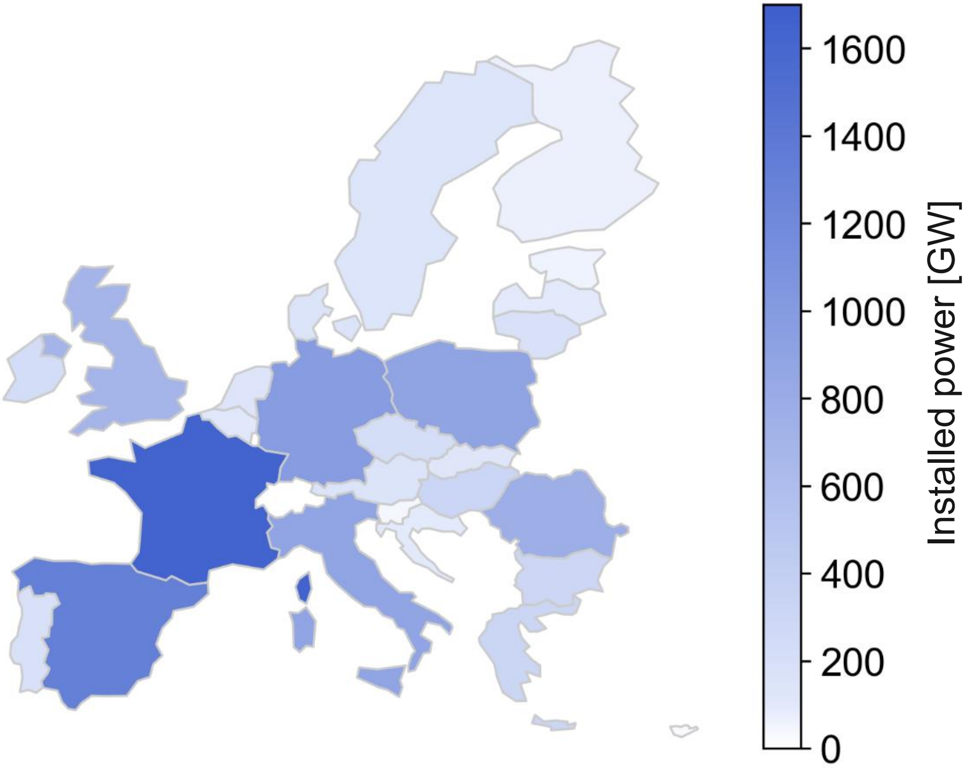
Renewable Energy – Potentials and Implications for Mobility

Energy Potentials – Solar

Assumptions

- **Available areas and choice of locations**
  - **Installation on buildings**
    - 50 % of available and suitable roof and facade areas
  - **Installation on open and agricultural areas**
    - Exclusion of protected areas, forests, etc.
    - 1.5 % of unused, cultivated and farmed land per nation
    - Inclination < 2.1°
- **Power**
  - Installation density: 5 MW/km²
  - Performance ratio: 75 %

Solar

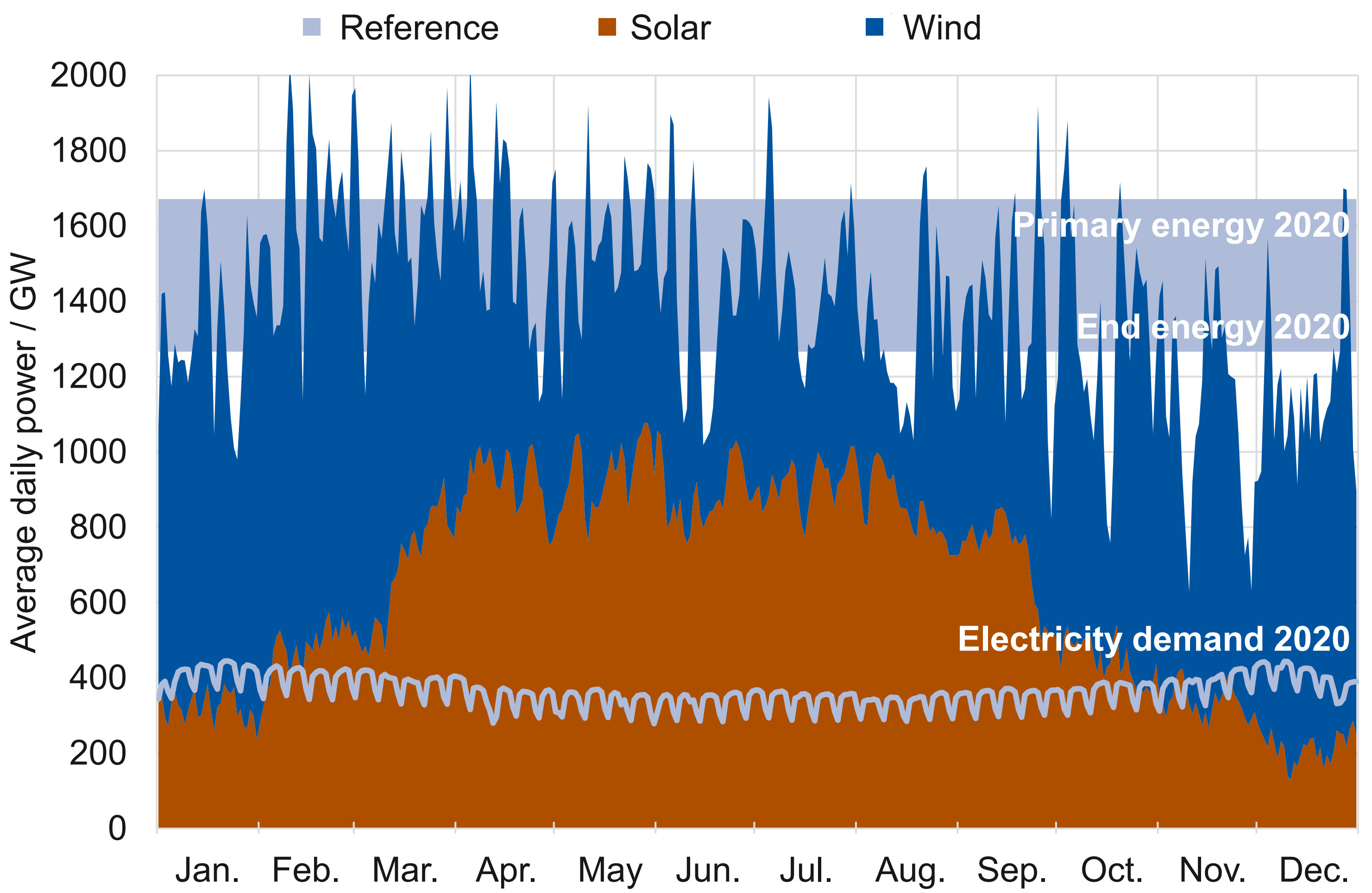


[DBA24]

Renewable Energy – Potentials and Implications for Mobility

Energy Potentials

Available electric power



Assumptions

- Current regulations are considered
- No technical advancements in efficiency and locations
- Construction of wind turbines only at locations with $k > 25$ %
- Construction of solar as on-roof installment and on 1.5 % of unused, cultivated and farmed land

Resulting peak power:

- Wind: 2,700 GW
- Solar: 5,000 GW

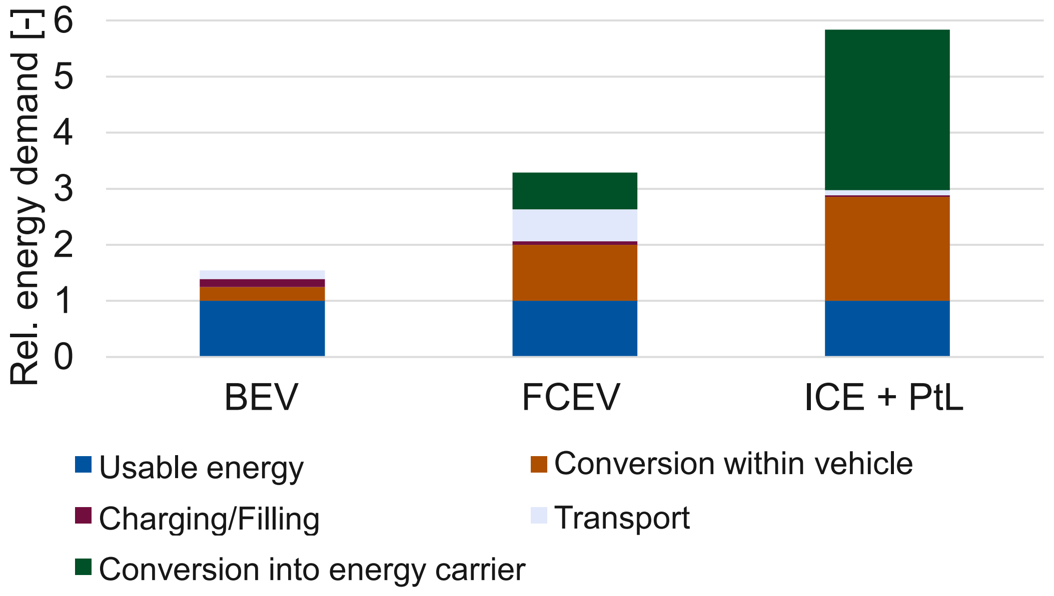
- Comparison with EU targets 2030:
  - Wind: 1,300 GW
  - Solar: 750 GW

[DBA24]

Renewable Energy – Potentials and Implications for Mobility

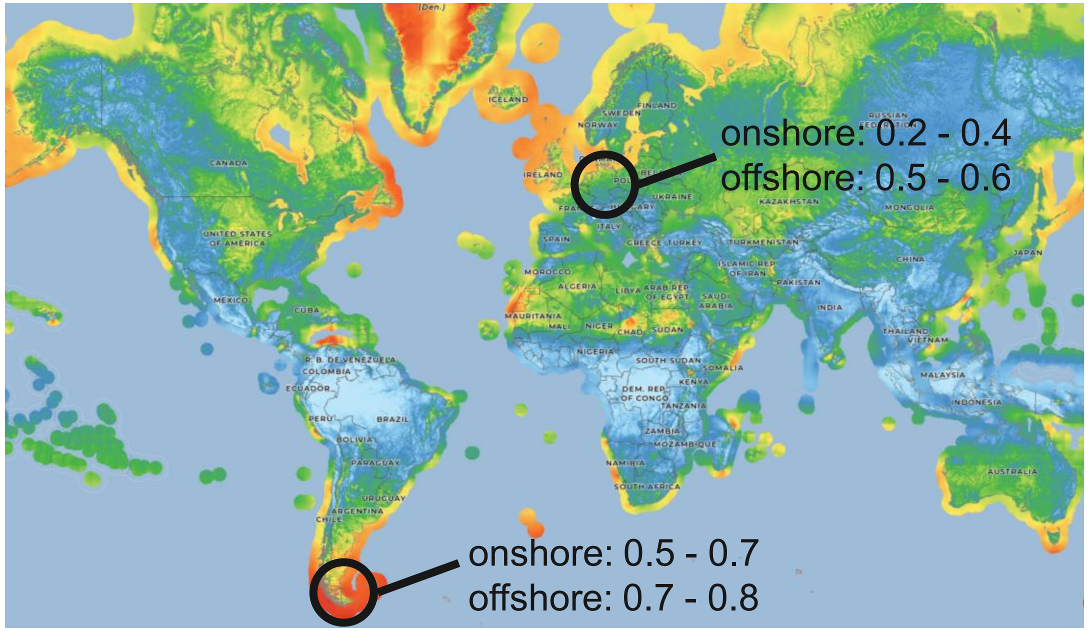
Power Demand

Primary energy demand



- Higher primary energy demand for hydrogen- and PtL-path, wide distribution in literature
  - Hydrogen: approx. factor 2 - 3
  - Power-to-Liquid: approx. factor 2.4 - 5

Global potential of wind



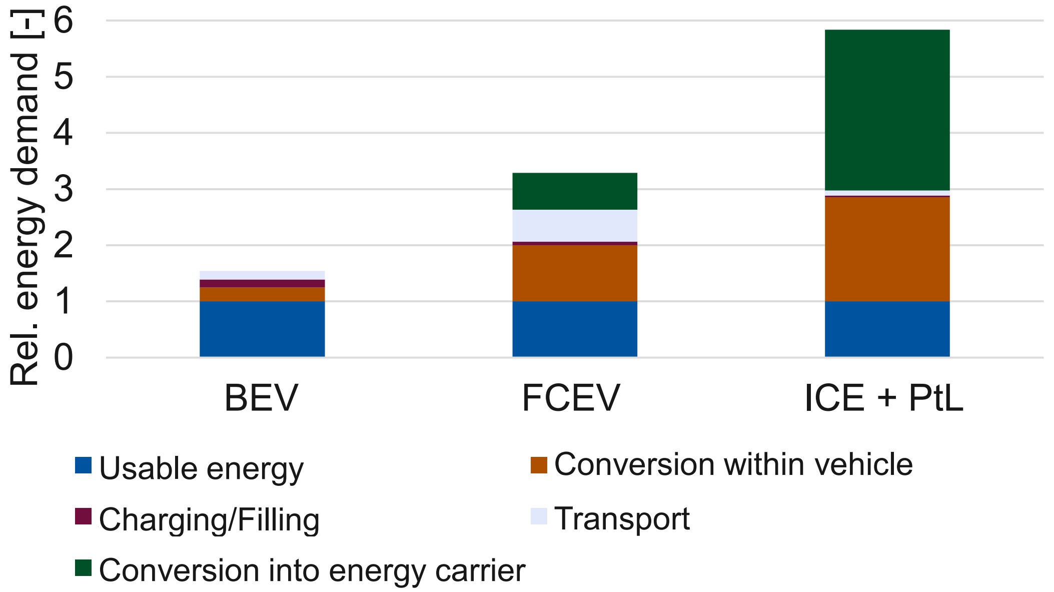
Capacity factors for wind turbines Class I

[EFU23], [SPE22], [ALE23], [PIS23], [GWA24]

Renewable Energy – Potentials and Implications for Mobility

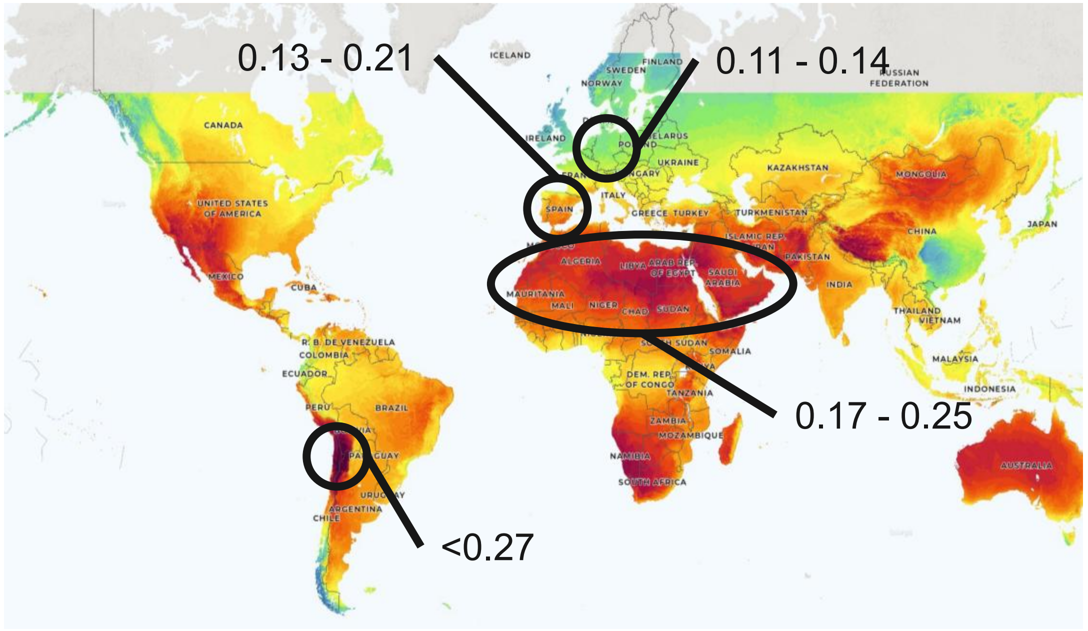
Power Demand

Primary energy demand



- Higher primary energy demand for hydrogen- and PtL-path, wide distribution in literature
  - Hydrogen: approx. factor 2 - 3
  - Power-to-Liquid: approx. factor 2.4 - 5

Global potential of solar



Capacity factors for solar, optimal positioning

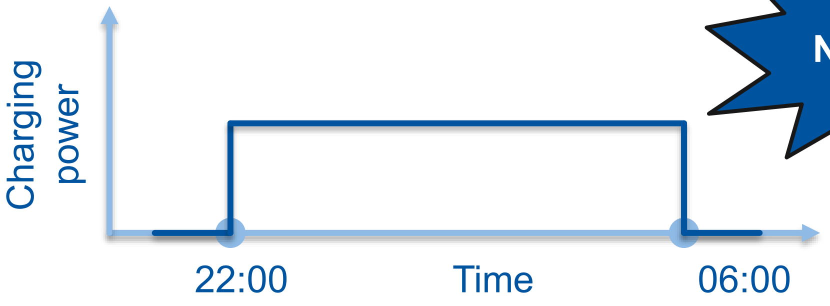
- ➢ Global potentials of renewable energies allow for approx. factor 2 at same installed power
- ➢ Well-to wheel efficiency can be compensated for fuel cell electric vehicles, but not for ICE with PtL

[EFU23], [ALE23], [PIS23], [GSA24]

Renewable Energy – Potentials and Implications for Mobility
Mobility Supporting Renewable Electricity

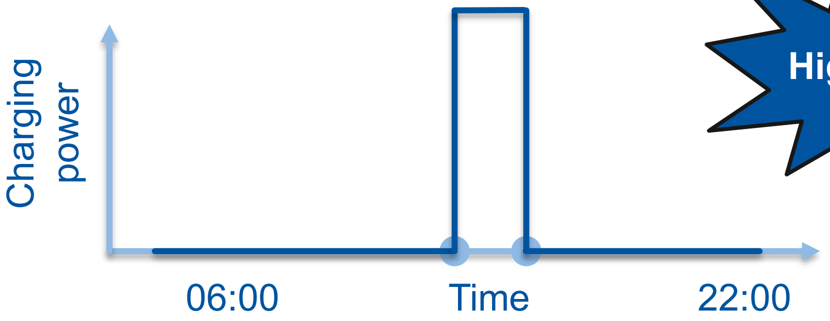
Example: Charging of heavy-duty trucks

- At high electrification rate, charging of battery-electric heavy-duty trucks will have significant impact on demand of electric power
- Scenarios
  - Charging over night:



No solar!

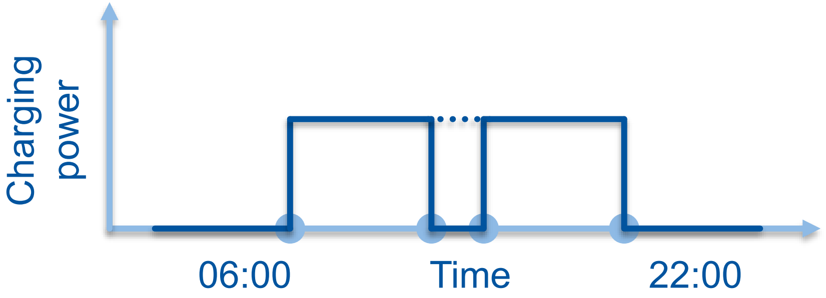
  - Charging during driver break:



High peaks!

Alternative: Dynamic Charging?

- Charging while driving can reduce peak loads



- Several technologies in research, successful field trials of overhead line trucks

> EU can meet its primary energy needs!
> There is more than one solution!
> Mobility and energy transition need to be thought together!

[BEE25]

THANK YOU

Driving the future, together.

Gordon Witham

Head of Energy &
Powertrain Systems

+49 241 80 23919

gordon.witham@ika.rwth-aachen.de

www.ika.rwth-aachen.de

Sources

Sources

[ALE23]: Alexander Alekseev et al. – „Wasserstoff-Verflüssigung, Speicherung, Transport und Anwendung von flüssigem Wasserstoff“, https://doi.org/10.5445/IR/1000155199, 2023
[BAK23]: Stefan Bakker et al. – „Land use of energy supply for carbon neutral mobility: a well-to-wheel analysis”, https://doi.org/10.1186/s12544-023-00601-5, 2023
[BDE22]: https://www.bdew.de/media/documents/Jahresvolllaststunden_2020_2021_o_online_jaehrlich_Ba_09062022_usfddti.pdf, accessed on 09.11.2025
[BEE25]: BEV Goes eHighway – BEE – www.bee-ehighway.de, 2025
[BON18]: Dominik Bongartz et al. – „Comparison of light-duty transportation fuels produced from renewable hydrogen and green carbon dioxide”, https://doi.org/10.1016/j.apenergy.2018.09.106, 2018
[C3S21]: Copernicus Climate Change Service – „Climate and energy indicators for Europe from 2005 to 2100 derived from climate projections“, https://doi.org/10.24381/cds.f6951a62, 2021
[DAH21]: Karna Dahal et al. – „Techno-economic review of alternative fuels and propulsion systems for the aviation sector”, https://doi.org/10.1016/j.rser.2021.111564, 2021
[DBA24]: Damian Backes – “Erneuerbare Energien – Potentiale und Implikationen für die Mobilität“. Dissertation defense, 2024
[EFU23]: https://www.efuel-alliance.eu/faq, accessed on 09.11.2025
[EIA24]: https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_6_07_a, accessed on 09.11.2025
[EUC23a]: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Archive:EU_energy_mix_and_import_dependency, accessed on 09.11.2025
[EUC23b]: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Oil_and_petroleum_products_-_a_statistical_overview#Consumption_in_sectors, accessed on 09.11.2025
[GOV23]: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/904826/DUKES_6.5.xls, accessed on 09.11.2025

Sources

[GRA21]: Nathan Gray et al. – „Decarbonising ships, planes and trucks: An analysis of suitable low-carbon fuels for the maritime, aviation and haulage sectors”, https://doi.org/10.1016/j.adapen.2021.100008, 2021
[GSA24]: https://globalsolaratlas.info/, accessed on 09.11.2025
[GWA24]: https://globalwindatlas.info/, accessed on 09.11.2025
[HIM24]: https://www.h2inframap.eu/, accessed on 09.11.2025
[JRC21]: European Commission, Joint Research Centre (JRC) – ENSPRESO, http://data.europa.eu/89h/88d1c405-0448-4c9e-b565-3c30c9b167f7, 2021, accessed on 09.11.2025
[KOR21]: Andrei Korberg et al. – „Techno-economic assessment of advanced fuels and propulsion systems in future fossil-free ships”, https://doi.org/10.1016/j.rser.2021.110861, 2021
[LES20]: Mason Lester et al. – „Analysis on Electrofuels in Future Energy Systems: A 2050 Case Study”, https://doi.org/10.1016/j.energy.2020.11740, 2020
[PIS23]: Stefan Pischinger – „Mobilität und Wasserstoff“, https://youtu.be/BAsQ75vGzk4, 2023, accessed on 09.11.2025
[RIT20]: Hannah Ritchie - “Cars, planes, trains: where do CO2 emissions from transport come from?” - https://ourworldindata.org/co2-emissions-from-transport, accessed on 09.11.2025
[SPE22]: Jan Martin Specht et al. – “Vergleich von Wasserstoff und Elektromobilität - Technische, ökonomische, soziale und ökologische Aspekte“, https://www.kopernikus-projekte.de/lw_resource/datapool/systemfiles/cbox/2378/live/lw_datei/fcn__2022__vergleich_von_wasserstoff-_und_elektromobilit-C3-A4t_final_02.pdf, 2022, accessed on 09.11.2025
[STA18]: Mark Staples et al. – „Aviation CO2 emissions reductions from the use of alternative jet fuels”, https://doi.org/10.1016/j.enpol.2017.12.007, 2018
[TOR24]: Mikkel Torud – “Developing Green Ammonia for Shipping”, Virtual Green Ammonia Summit January, https://vimeo.com/905992286 , 2024, accessed on 09.11.2025