

# DIE VERBLÜFFEND EINFACHE MATHEMATIK DES KLIMASCHUTZES

## THE AMAZINGLY SIMPLE MATHEMATICS OF CLIMATE PROTECTION

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Hydrogen Mission Webinar 10 June 2020



# THE AMAZINGLY SIMPLE MATHEMATICS OF CLIMATE PROTECTION

## Objectification of the discussion on climate protection measures

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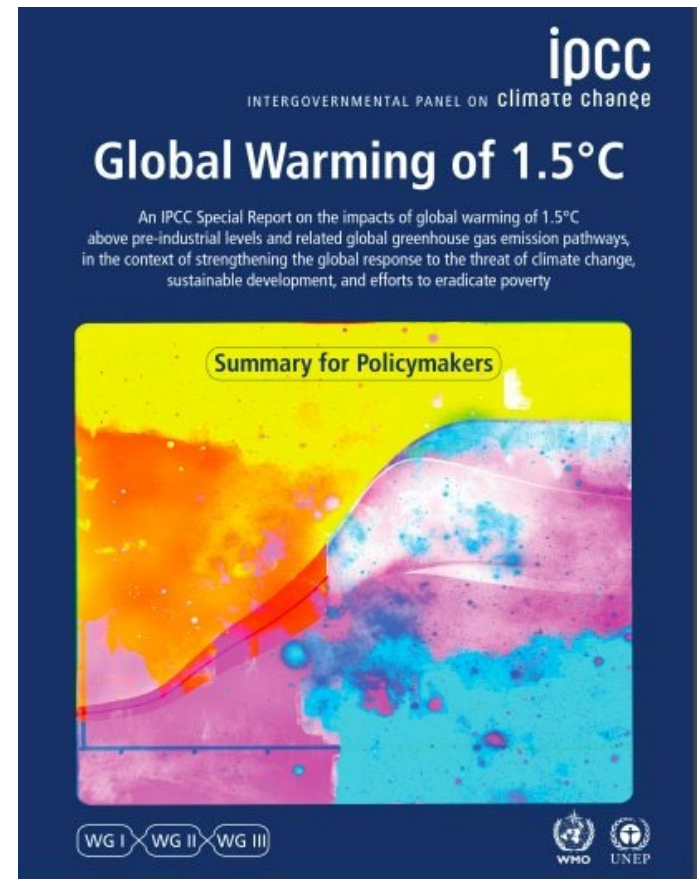
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# MATHEMATICS OF CLIMATE PROTECTION

## Boundary conditions and data basis

- **Target: 1.5 degree target**
- **Basis: IPCC Special Report on Global Warming of 1.5 C, October 2018**
- **But, according to risk analysis:**
  - No ticking time bombs:**
    - > no CCS (Carbon Capture and Storage)  
with pressurized CO<sub>2</sub> storage
    - > no global renaissance of nuclear power



# LINKING THE MATHEMATICS OF CLIMATE PROTECTION WITH CLIMATE PROTECTION MEASURES

## Application example:

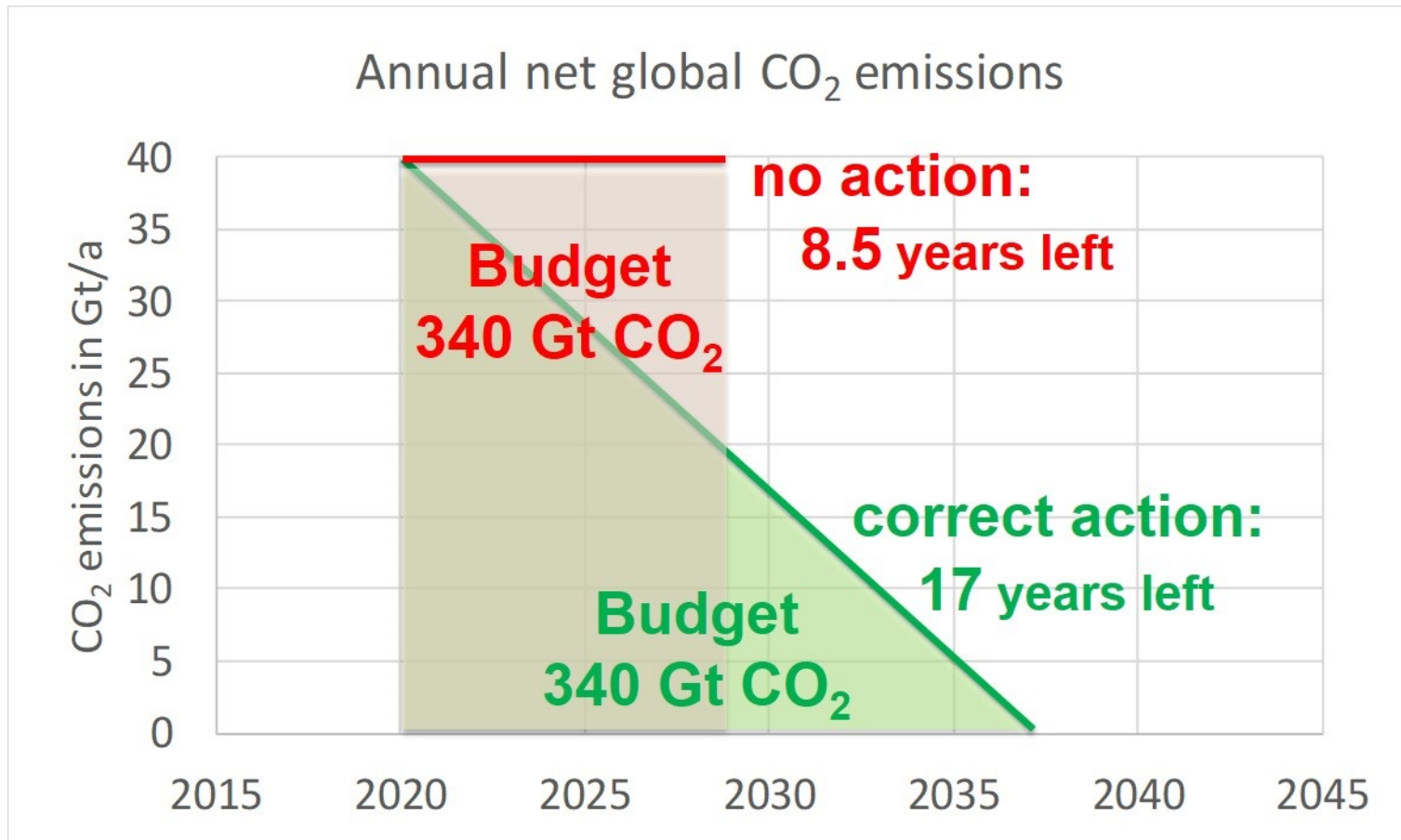
Scientific analysis of climate protection measures in the  
transport sector

## Method:

- technology neutral analysis
- the climate performance counts
- the mathematics evaluates the measures

# MATHEMATICS OF CLIMATE PROTECTION

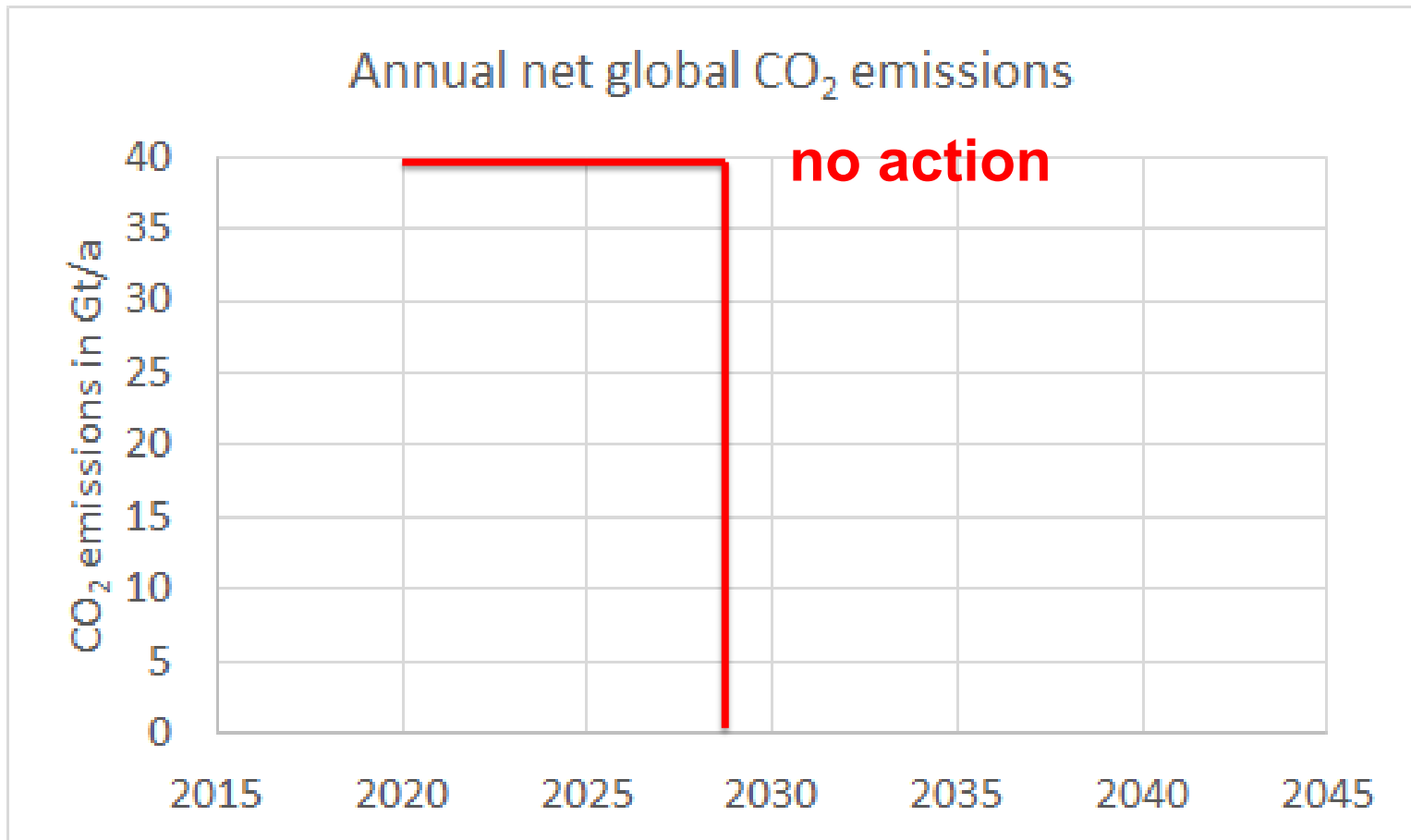
CO<sub>2</sub> emission budget (1.5-degree target) from Jan. 2020: **340 Gt CO<sub>2</sub>**  
Current level of CO<sub>2</sub> emissions: **40 Gt CO<sub>2</sub> per year**



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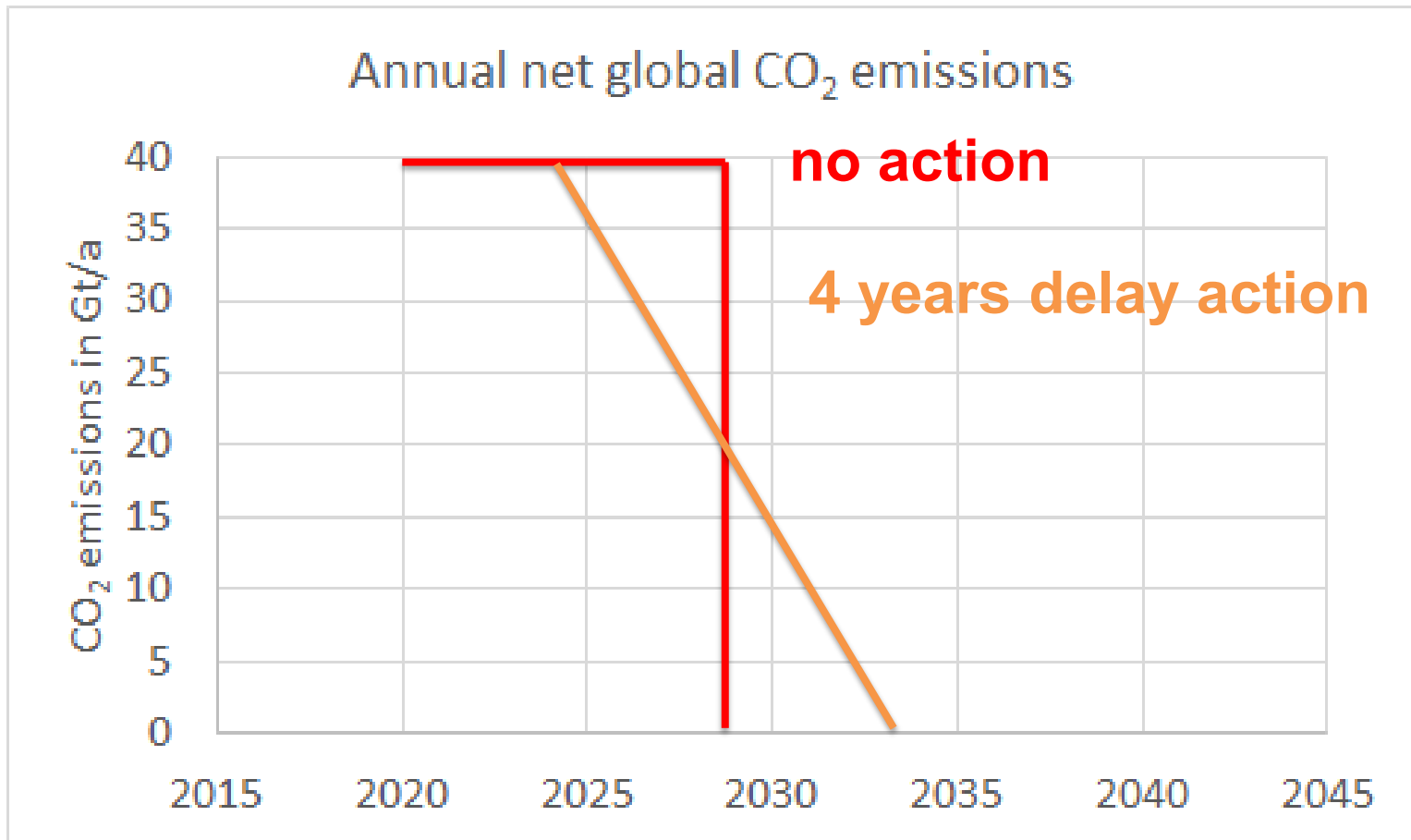
# MATHEMATICS OF CLIMATE PROTECTION

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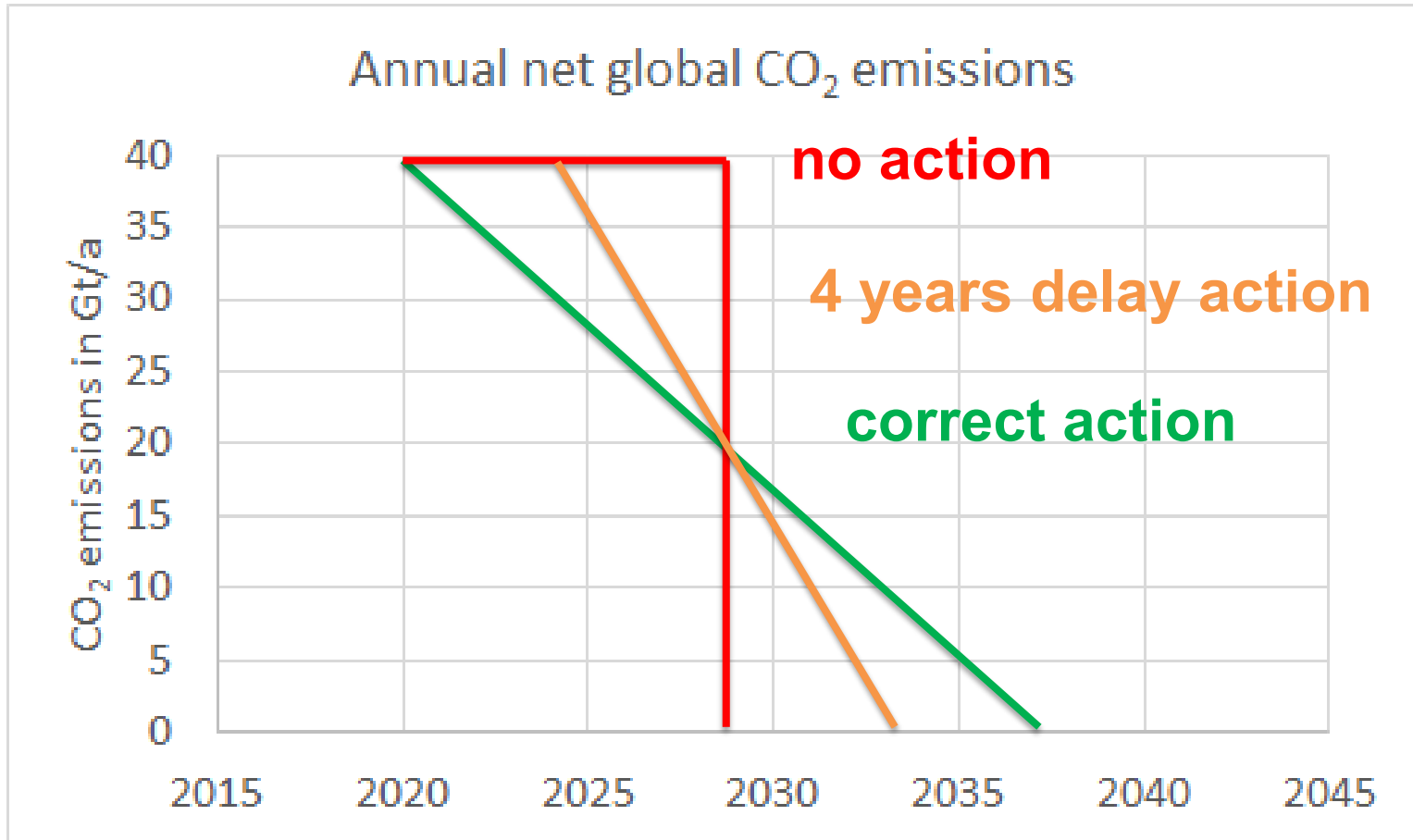
# MATHEMATICS OF CLIMATE PROTECTION

CO<sub>2</sub> emission budget (1.5-degree target) from Jan. 2020: **340 Gt CO<sub>2</sub>**  
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# MATHEMATICS OF CLIMATE PROTECTION

CO<sub>2</sub> emission budget (1.5-degree target) from Jan. 2020: **340 Gt CO<sub>2</sub>**  
Current level of CO<sub>2</sub> emissions: **40 Gt CO<sub>2</sub> per year**



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## Conclusions for the requirements for climate protection measures:

- **No delay: Immediate GHG reducing effect**
- **No GHG export: GHG reduction in one sector (or country) must not lead to GHG increases in other sectors (or countries)**
- **Fast roll-out: It must be possible to implement the measure quickly worldwide**

# CLIMATE PROTECTION MEASURES FOR TRANSPORT

## German Climate Protection Program (CPP) 2030:

- **Reference 1990: 164 Mt/a CO<sub>2</sub>**  
transport sector without international aviation and shipping
- **Target 2030: 95 to 98 Mt/a CO<sub>2</sub>**  
Net reduction = about -41%

# CLIMATE PROTECTION MEASURES FOR TRANSPORT

## German Climate Protection Program (CPP) 2030:

**No technology neutrality:**

**Strong focus on electric mobility**

**13,000 €/BEV German tax revenue losses = 130 billion €/10 Mio. BEV)**

Source: MWV 2020

# CLIMATE PROTECTION MEASURES FOR TRANSPORT

Measures to meet the targets of the German Climate Protection Program 2030

**4 groups of measures** (aligned with BDI, but gases shifted to group 4):

- 1. Transport shift: from road and air to rail and water\***
- 2. Efficiency: improvement in all propulsion systems**
- 3. Electric vehicles: esp. battery electric vehicles (BEV)**
- 4. Renewable fuels: liquids and gases incl. hydrogen**

**\* including cycling**

Source: BDI 2019

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# CLIMATE PROTECTION MEASURES FOR TRANSPORT

Measures to meet the targets of the German Climate Protection Program 2030

## Group 1: Transport shift:

- **Heavy road transport (>3.5 t) (ISI):** **about 40 Mt/a CO<sub>2</sub>**
- **CO<sub>2</sub> savings potential (BDI):** **> 20 Mt/a CO<sub>2</sub>**
- **Assumed CO<sub>2</sub> savings 2030 (BDI):** **7 Mt/a CO<sub>2</sub>**

Sources: Fraunhofer ISI 2018, BDI 2019

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# CLIMATE PROTECTION MEASURES FOR TRANSPORT

Measures to meet the targets of the German Climate Protection Program 2030

## Group 2: Efficiency:

- Assumed CO<sub>2</sub> savings 2030 (BDI): **15 Mt/a CO<sub>2</sub>**

**(Rebound effects not considered)**

Source: BDI 2019

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# CLIMATE PROTECTION MEASURES FOR TRANSPORT

Measures to meet the targets of the German Climate Protection Program 2030

## Group 3: Electric vehicles (BEVs only):

- **Assumed number of BEVs 2030** (aligned with BDI): **7 Mio.**
  - **CO<sub>2</sub> savings potential** (own calc.): **2.44 t CO<sub>2</sub> per car**  
**Sectoral approach (BEVs and Ren. Fuels counted with zero emission)**
  - **Resulting CO<sub>2</sub> savings 2030:** **17 Mt/a CO<sub>2</sub>**

Source: BDI 2019, own calculation

Electric vehicles = BEVs = Battery Electric Vehicles (Hybrides considered in the group 4 „Renewable Fuels“)

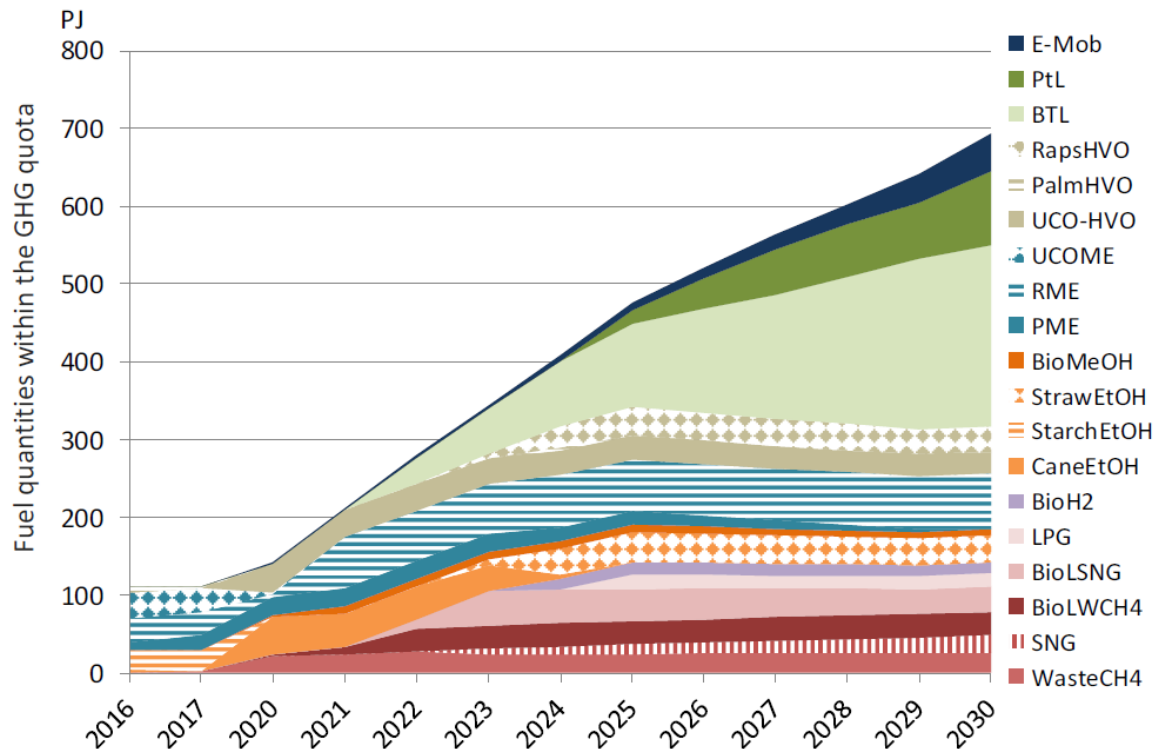
Electrification of road freight transport should be part of group 1 „Transport shift“

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# CLIMATE PROTECTION MEASURES FOR TRANSPORT

## Measures to meet the targets of the German Climate Protection Program 2030

### Group 4: Renewable fuels (liquids and gases):



Renewable fuels (DBFZ):

**650 PJ (2030) =**

**540 PJ more than 2017**

Emission factor (UBA):

**73.7 t CO<sub>2</sub>/TJ**

**(sectoral approach)**

Resulting CO<sub>2</sub> savings

**2030: 40 Mt/a CO<sub>2</sub>**

Source: DBFZ 2019; UBA 2016

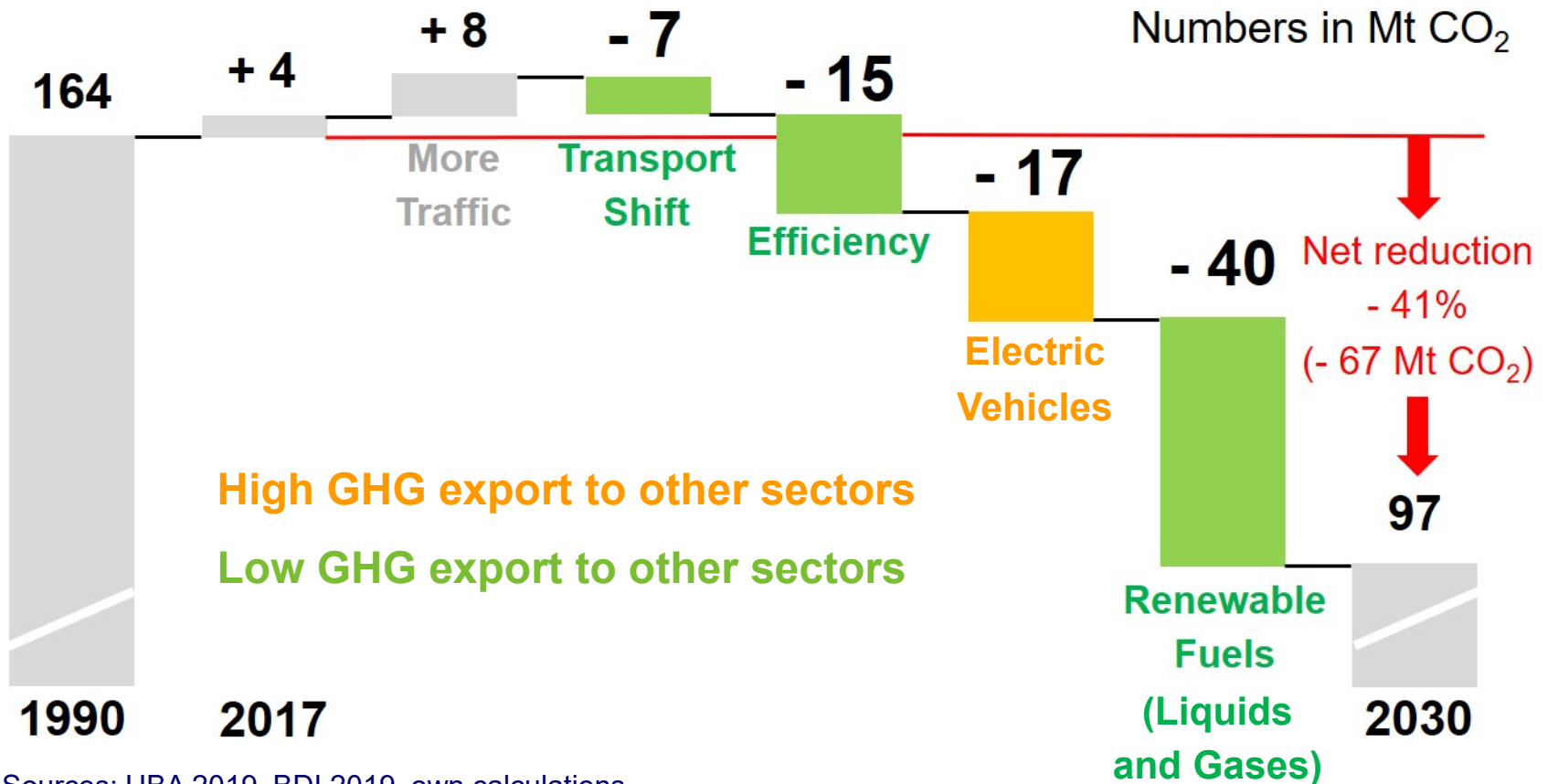
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# CLIMATE PROTECTION MEASURES FOR TRANSPORT

Measures to meet the targets of the German Climate Protection Program 2030

**Sectoral approach** (BEVs and Ren. Fuels counted with zero emission)



Sources: UBA 2019, BDI 2019, own calculations

Electric Vehicles = BEVs = Battery Electric Vehicles (Hybrides considered in pillar „ Renewable Fuels“)

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# CLIMATE PROTECTION MEASURES FOR TRANSPORT

## Real CO<sub>2</sub> emission reduction performance of BEVs

- The real CO<sub>2</sub> emissions of BEVs are much higher than zero due to:
  - CO<sub>2</sub> emissions for the battery production and
  - CO<sub>2</sub> emissions for the power mix production

# CLIMATE PROTECTION MEASURES FOR TRANSPORT

## Real CO<sub>2</sub> emission reduction performance of BEVs

### Joanneum Research (JR) study

- **Golf type car: Comparison of diesel car and BEV**
  - **Diesel fuel: 2019 to 2030: B7 (7 vol% biodiesel)**
  - **Power: 2019: 580 g CO<sub>2eq</sub>/kWh (BA<sub>nz</sub> AT 30.10.18)**  
**2030: 435 g CO<sub>2eq</sub>/kWh**
  - **Result: BEV needs 219,000 km to undercut the diesel car in CO<sub>2</sub> emissions**

Source: JR 2019; Bund 2018

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# CLIMATE PROTECTION MEASURES FOR TRANSPORT

## Real CO<sub>2</sub> emission reduction performance of BEVs

### Fraunhofer ISE study

- Hyundai SUV type car (generic):

#### Comparison of diesel car and BEV

- Diesel fuel: 2019 to 2030: fossil
- Power: 2020 to 2030: Ø 421 g CO<sub>2eq</sub>/kWh
- Result: BEV needs 160,000 km to undercut the diesel car in CO<sub>2</sub> emissions

Source: Fraunhofer ISE 2019

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# CLIMATE PROTECTION MEASURES FOR TRANSPORT

## Real CO<sub>2</sub> emission reduction performance of BEVs

### Own calculation

- **Small cars:** Comparison (basis ADAC test data) of Opel Corsa diesel car (4 l/100 km WLTP = 126 g CO<sub>2eq</sub>/km) and Renault Zoe BEV (20.3 kWh/100 km = Ø 103 g CO<sub>2eq</sub>/km)
  - **Diesel fuel:** 2019 to 2030: B7 with 6% CO<sub>2</sub> reduction
  - **Power:** 2019 to 2030: Ø 508 g CO<sub>2eq</sub>/kWh (=JR)
  - **Result:** BEV needs about 210,000 km to undercut the diesel car in CO<sub>2</sub> emissions

Sources: JR 2019; ADAC 2020; Bund 2018

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# CLIMATE PROTECTION MEASURES FOR TRANSPORT

## Real CO<sub>2</sub> emission reduction performance of BEVs

**210,000 km** driving until a BEV undercuts a status quo diesel car (B7 diesel) in CO<sub>2</sub> emissions:

**What does this mean on the time line?**

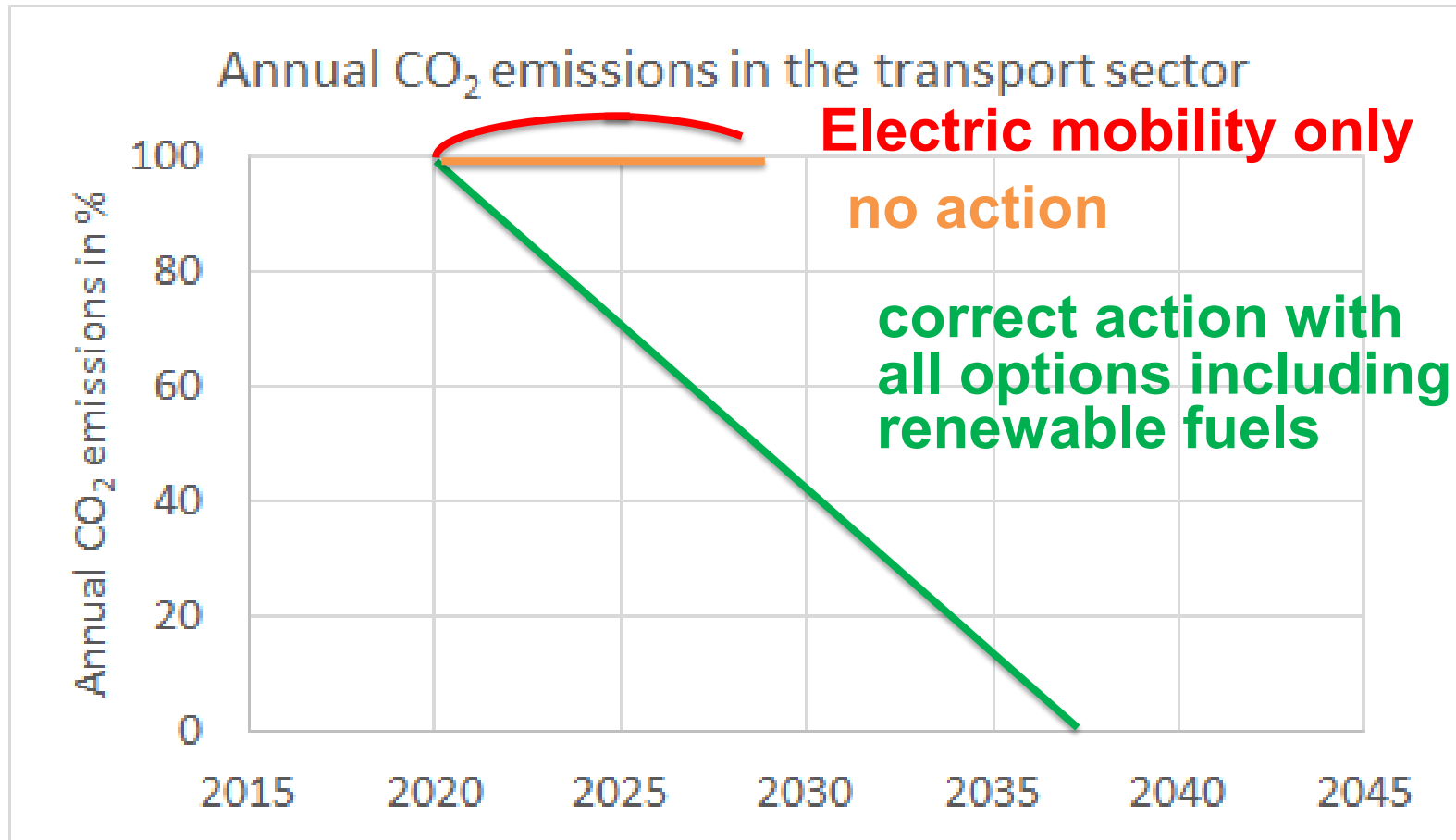
- **Ø mileage of a German gasoline car (BMVI):** **10,900 km/a**
- **Assumption for a BEV:** **10,000 km/a**
- **Result:** **A BEV needs 21 years to undercut a status quo diesel fuel car in CO<sub>2</sub> emissions**  
**= 21 years “no action” = 21 years “delay”**

Source: BMVI 2018

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# CLIMATE PROTECTION MEASURES FOR TRANSPORT

## Real CO<sub>2</sub> emission reduction performance of BEVs



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# CLIMATE PROTECTION MEASURES FOR TRANSPORT

## Real CO<sub>2</sub> emission reduction performance of BEVs

**What is the CO<sub>2</sub> savings of BEVs just based on the power mix without considering the battery production?**

- Opel Corsa diesel car: 4 l/100 km = fossil 134 g CO<sub>2eq</sub>/km
- Renault Zoe BEV: 20.3 kWh/100 km:
  - 2019: 580 g CO<sub>2eq</sub>/kWh: 118 g CO<sub>2eq</sub>/km = 12 % savings
  - 2019-2030: 508 g “ : 103 g CO<sub>2eq</sub>/km = 23 % savings
  - 2030: 435 g CO<sub>2eq</sub>/kWh: 88 g CO<sub>2eq</sub>/km = 34 % savings
  - 2030: 400 g CO<sub>2eq</sub>/kWh: 81 g CO<sub>2eq</sub>/km = 39 % savings

Sources: Bund 2018; BLE 2019; JR 2019; own calculation

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# CLIMATE PROTECTION MEASURES FOR TRANSPORT

## Real CO<sub>2</sub> emission reduction performance of BEVs

What is the CO<sub>2</sub> savings of BEVs just based on the power mix without considering the battery production?

- **Result:** CO<sub>2</sub> savings of BEVs against fossil diesel fuel in the range of 12% for 2019 or optimistically 39% for 2030 according to the power mix only is very poor.
- **For comparison:**
  - REDII for biofuels: min. 65% savings
  - Ø real average German biofuels: 83.8% (2018)
  - real German waste based biofuels: >90% (2018)

# CLIMATE PROTECTION MEASURES FOR TRANSPORT

## Real CO<sub>2</sub> emission reduction performance of BEVs

- **Overall Result:**
  - **Both the time delay and the GHG exports to the sector industry or to other countries (battery production) and to the sector energy (power mix) is by far too high.**
  - **BEVs can no longer be considered a climate protection measure for Germany or comparable boundary conditions, because it contradicts the mathematics of climate protection.**
  - **BEVs should no longer be supported from climate protection funds but rather, for example, from urban planning funds or others.**

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# CLIMATE PROTECTION MEASURES FOR TRANSPORT

## Real CO<sub>2</sub> emission reduction performance of BEVs

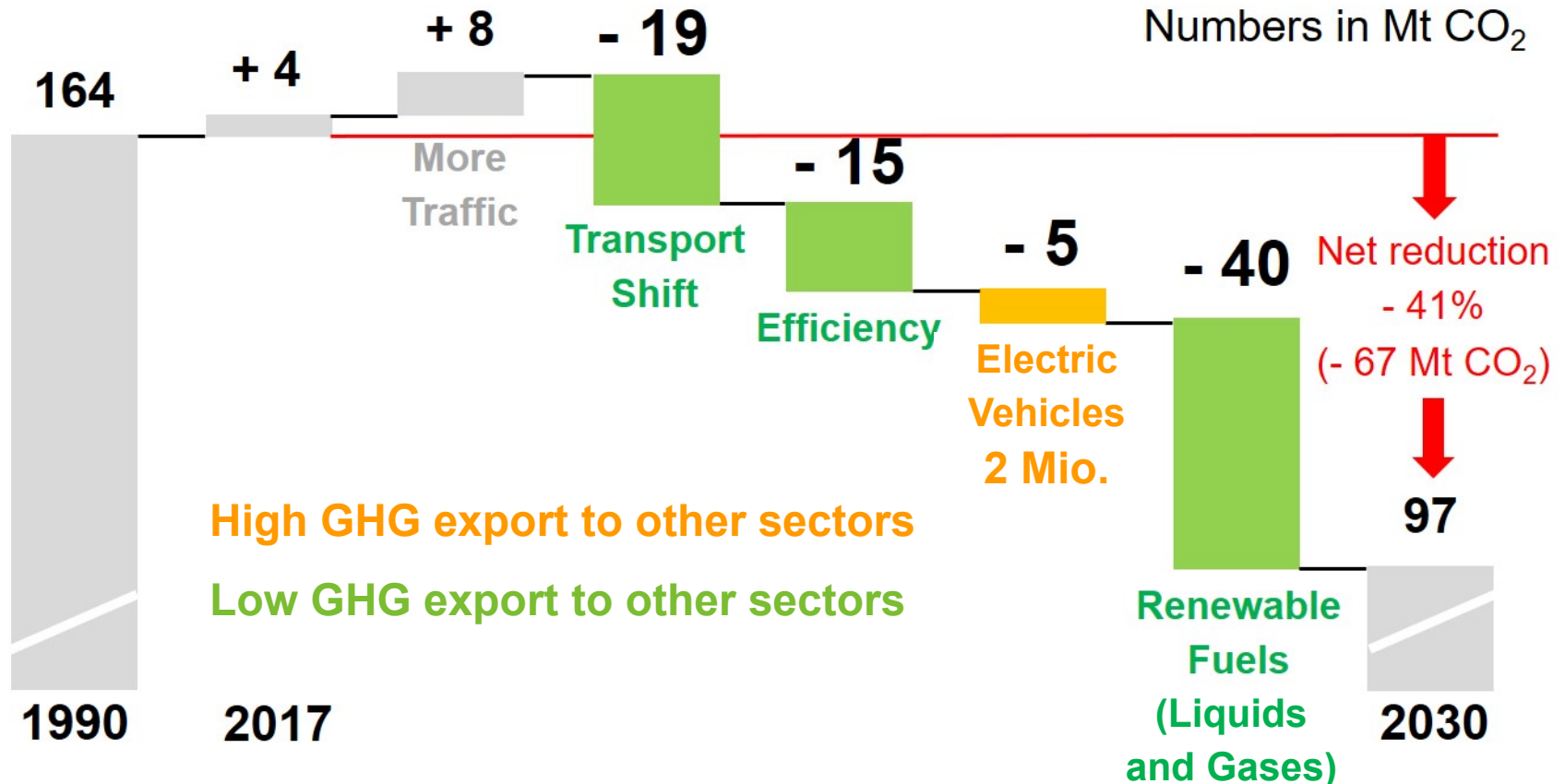
- **Recommendations for policy makers:**
  - **Electric mobility should meet the same strict sustainability criteria as renewable fuels already do today!**
    - This must include for example:
      - **Real CO<sub>2</sub> emissions including well-to-wheel (WTW)**
      - **Ecological and social issues of the lithium production in countries such as Bolivia, Chile or Argentina**
      - **Social issues of the copper mining for cobalt production in countries such as Congo**

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# CLIMATE PROTECTION MEASURES FOR TRANSPORT

Preferred scenario for the German Climate Protection Program 2030

**Sectoral approach** (BEVs and Ren. Fuels counted with zero emission)



Sources: UBA 2019, BDI 2019, own calculations

Electric Vehicles = BEVs = Battery Electric Vehicles (Hybrides considered in pillar „ Renewable Fuels“)

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# CLIMATE PROTECTION MEASURES FOR TRANSPORT

The real CO<sub>2</sub> emission reduction performance counts

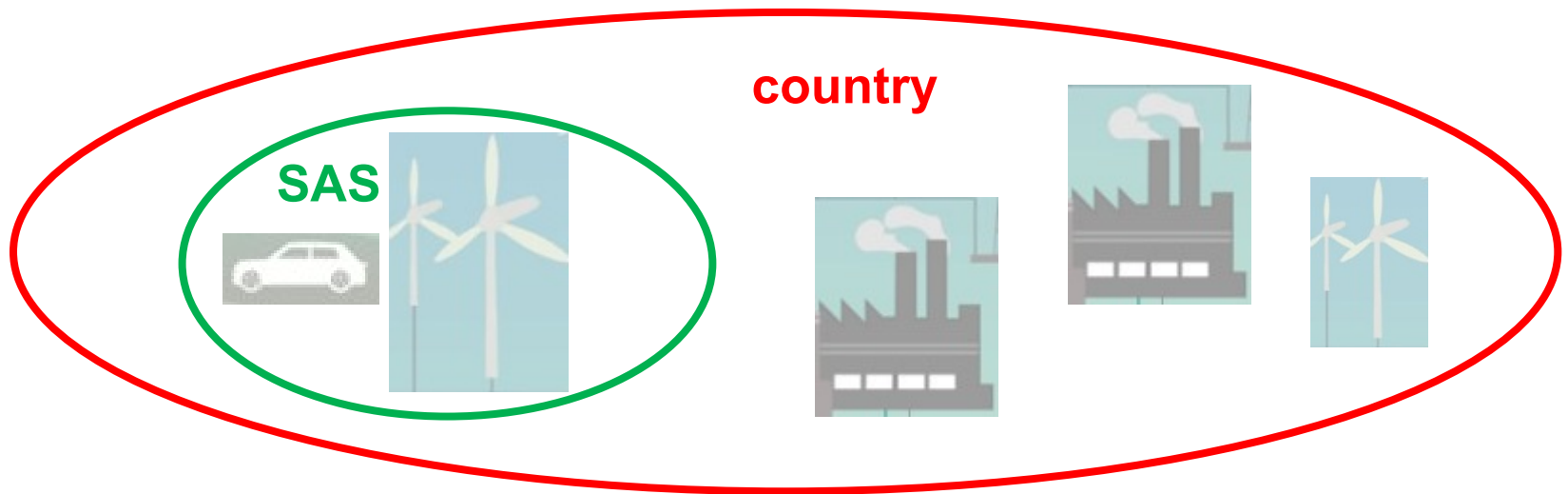
- **Recommendations for policy makers:**
  - **The best performing measures, such as transport shift and renewable fuels should be promoted the most.**
  - **The German BImSchV should be revised. The standard DIN EN 15940 for paraffinic fuels must be adopted.**
  - **The European fleet regulation system needs urgent correction: Renewable fuels must be counted towards the fleet limits. (Currently electric vehicles are counted with zero emission, but renewable fuels do not count at all.)**

# CLIMATE PROTECTION MEASURES FOR TRANSPORT

## FAQs

A company or a private person generates extra renewable energy only for the refuelling of the own BEVs (stand-alone solution SAS).

**Do these BEVs physically count as 100% renewable?**



**Answer: No, for the country counts the power mix.**

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# CLIMATE PROTECTION MEASURES FOR TRANSPORT

## FAQs

The efficiency of BEVs is very high.

**Does this count?**

**Answer: 1. The power production must be considered:**

	Today	Future 100% renewable
Power prod.:	48%	70% <b>Large capacity storage with efficiency 25% to 30%</b>
Grid:	90%	90%
Charge/Discharge:	80%	80%
Engine/Propulsion:	90%	90%
Heating/Cooling:	80%	80%
Overall efficiency:	<b>25%</b>	<b>36%</b>

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# CLIMATE PROTECTION MEASURES FOR TRANSPORT

## FAQs

The efficiency of BEVs is very high.

**Does this count?**

**Answer: 2. Renewable energy import must be considered:**

- **Germany is an energy importing country (70% today)**
- **It will remain an energy importing country**

**Renewable energy should be imported from countries with an oversupply of renewable energy in the form of hydrogen and e-fuels.**

**If these imports are in the country, it is more efficient to use them directly in FCs or CEs than to convert them into electricity for BEVs.**

FC = Fuel Cell; CE = Combustion Engine; BEV = Battery Electric Vehicle

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# CLIMATE PROTECTION MEASURES FOR TRANSPORT

## FAQs

Currently we have biodiesel, bioethanol and biogas as renewable fuels in the market. **What other options will be available?**

**Answer: BtX, WtX, PtX and hybrids**

**B = biomass including residues and waste**

**W = non-biogenic waste**

**P = power (PtX = e-fuels)**

**X = fuels and chemicals (liquids and gases)**

**Hydrogen** will play an important role

**DECHEMA Position Paper “Advanced alternative liquid fuels”**

[https://dechema.de/dechema\\_media/Downloads/Positionspapiere/2018\\_alternativeBrennstoffe\\_en.pdf](https://dechema.de/dechema_media/Downloads/Positionspapiere/2018_alternativeBrennstoffe_en.pdf)

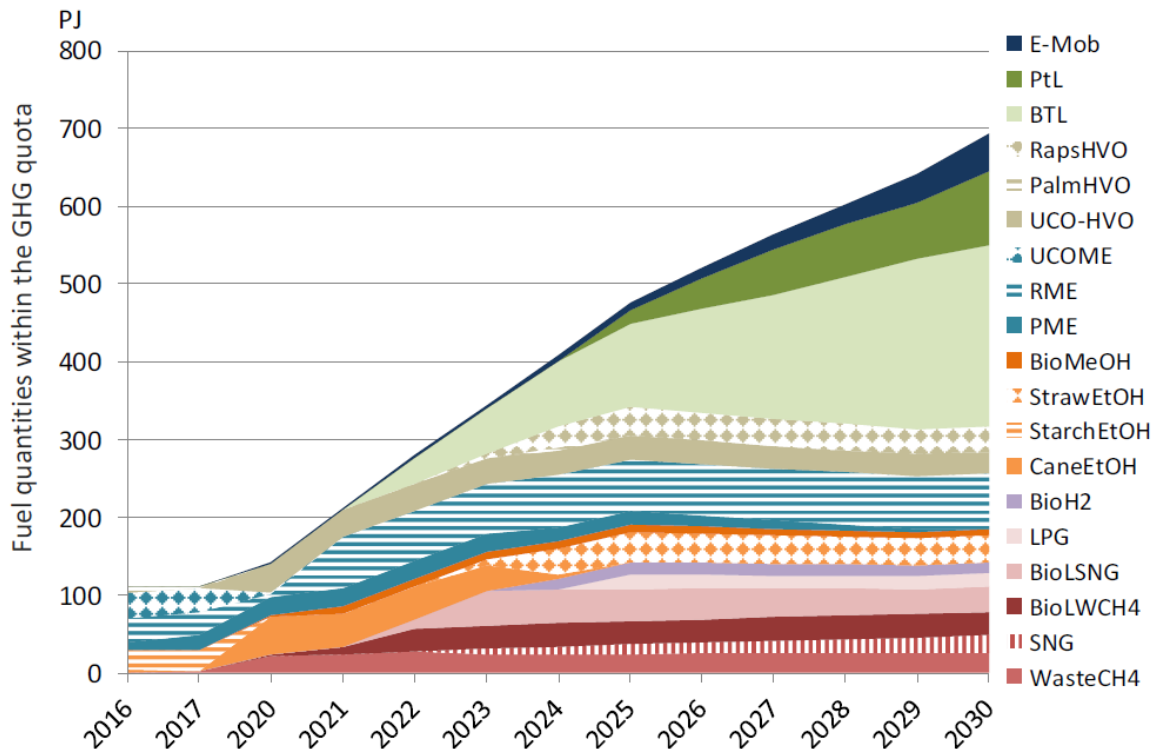
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# CLIMATE PROTECTION MEASURES FOR TRANSPORT

## FAQs

Currently we have biodiesel, bioethanol and biogas as renewable fuels in the market. **When will other options be available?**



**Answer: See studies on ramp-up curves**

**e.g. DBFZ study 2020**

Source: DBFZ 2019; DBFZ 2020

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# CLIMATE PROTECTION MEASURES FOR TRANSPORT

## FAQs

Currently the fuel price at the station is in the range of 1.20 €/Liter.

**What will renewable fuels cost?**

**Exemplary answers:**

**E-fuels (imported):** Siemens: Price is currently at a level of 2 €/ltr.,  
expected to go down to 1 €/ltr. within the next 5 years

**Waste based fuels:**

- **BtL (via Syngas):** Price level 1 €/ltr.
- **HVO:** Price level 1 €/ltr.
- **Plastic conversion:** Price well below 1 €/ltr.

**General tendency: Decreasing alternative fuel prices**

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# CLIMATE PROTECTION MEASURES FOR TRANSPORT

## FAQs

Currently we produce renewable fuels mainly from agricultural crops.

**Do renewable fuels require monocultures on this basis?**



**Answer: No,  
technologies are flexible**

**Examples:**

- **Biodiesel can be produced from any kind of vegetable or animal oil or fat or used cooking oil or ...**
- **Biogas can be produced from corn or flower meadows or food waste ...**

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# CLIMATE PROTECTION MEASURES FOR TRANSPORT

## FAQs

Currently we consume about 4.3 billion oil per year.

**Is there sufficient potential for renewable fuels?**

**Yes: Global situation:**

**Biomass growth and dying: 100 Gt/a C**

**Fossil carbon emission: 10 Gt/a C**

**Fossil carbon emission for transport: 2 Gt/a C**

**2% of the biomass carbon on the dying side would cover the total fuel demand.**

**But we do not need this, because there is**

**additional potential for waste based fuels and e-fuels**

# CLIMATE PROTECTION MEASURES FOR TRANSPORT

## FAQs

Currently we consume about 4.3 billion oil per year.

**Is there sufficient potential for renewable fuels?**

**Yes: Germany, considering the import potential from EU:**

**Potential for biofuels: 630 to 959 PJ/a**

**(CO<sub>2</sub> savings: 46 to 71 Mt/a)**

**without cropped biomass**

**plus non-biogenic waste fuels**

**plus e-fuels (imported)**

Sources:

- S2Biom Report Nov. 2016 D8.2 Vision for 1 billion dry tonnes lignocellulosic biomass as a contribution to biobased economy by 2030 in Europe
- EU Commission Sub Group on Advanced Biofuels (SGAB) Final Report March 2017
- Willner: NPM-AG2\_FG3 Workshop 29 April 2019

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**We not only need biodiversity,  
we also need technology diversity.**

**No technical monocultures.**

**“All-Electric” would be a monoculture.**

## Engineers to the front!

### Let`s start!



# SOURCES 1

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- ADAC (2019a): Allgemeiner Deutscher Automobil-Club (ADAC): „Durchwachsene Bilanz“. ADAC motorwelt 11/2019 pp 24-28.
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- Buchspies, B.; Kaltschmitt, M. (2018): „A consequential assessment of changes in greenhouse gas emissions due to the introduction of wheat straw ethanol in the context of European legislation“. In: Applied Energy 211, pp 368-381.

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