95% GREENHOUSE GAS REDUCTION: WHAT THIS IMPLIES FOR THE TRANSFORMATION OF THE ENERGY SYSTEM IN GERMANY

ANALYZING AND DESIGNING POLICIES AND MARKETS FOR LARGE-SCALE UTILIZATION OF RENEWABLE ENERGY SOURCES

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Background
German target: 80-95% reduction (to 1990)

- "Climate Protection Plan 2050" leaves Germany’s 2050 climate target unclear:

  We want to set out the further reduction steps up to the ***target value of 80 to 95 percent*** *[less greenhouse gas emissions than 1990] in 2050 and underlay them with measures in a broad dialogue process.*
  Coalition agreement between CDU, CSU and SPD

- Until 2016 there were only two detailed ‘95% scenarios’, most scenario studies focused on the 80% part.
- Afterwards (especially in the run-up to the coalition agreement) a large number of studies on the (almost) complete decarbonisation of Germany suddenly followed in rapid succession.
- → Currently, there is a strong focus on how to achieve 95% or “net zero” emissions by 2050

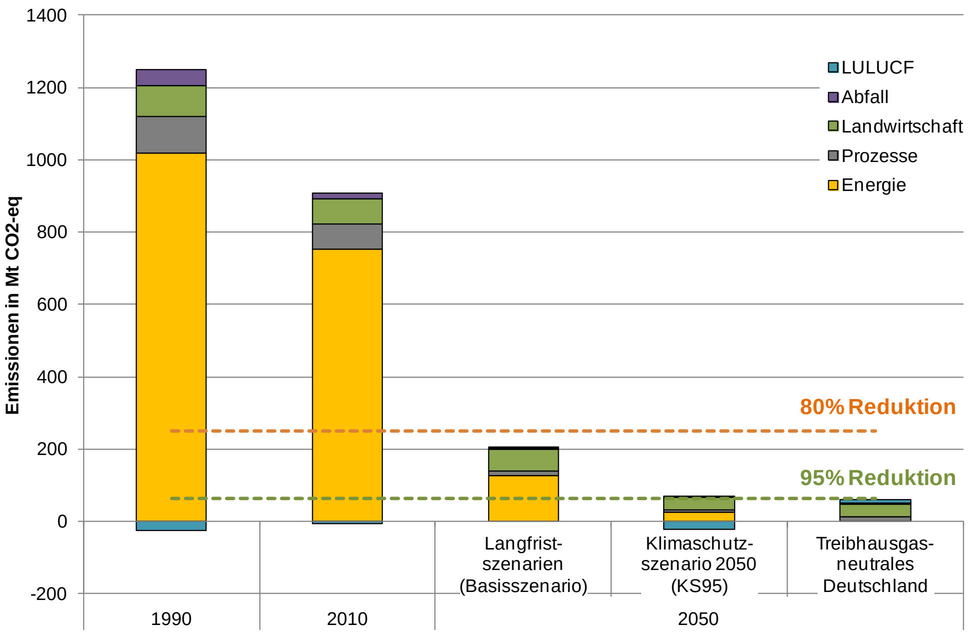
Background
80% reduction of GHG

- Picture for 80 % GHG reduction (to 1990) fairly clear and agreed upon
  - **Power sector**
    - RES!
    - In Germany: No nuclear (phase-out policy until 2022), no CCS (by law)
  - **Transport**
    - Cars: e-Mobility (though certain push for Power-to-Liquids by some actors)
    - HDV: Biofuels, Trolley trucks
  - **Buildings**
    - Energy efficiency first!
    - Heat pumps, solar thermal, biomass (some houses can still use natural gas)
  - **Industry**
    - Diverse mix of energy efficiency, electrification, biomass, new processes…
  - **Agriculture**
    - Less meat, less fertilizer, …

95 % reduction of GHG is more complicated …

- **A 95 % reduction in greenhouse gas emissions goes well beyond the acceleration of an 80 % transformation path and means that the technically available reduction potentials are fully exploited.**
- The virtually unavoidable emissions from agriculture and industry already fill almost the entire remaining emissions budget.

→ 95 % reduction basically means full decarbonisation (or defossilization) by 2050 latest



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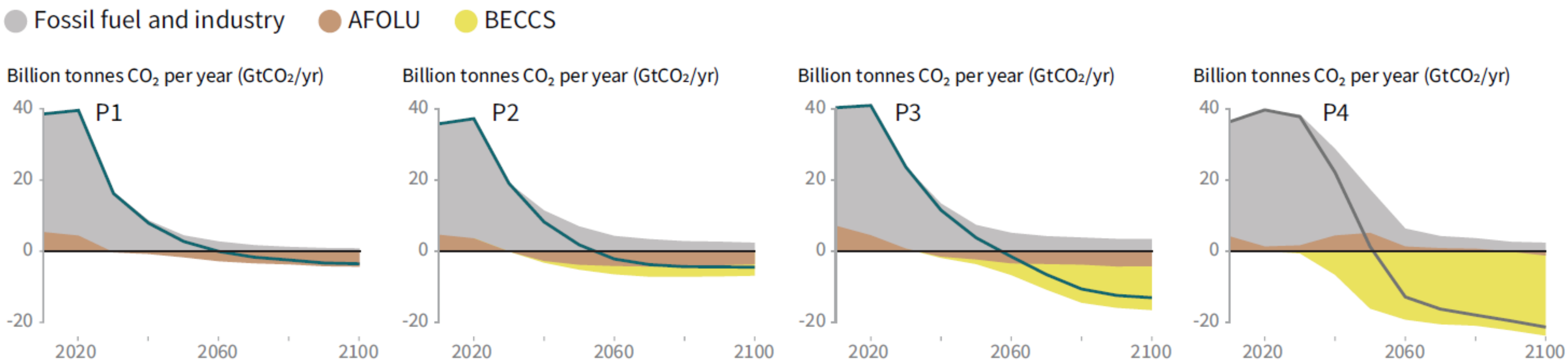
IPCC: limiting warming to 1.5°C with no/low overshoot is possible → rapid action

Breakdown of contributions to global net CO_2 emissions in four illustrative model pathways



P1: A scenario in which social, business and technological innovations result in lower energy demand up to 2050 while living standards rise, especially in the global South. A downsized energy system enables rapid decarbonization of energy supply. Afforestation is the only CDR option considered; neither fossil fuels with CCS nor BECCS are used.

P2: A scenario with a broad focus on sustainability including energy intensity, human development, economic convergence and international cooperation, as well as shifts towards sustainable and healthy consumption patterns, low-carbon technology innovation, and well-managed land systems with limited societal acceptability for BECCS.

P3: A middle-of-the-road scenario in which societal as well as technological development follows historical patterns. Emissions reductions are mainly achieved by changing the way in which energy and products are produced, and to a lesser degree by reductions in demand.

P4: A resource- and energy-intensive scenario in which economic growth and globalization lead to widespread adoption of greenhouse-gas-intensive lifestyles, including high demand for transportation fuels and livestock products. Emissions reductions are mainly achieved through technological means, making strong use of CDR through the deployment of BECCS.

Global indicators	P1	P2	P3	P4	**Interquartile range**
Pathway classification	No or limited overshoot	No or limited overshoot	No or limited overshoot	Higher overshoot	No or limited overshoot

Sources: IPCC SR1.5, Summary for Policy-makers

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95 % reduction of GHG is more complicated

- Full decarbonization means we have to find solutions for the tricky parts (the remaining emissions in the 80% scenarios)
  - **Aviation and navigation**
    - So far, no alternative to hydrocarbon in sight
  - **Transport: High duty vehicles**
    - What fuel to use for the without without overhead lines?
  - **Buildings**
    - What to do with Berlin, what to do with historic inner cities? (Currently, renovation rates are ~1%, need to rise to at least ~2%
  - **Industry**
    - What is the source for feedstocks for the chemical industry(ethylene, ammonia)
    - How to produce steel? Direct reduction with hydrogen? PtG?
    - How to produce cement?
  - How to change behaviors and diets?

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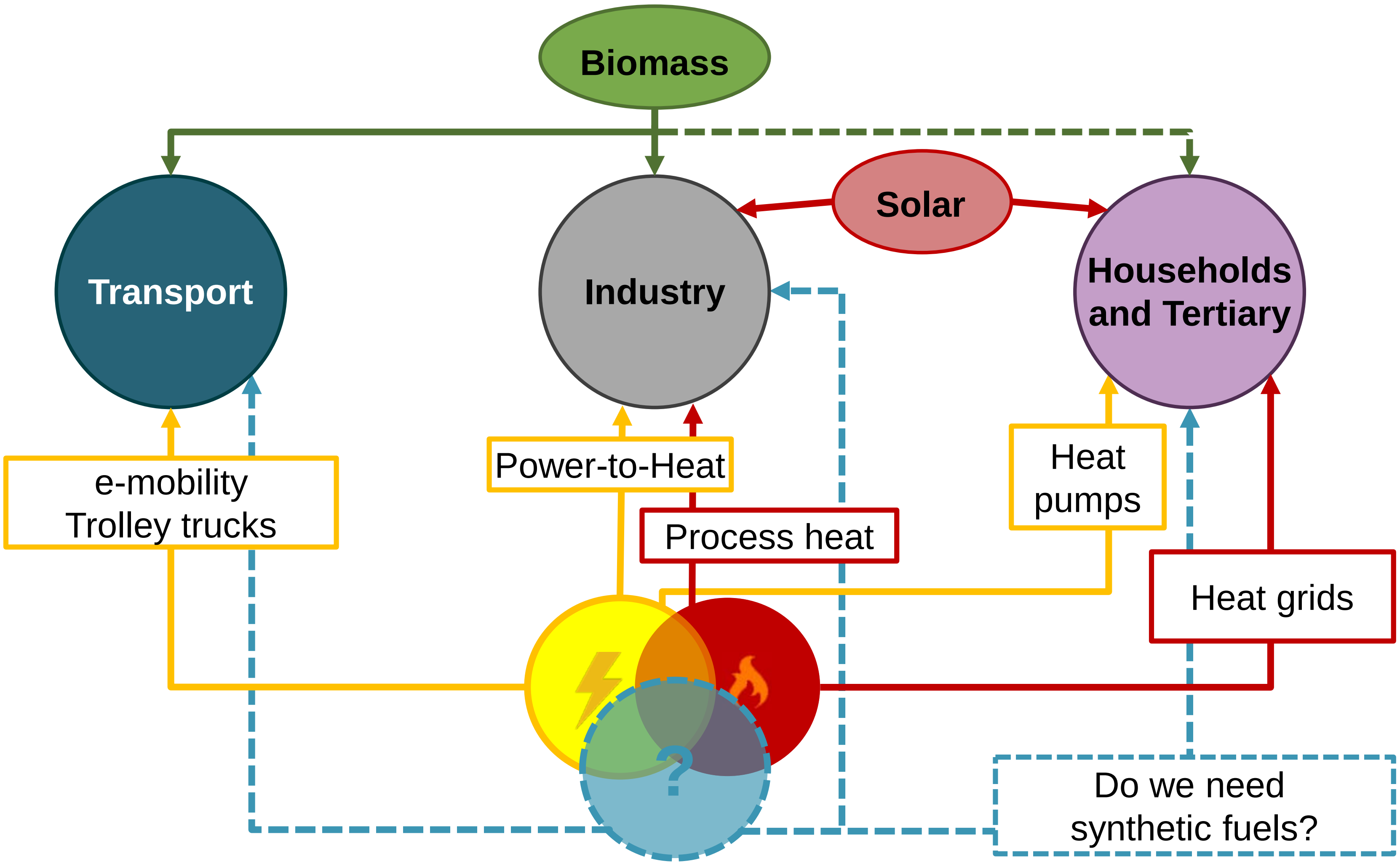
Deep decarbonisation scenarios
Sector coupling



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95 % reduction scenarios
Stylized strategies for going beyond 80%

- Recent scenario studies more or less follow three narratives / main strategies
  1. Predominantly electric
  2. Hydrogen economy
  3. Synthetic hydrocarbons

- Further big differences in assumptions
  - Availability of CCS
  - Biomass potential
  - Success level of energy efficiency measures
  - Willingness for behavourial change and sufficiency

95% strategies 1/3
Predominantly electric

- **General idea**
  - “Electricity first”, use synthetic forms only if electricity is not possible or too expensive
- **Advantages**
  - Most efficient energy transformation path → Potentially low costs
- **Challenges**
  - Building renovation rate needs to double quickly
  - More flexibility options need to be used (Demand-response, international grids, storages…)
  - Expanding electricity grids “both transmission and distribution grids” → acceptance issues

95% strategies 2/3
Hydrogen economy

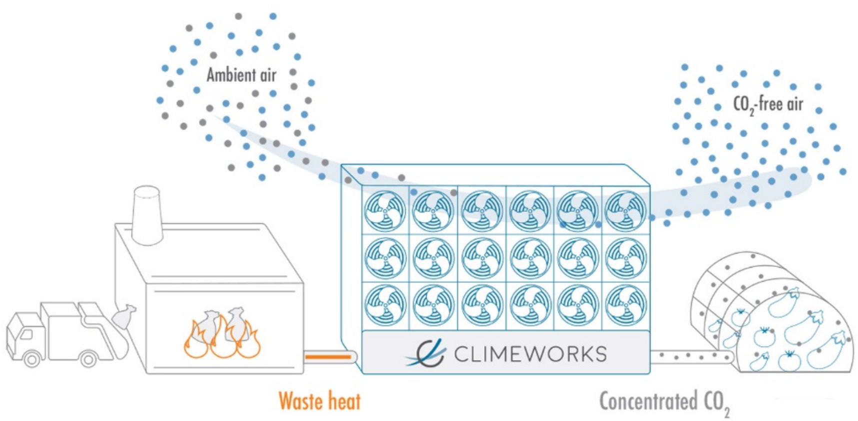
- **General idea**
  - Use hydrogen as fuel for vehicles, heating and in other application
- **Advantages**
  - Storable
  - No CO_2 input needed
  - More efficient conversion chain than hydrocarbons
- **Challenges**
  - More expensive than the purely electric path
  - Conversion losses → mores RES plants needed
  - New infrastructure needed, or changes to the existing infrastructure

95% strategies 3/3
Synthetic hydrocarbons

- **General idea**
  - Predominantly electric is not possible and hydrocarbons are already used
- **Advantages**
  - Lowest necessity for change in the demand sectors
  - Existing infrastructures for gas and liqiuds
  - Potential for importing RES from beyond Europe
- **Challenges**
  - Expensive!
  - Where to build the required RES plants, as this strategy uses much more RES? → Import from Middle East, North Africa, Australia, Asia?
  - How to deal with nonetheless declining demand (e.g. substantially shrinking utilization of gas distribution grids)
  - Where to get vast amounts of non-fossil CO_2 for methanisation?

Excursion:
The PtG-DACS-dilemma 1/3

- Synthetic hydrocarbon require carbon input (primarily CO_2)
- To be a climate neutral, no fossil sources can be used
- Certain concentrated sources exist (biogas treatment, but for the amounts needed in “Synthetic hydrocarbons”-scenarios (~500 - 1,000 Mt/a for the EU), Direct Air Capture is a mandatory key technology.



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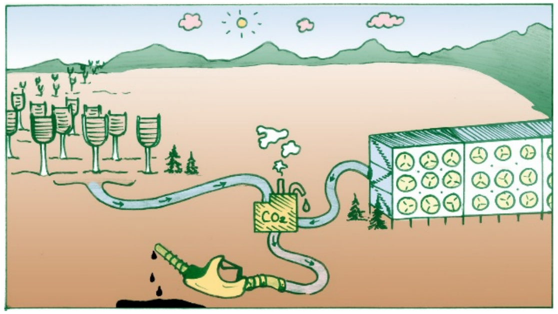
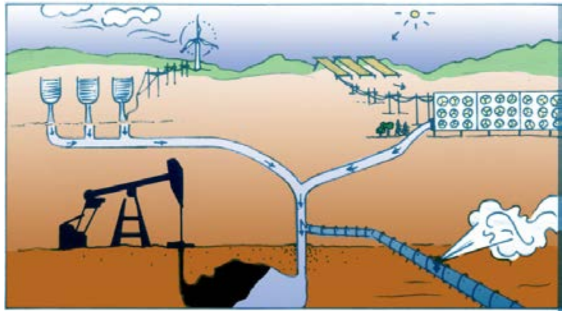
Excursion:
The PtG-DACS-dilemma 2/3

- At any given cost for atmospheric CO_2, using fossils and compensating the emissions is cheaper. (→ CCUS)





PtG path (1 MWh) MWh fuel, net zero GHG)	**DACS path** (1 MWh fuel, net zero GHG)
0,2 t CO_2 from DAC	0,2 t CO_2 from DAC
1,25 MWh RES electricity	0,2 t underground storage
electrolysis	1 MWh natural gas
methanization	

Images from: www.geoengineeringmonitor.org

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Excursion: The PtG-DACS-dilemma 3/3

- “At any given cost for atmospheric, using fossils and compensating the emissions is cheaper.”
- If there are countries willing to store CCS, compensating fossil emissions DACS is cheaper than PtG/PtL production and usage.
- This is true for a relative wide range of assumptions.
- This does not mean that fossils with DACS is cheaper than other options (like renewable electricity, …).
- If this is true, synthetic hydrocarbons will play a long-term role.

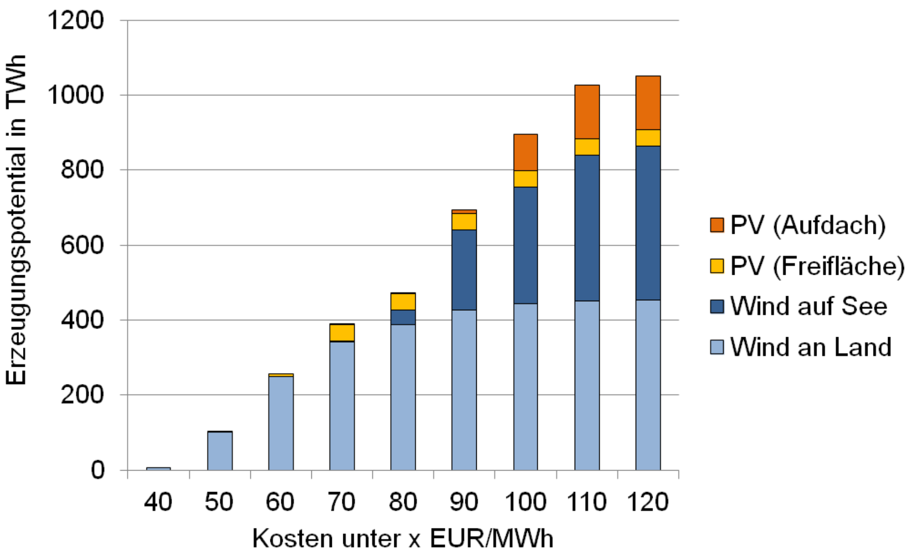
Thank you for your attention!

Power-to-Gas
Main issues: Efficiency and clean CO_2

	Direct electricity	Hydrogen	Synthetic hydrocarbons
Pros	• Most efficient path • Often cheap	• More efficient than hydrocarbon path • Storable	• Existing infrastructure, including demand side applications and storages
Cons	• Strong grid expansion necessary • Expansion of flexibility measures (including RES) necessary when reaching high RES shares	• Complex and expensive conversion of infrastructure necessary • Path dependency	• CO_2 input necessary • Potential for climate neutral CO_2 severely limited • Expensive (avoidance costs over EUR 500/t) • Most inefficient of the three options (highest losses)
Efficiency today	~95 %	~67 %	~50 %
Costs today	70 EUR/MWh	148 EUR/MWh	221-321 EUR/MWh
Efficiency 2050	95 %	67-87 %	50-74 %
Costs 2050	50 EUR/MWh	74-118 EUR/MWh	97-281 EUR/MWh

Conclusions from our work on scenarios

- A carbon neutral electricity sector is the backbone of the energy sector, also for the provision of heat and other energy carriers.
- The central motivation for an efficient use of energy is the reduction of acceptance issues in the expansion of the generation and grid infrastructures for electricity.
- Wind and photovoltaics will dominate power generation. Long-term potential in Gemany: In the order of **1,000 TWh** with costs of a maximum of **11 cent/kWh**. In Europe, the total potential is even much larger and in some cases also cheaper.



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