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H_2 utilisation pathways and their climate impact

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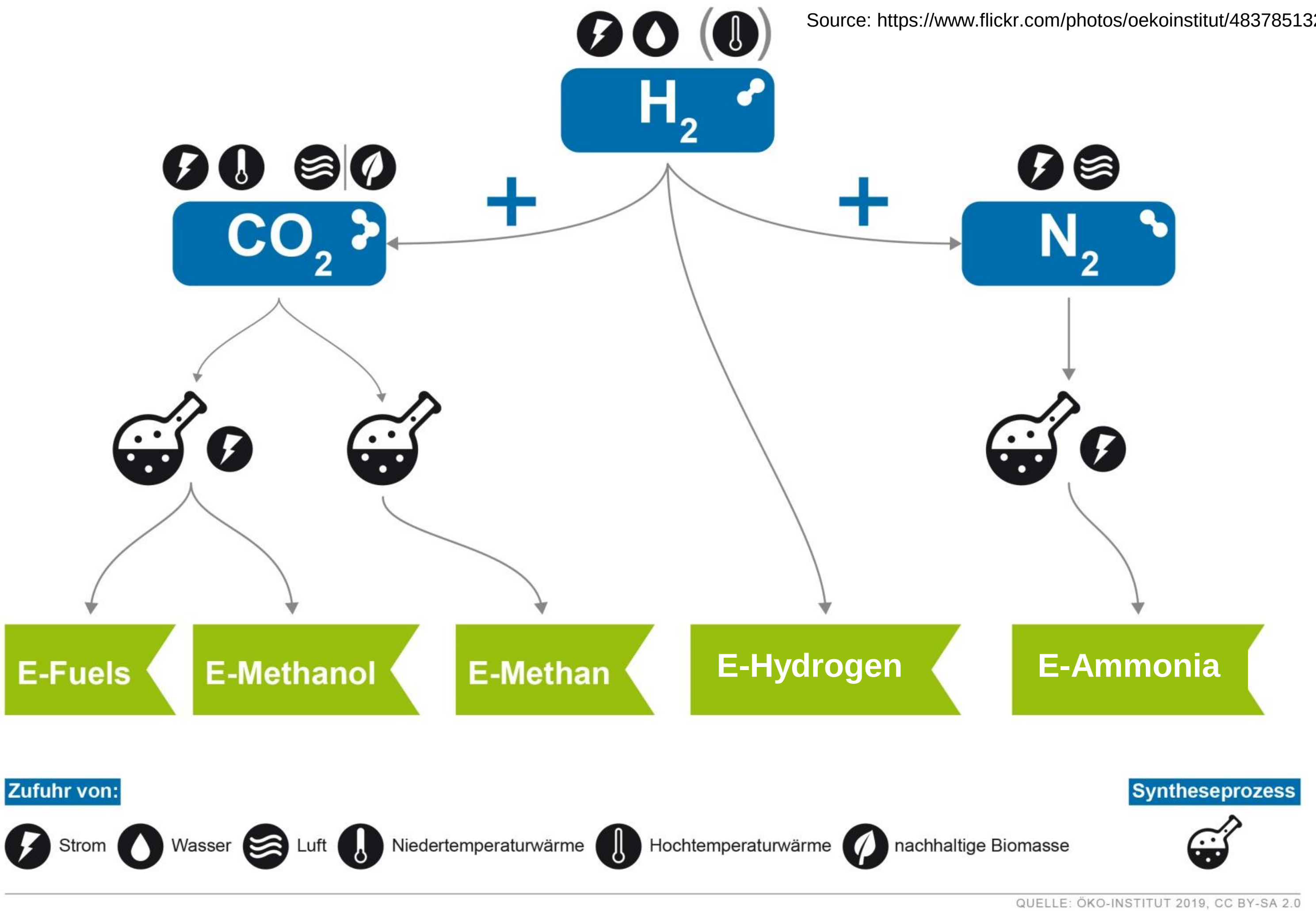
Bruxelles, October 16th 2019

H_2 utilisation pathways

Source: https://www.flickr.com/photos/oekoinstitut/48378513216/in/photostream/



Electrical efficiency ratio H_2 utilisation pathways

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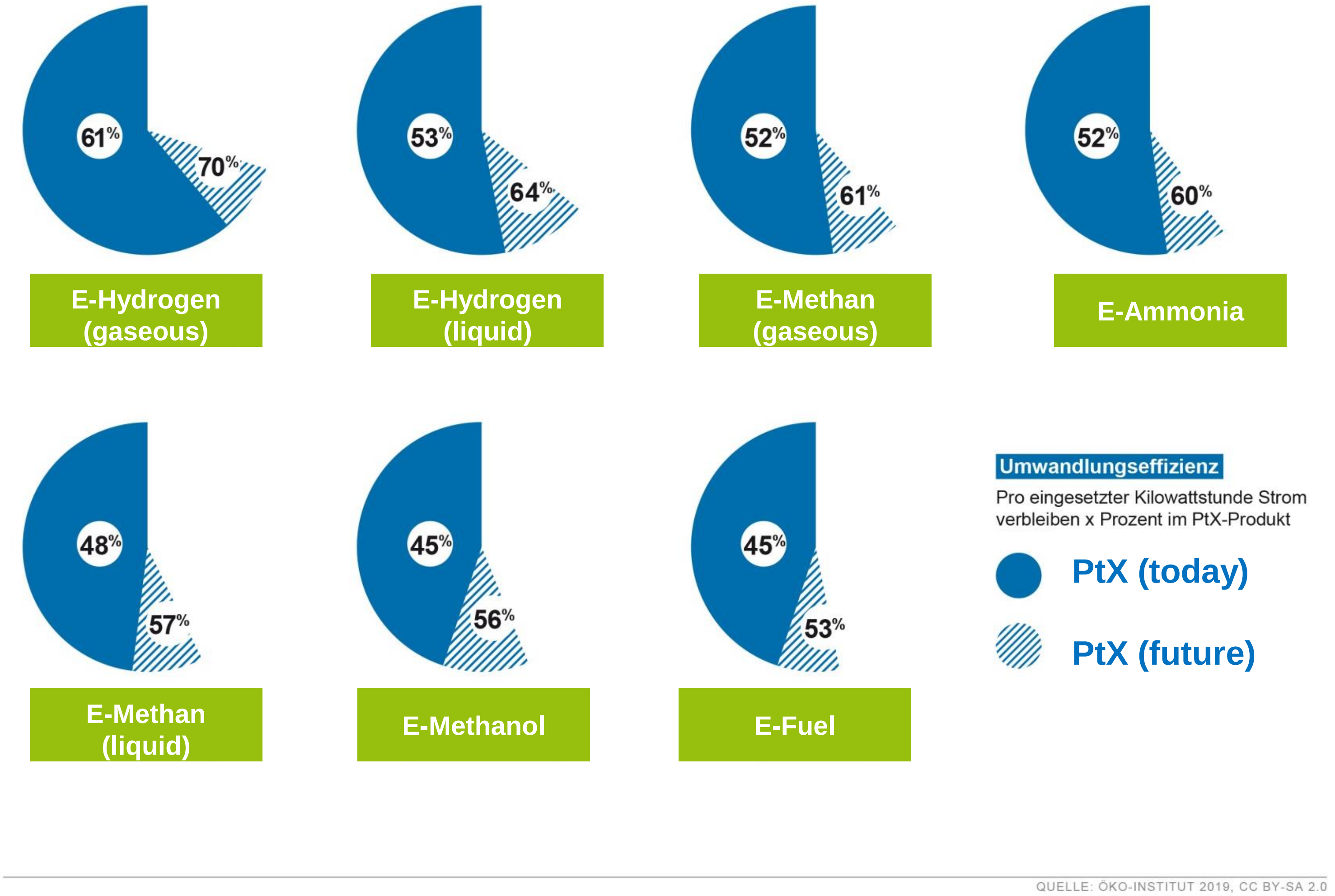

Relevant components for H_2 production pathways

- Conventional production: Reforming of **natural gas or other hydrocarbons**
  - Steam reforming (endothermic process): heat and water vapour
  - Partial oxidation (exothermic process): oxygen or air

  → CO_2-emissions of H_2 result from natural gas and other fossil hydrocarbons

- Electrolysis of water:
  - PEM (Polymer Electrolyte Membrane) Electrolysis: **electricity**
  - High Temperature Electrolysis: heat and **electricity**

  → CO_2-emissions of H_2 depend on specific CO_2-emissions of electricity generation

Source: https://www.flickr.com/photos/oekoinstitut/48704349031/

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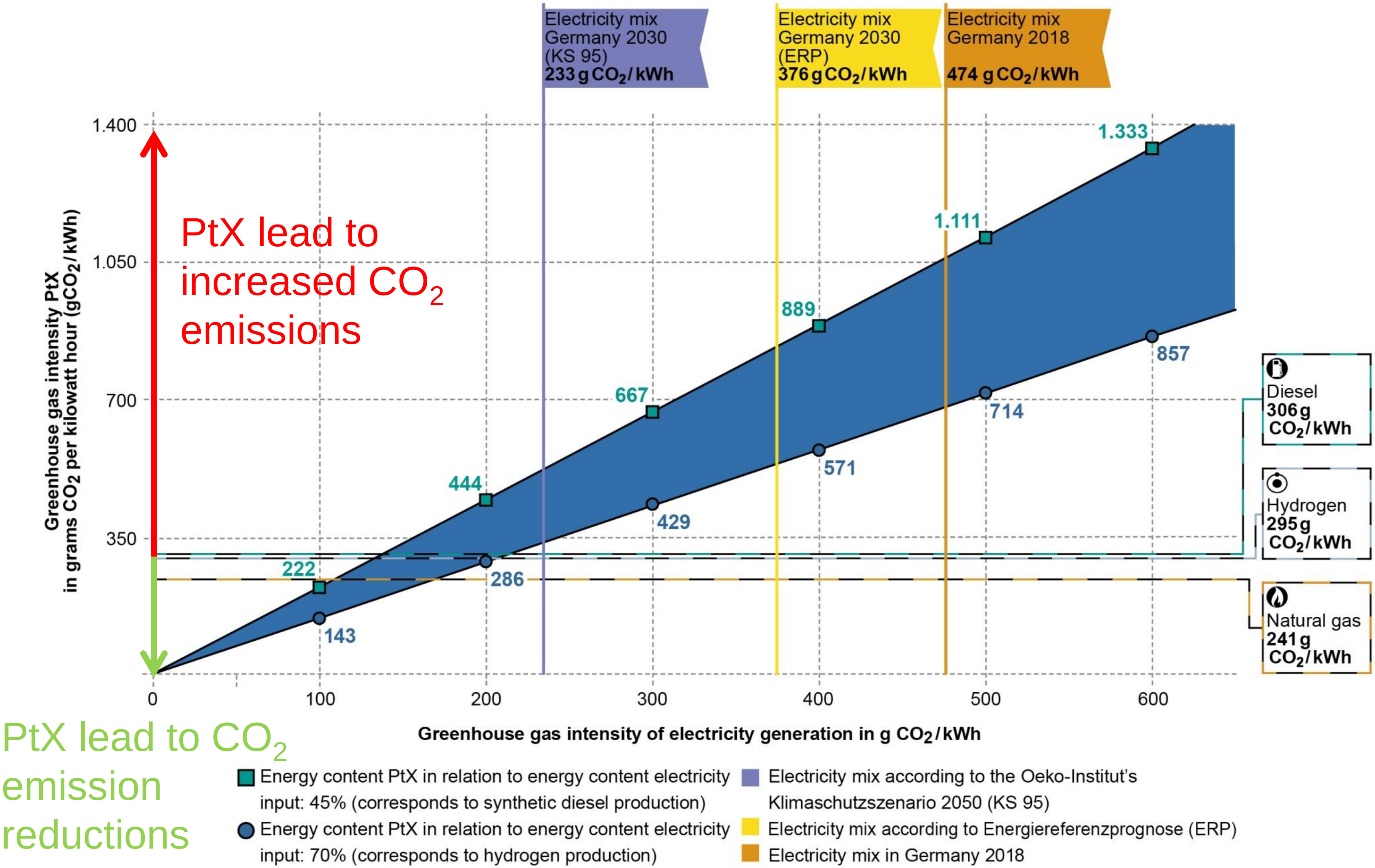
Power-to-X: Comparison of CO_2 emissions from PtX and fossil fuels

Climate-friendly only with very high shares of renewable electricity



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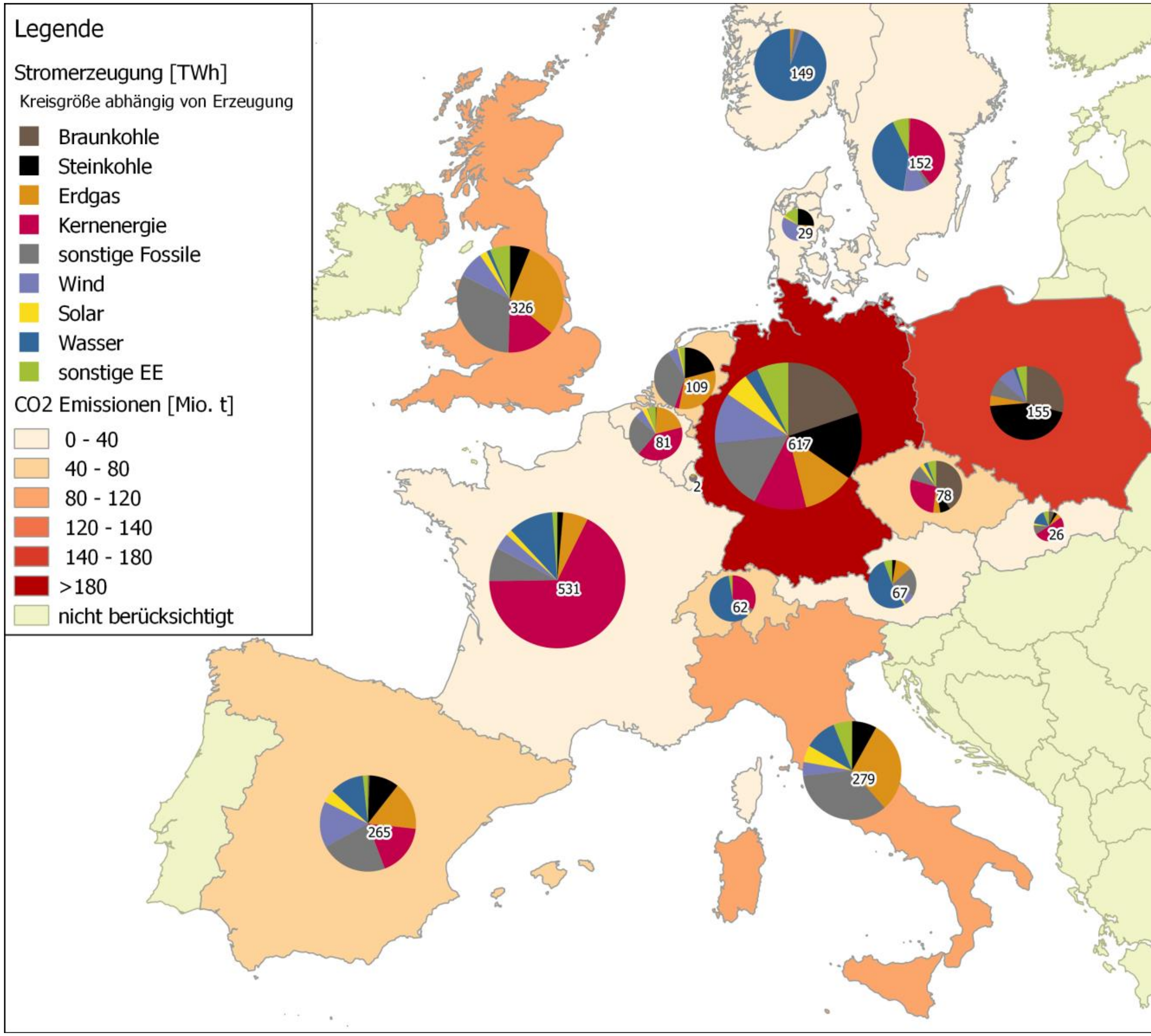
Fuel mix and CO_2-emissions of electrictiy generation in Europe 2016

Specific CO_2-emissions of electricity generation in 2016:

- Norway: 10 g CO_2/kWh
- Sweden: 40 g CO_2/kWh
- Switzerland: 50 g CO_2/kWh
- France: 60 g CO_2/kWh
- Austria: 85 g CO_2/kWh
- Slovakia: 195 g CO_2/kWh

→ Countries with large amounts of hydro and / or nuclear power stay currently below 200 g CO_2/kWh.



Source: https://www.oeko.de/publikationen/p-details/modellbasierte-szenarienuntersuchung-der-entwicklungen-im-deutschen-stromsystem-unter-beruecksichtigu/

Renewable targets of electrictiy generation in Europe

More than 100% target

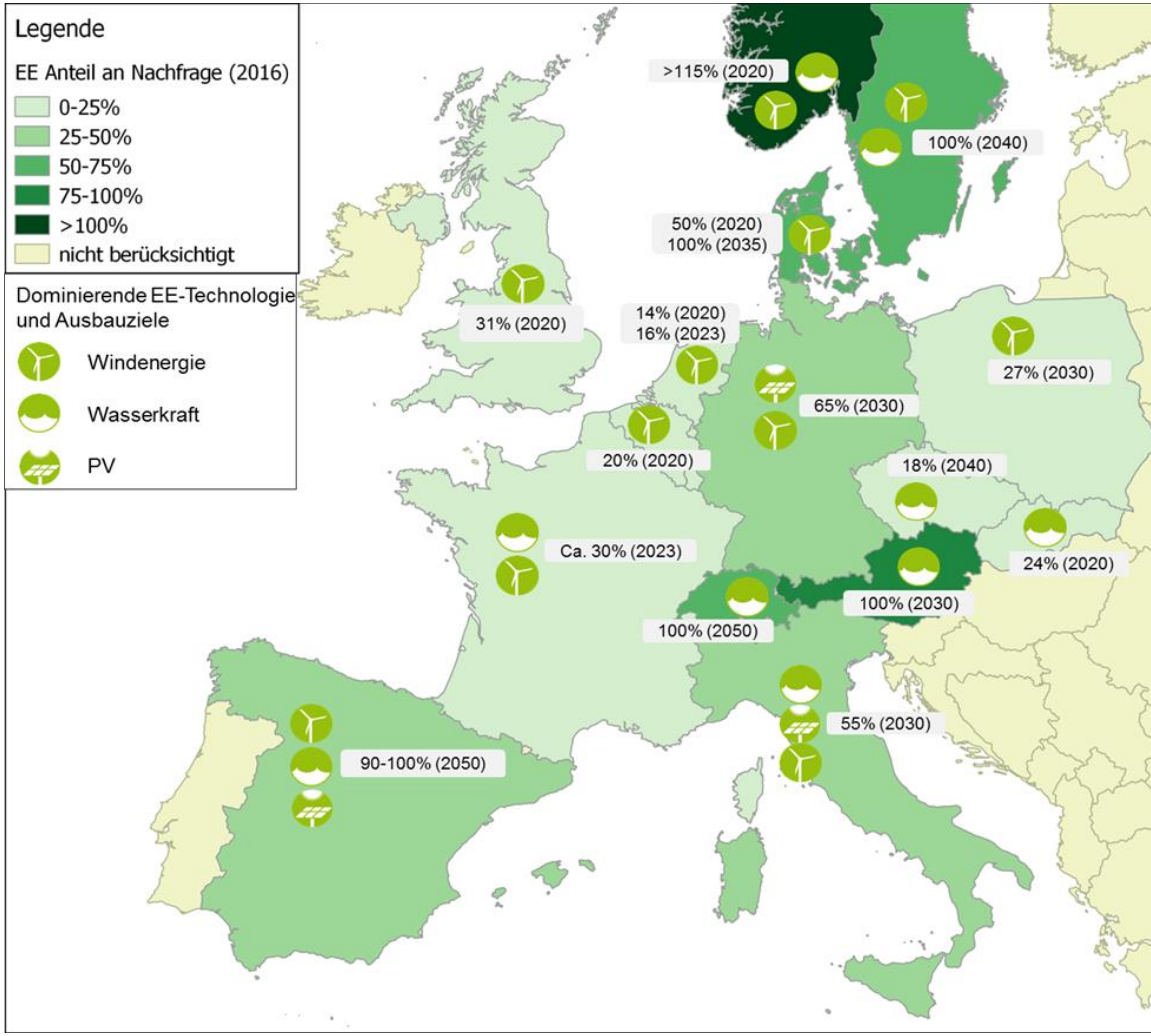
- Norway: 115 % (2020)

100% target

- Austria (2030)
- Denmark (2035)
- Sweden (2040)
- Switzerland (2050)
- Spain (2050)

At least 50% target

- Germany: 65% (2030)
- Italy: 55% (2030)



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Parameters for PtX plants with positive climate impact

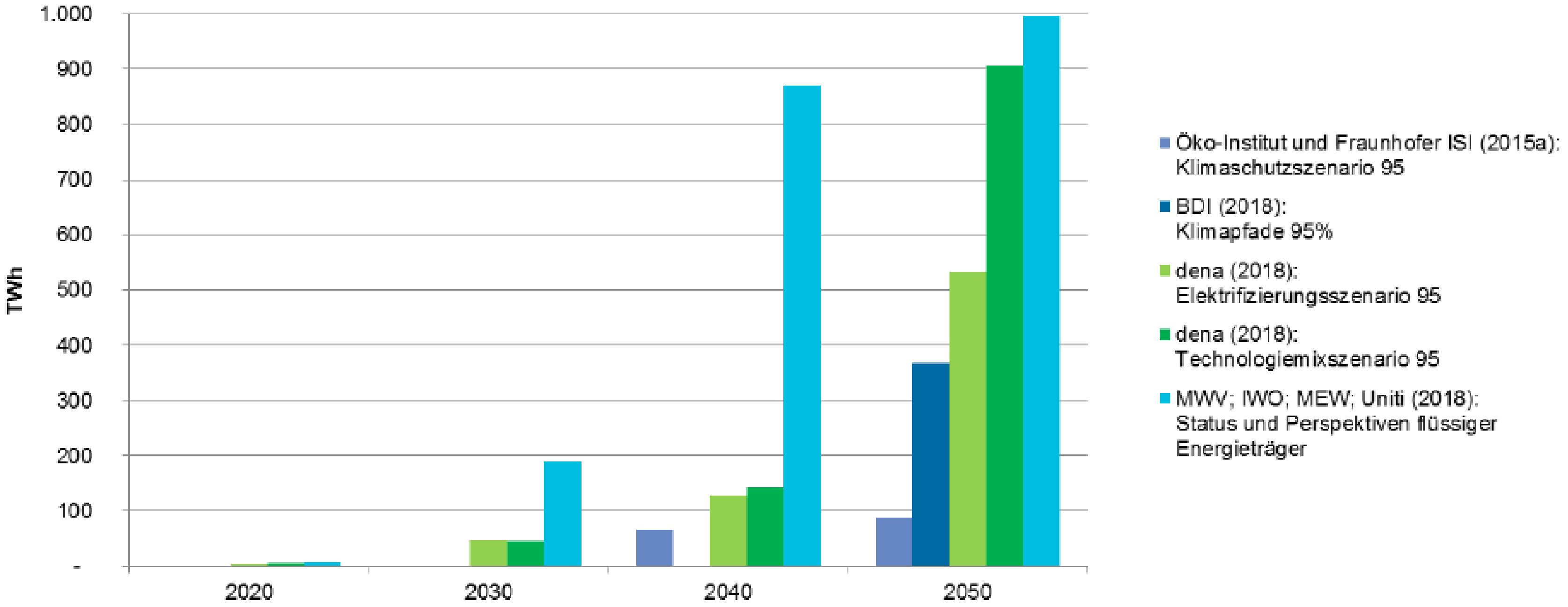
- CO_2 intensity of electricity generation must be
  - less than 200 g CO_2/kWh for e-hydrogen and
  - less than 140 g CO_2/kWh for e-fuels respectively.
  - → PtX plants need criteria for **additional** renewable electricity.
  - → PtX plants should be **flexible** enough for fluctuating renewables.

- Scale up of PtX plants should start with industrial e-hydrogen production
  - Show highest efficiency ratio
  - Comparatively low further infrastructure is needed

→ Refineries, chemical plants, steel production (e.g. voestalpine in Linz, https://h2future-project.eu/)

Demand of Power-to-X fuels in different climate protection scenarios for Germany

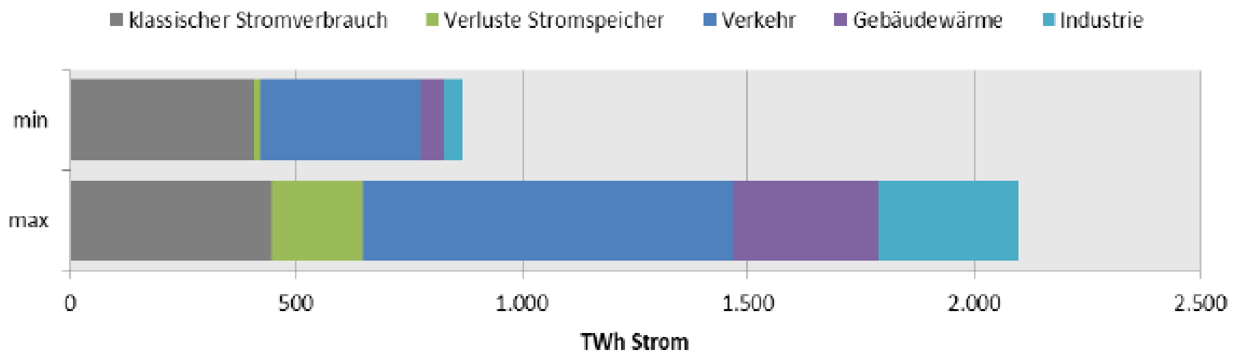
Source: Christoph Heinemann, Peter Kasten and others (2019) „Die Bedeutung strombasierter Stoffe für den Klimaschutz in Deutschland“

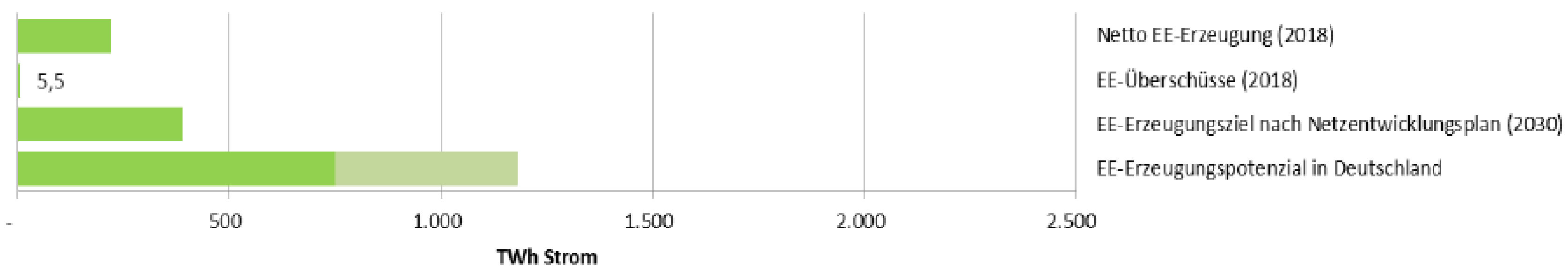


- PtX is not a relevant climate protection measure until 2030
- Significant increase of PtX between 2040 and 2050, depending on the assumed climate protection strategies

Electricity demand in Germany 2050: minimum and maximum approximation

Source: Christoph Heinemann, Peter Kasten and others (2019) „Die Bedeutung strombasierter Stoffe für den Klimaschutz in Deutschland“





- Electricity demand is going to increase significantly due to sector coupling
- Minimum approximation: more efficiency measures and biomass utilization
- Maximum approximation: more Power-to-X → import

Conclusions I

- Cascade of using (renewable) electricity
  - Efficiency first! – reducing demand
  - Direct utilization of electricity (e.g. e-mobility or heat pumps)
  - Power-to-X, where there is no other possibility (e.g. aviation)
- For a positive climate impact of e-hydrogen, the electricity used must show a CO_2 intensity less than 200 g CO_2/kWh.
  - Only few countries reach this target today, especially hydro and nuclear power dominated countries
  - An electricity mix of natural gas and renewable energies starts getting below of 200 g CO_2/kWh from 50% RES share
  - Coal phase out is essential for Power-to-X

Conclusions II

- For Power-to-X **additional** RES is needed (outside the national and European support schemes and frameworks)
- Flexibility of Power-to-X components is essential for using fluctuating renewable energies (trade of between flexibility and efficiency of electrolysis technologies)
- A significant part of the demand of e-fuels must be produced outside Europe, which leads to further interactions:
  - Renewable electrification of the country
  - Political stability of the country
  - Development of the country

Modeling aspects of Power-to-X

- Model based evaluation of the climate impact of Power-to-X plants via scenario comparison
  - **Baseline scenario** without Power-to-X and with conventional production of X (including the corresponding CO_2-Emissions of using X)
  - **PtX scenario** with electricity based production of X (including the corresponding CO_2-Emissions for electricity production)
  - Delta of baseline scenario and PtX scenario is the positive or negative climate impact.
- Additional demand constraint to produce X
  - Option 1: conventional process
  - Option 2: electrolysis process

Techno-economic and additional framework aspects of modeling Power-to-X

- Modeling flexibility of the plants
  - Minimum load, maximum load and available load change rate of the different components of the process chain (electrolysis, methanation, Fischer-Tropsch Synthesis, Hbaer-Bosch Synthesis,…)
  - Storage capacity for different X-products within the process chain
- Efficiency ratio and variable costs
- Indirect constraints for using only electricity with a maximum CO_2 intensity for Power-to-X to guarantee in advance that the climate impact is positive.

Further information I

- Strombasierte Kraftstoffe im Vergleich – Stand heute und die Langfristperspektive https://www.oeko.de/oekodoc/1826/2013-496-de.pdf
- Prüfung der klimapolitischen Konsistenz und der Kosten von Methanisierungsstrategien https://www.oeko.de/oekodoc/2005/2014-021-de.pdf
- Presseerklärung zur Förderung von PtX https://www.oeko.de/presse/archiv-pressemeldungen/2019/power-to-x-transparent-und-nachhaltig-foerdern/
- Essential elements of sound sustainability criteria for powerfuels Impulsvortrag von Christof Timpe, Powerfuels in the European energy transition: The need for effective regulation, 17 Juni 2019, Brüssel https://www.oeko.de/fileadmin/oekodoc/Impulse-GA-Powerfuels-Brussels.pdf

Further information II

- Koch and other (2019): Modellbasierte Szenarienuntersuchung der Entwicklungen im deutschen Stromsystem unter Berücksichtigung des europäischen Kontexts bis 2050 https://www.oeko.de/publikationen/p-details/modellbasierte-szenarienuntersuchung-der-entwicklungen-im-deutschen-stromsystem-unter-beruecksichtigu/
- Christoph Heinemann, Peter Kasten and others (2019) „Die Bedeutung strombasierter Stoffe für den Klimaschutz in Deutschland"; working paper written within the Kopernikus project ENSURE https://www.oeko.de/fileadmin/oekodoc/PtX-Hintergrundpapier.pdf

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