
# *Klimaneutralität und Kreislauffähigkeit: Herausforderungen und Lösungen fürs Automobil*

*Gerfried JUNGMEIER*

*FORUM JOANNEUM | Zukunft der Mobilität – Teil 1: Automobil*
*25. Februar 2025, Graz*

JOANNEUM RESEARCH LIFE

evtcp

***Austrian participation financed by***

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Climate Action, Environment,
Energy, Mobility,
Innovation and Technology

FFG

# *The Origin of Mobility*

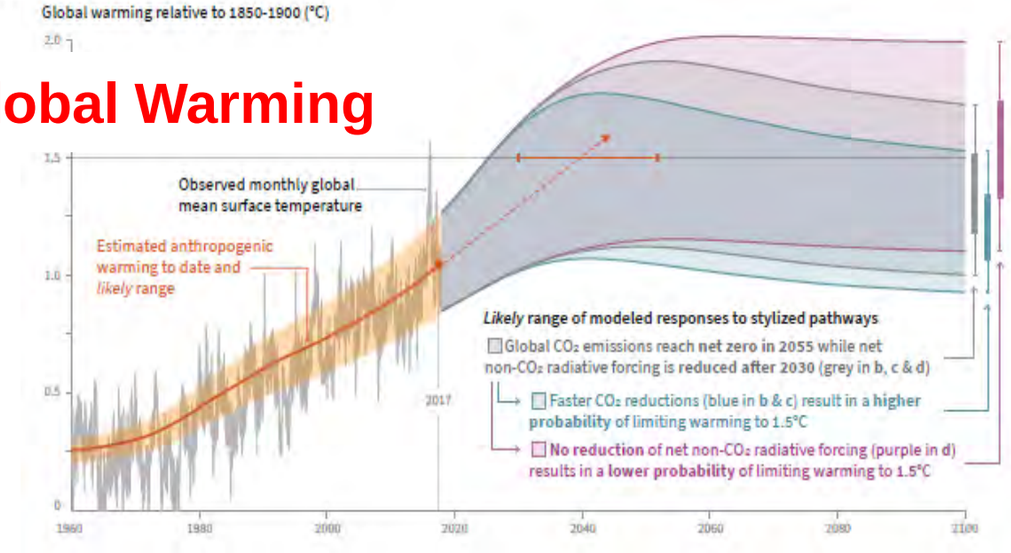
**Why** I have to go somewhere else?

**Which** possibilities do I have?

**How** do I decide?

# *The LCA Approach to Face the Challenges*

## Global Warming



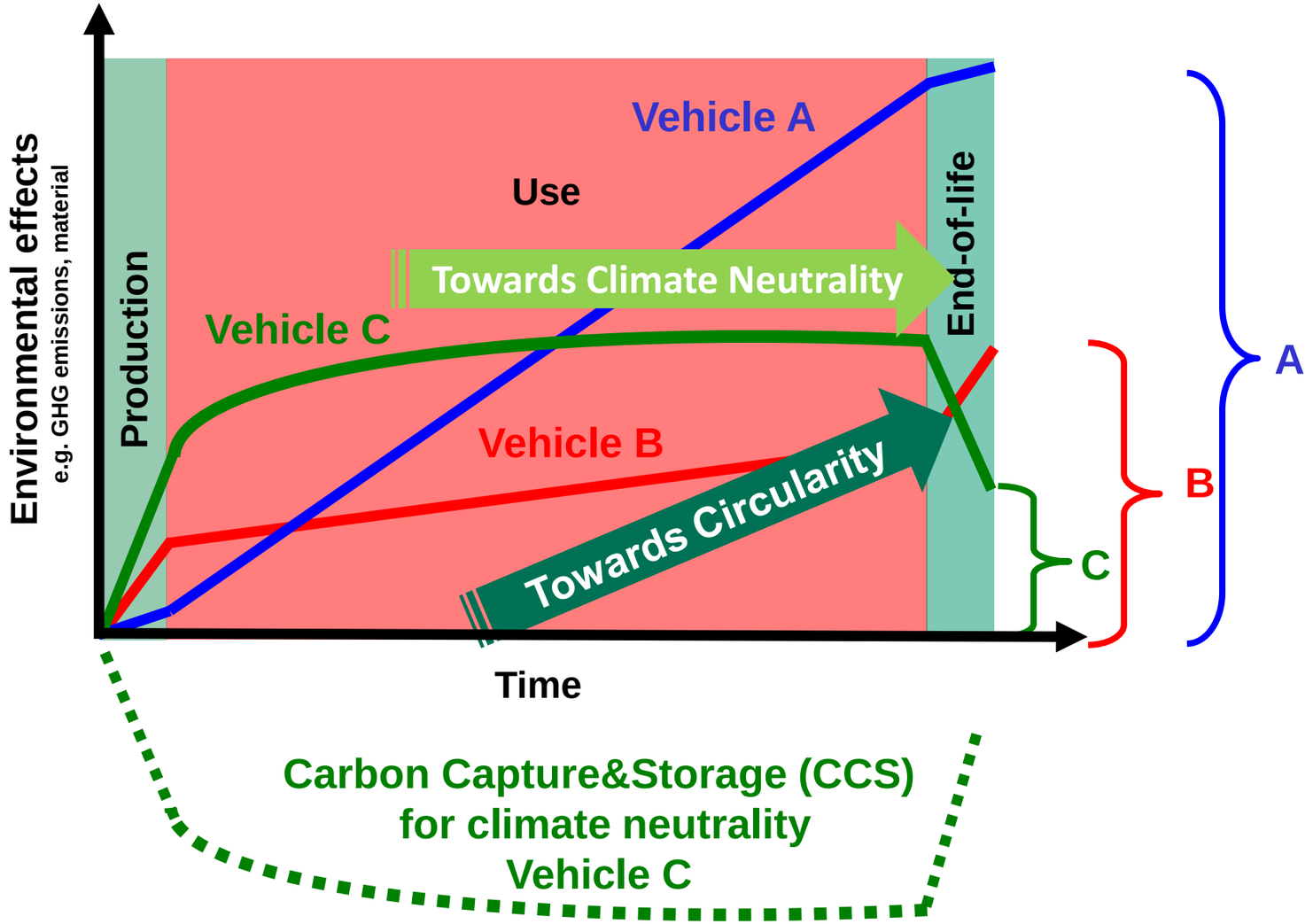

## Circularity


## Life Cycle Assessment (LCA)

- ✓ Environmental effects of products & services analysed with **Life Cycle Assessment (LCA)** covering production, use & end-of-life
- ✓ **“Climate Neutrality“** and **“Circularity“** must be addressed by dynamic Life Cycle Assessment (dLCA) considering **timing** of GHG emissions, raw material extraction, reuse & recycling.

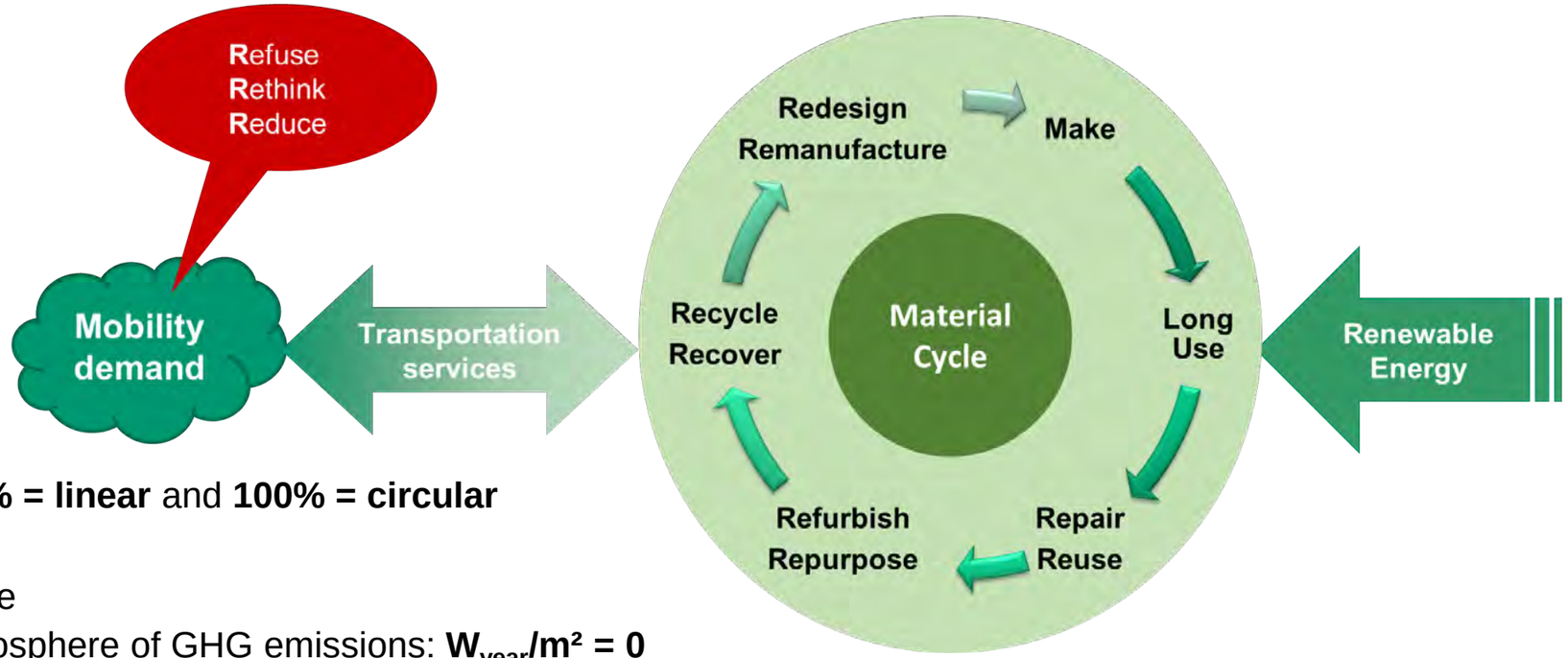
Sources: www.ipcc.ch, www.europarl.europa.eu/news/en

# *The Three Phases in Life Cycle Assessment*



# Definitions
# „Climate Neutrality“ and „Circularity“

- A **product or service** is „climate neutral“ and „circular“, if whole life cycle - production, operation & end-of-life
  - **uses only**
    - reused components
    - recycled material
    - renewable energy
  - **makes**
    - zero waste and
    - zero GHG emissions
- **Indicators for assessment**
  - **Circularity Potential**
    - based on mass balance in lifetime
    - Material Circularity Index (MCI): **0% = linear** and **100% = circular**
  - **Climate Neutrality Potential**
    - based on GHG emissions in lifetime
    - total radiative forcing at top-of atmosphere of GHG emissions: **$W_{year}/m^2 = 0$**
    - „Towards“ climate neutrality“: Zero GHG emissions in operation phase



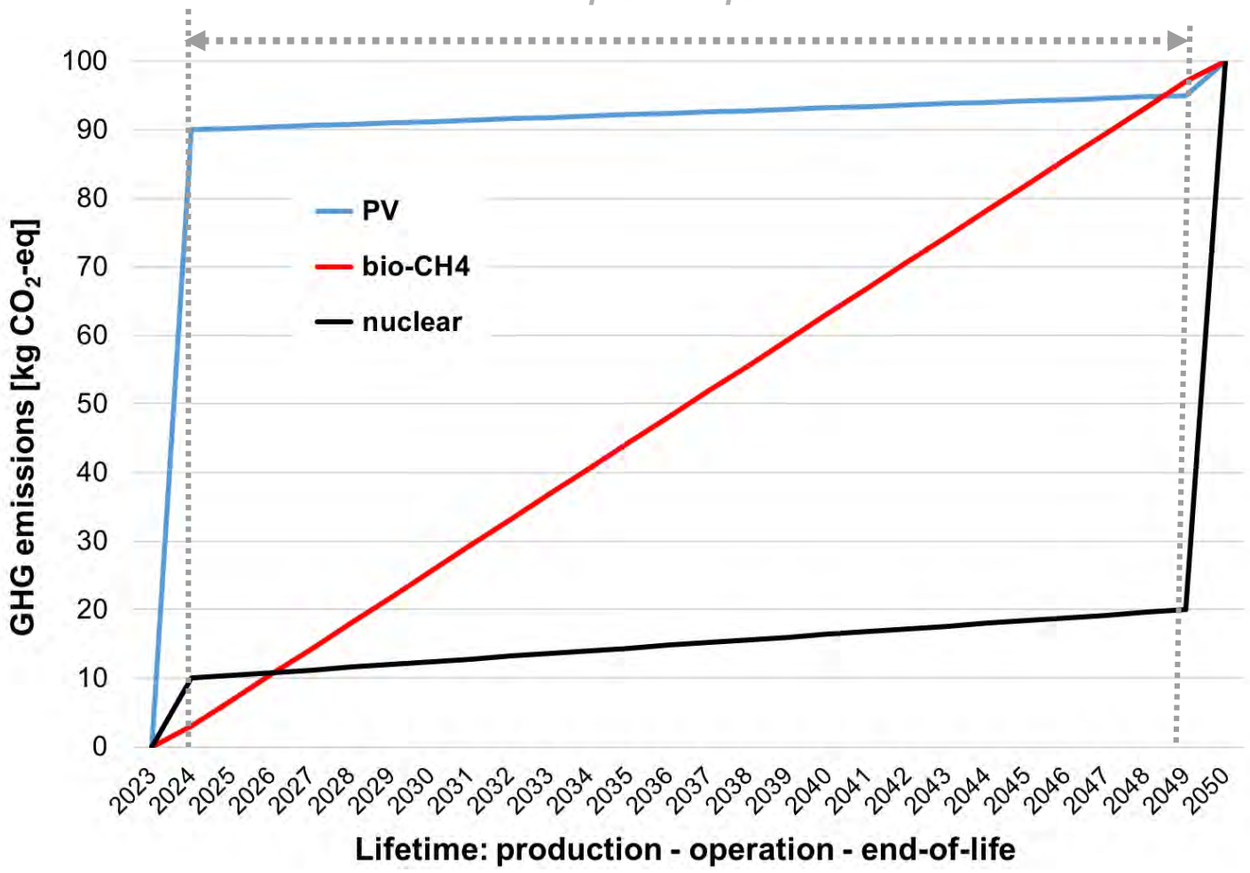

- **Concluding**
  - *Climate Neutrality* and *Circularity* are visionary and long term targets
  - **BUT**: future products and services must be developed and assessed ***towards*** *Climate Neutrality* and *Circularity*

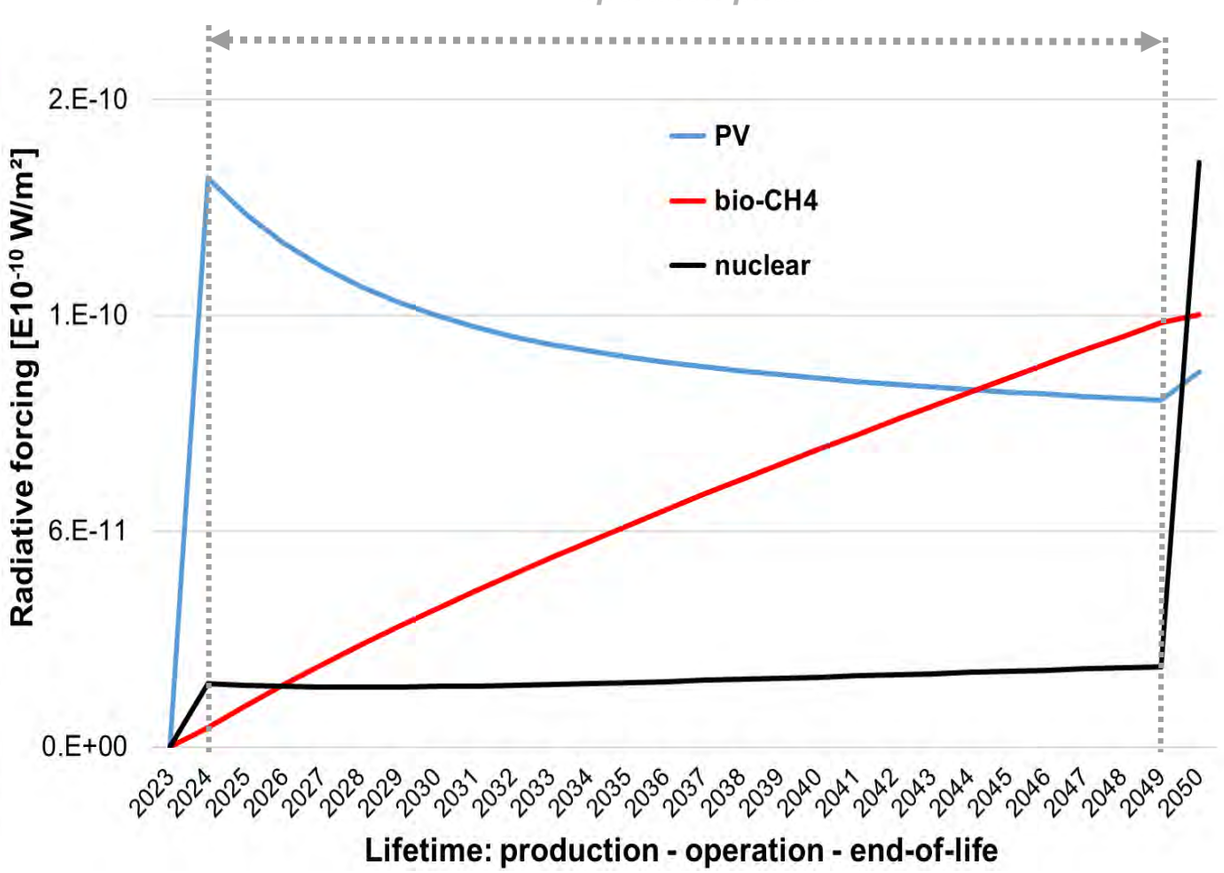
# *Same GHG Emissions but Different Climate Neutrality Potential!*

## GHG emissions

## Climate Neutrality Potential

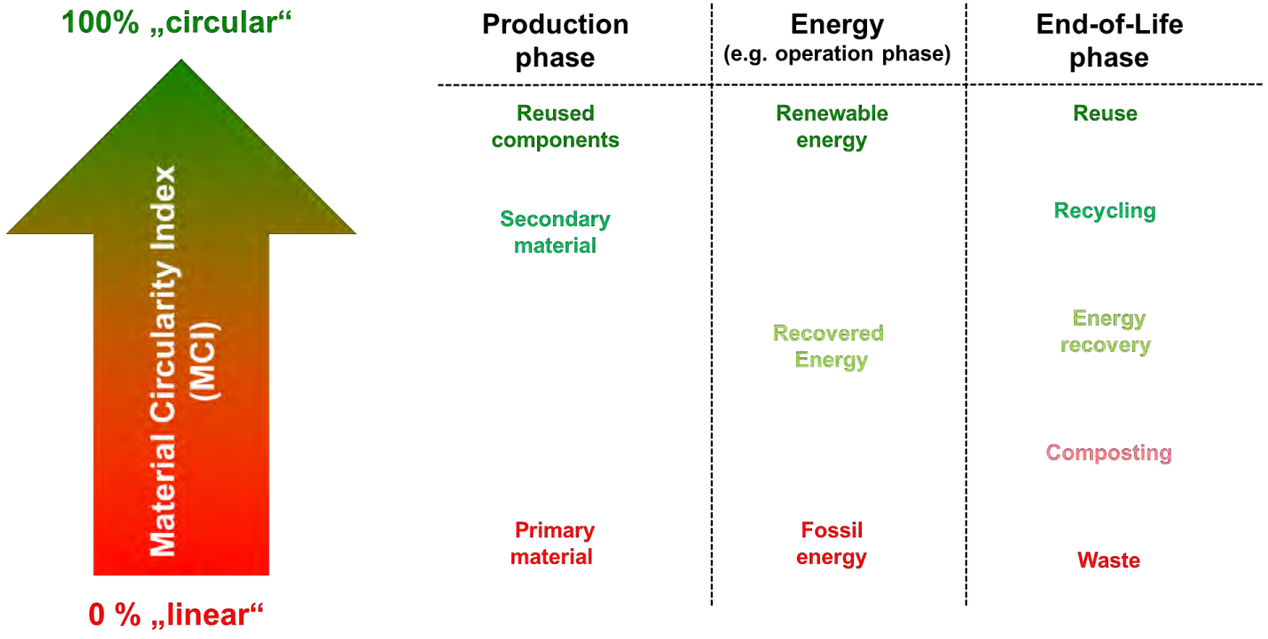
*Same service and lifetime*



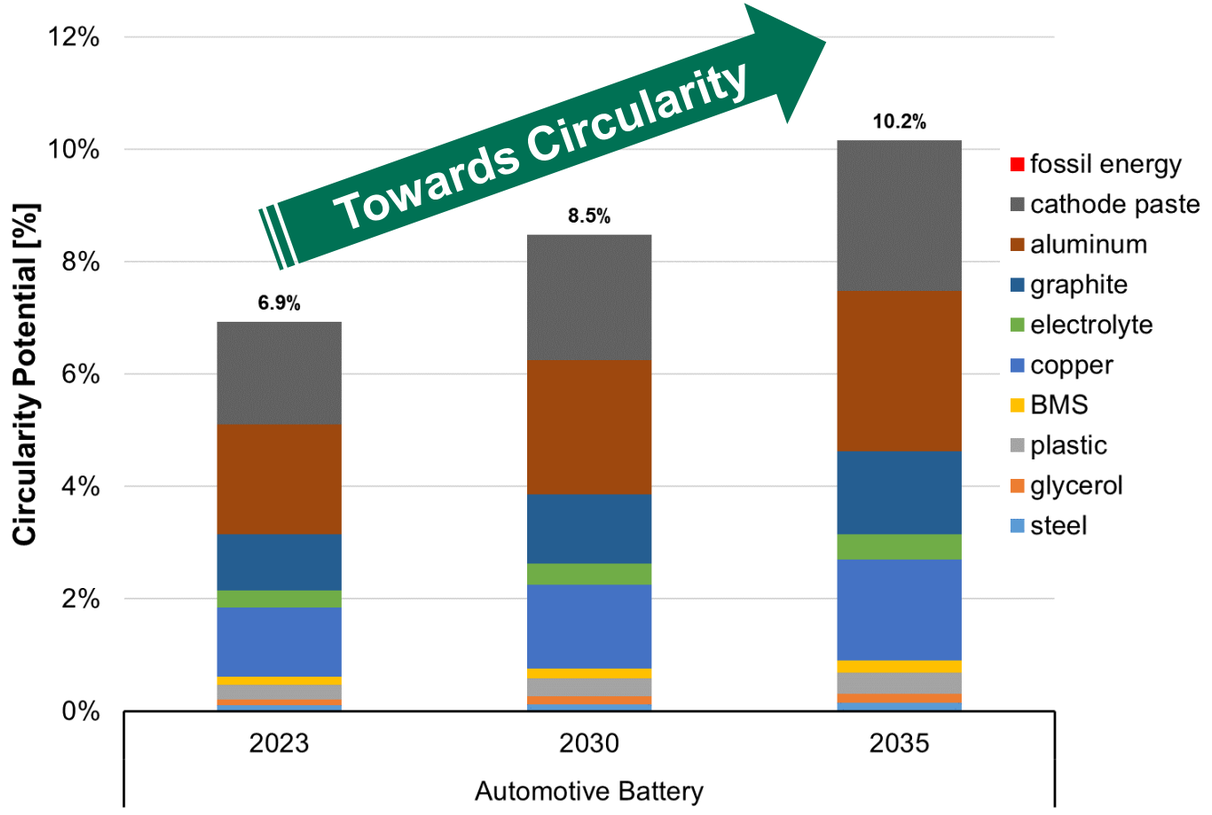



# The Circularity Potential

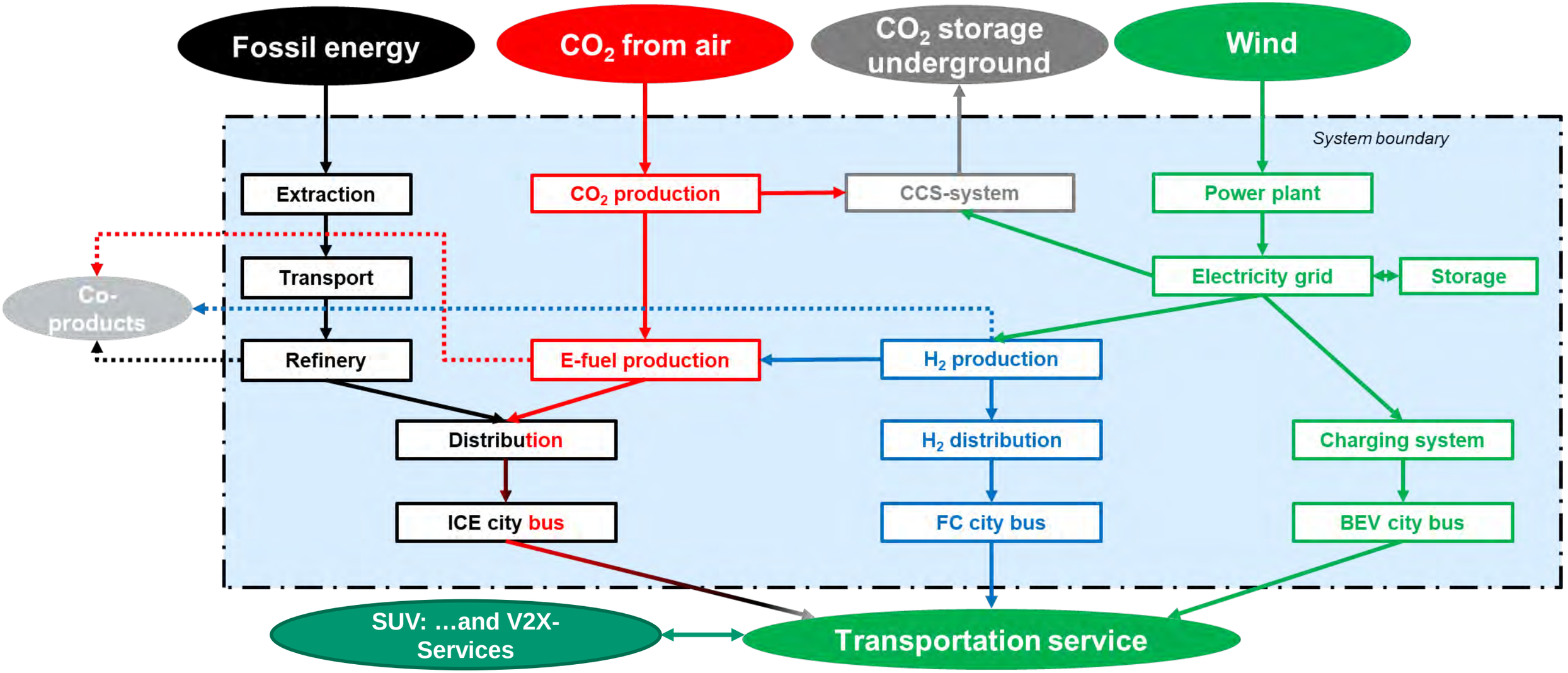
- **Linear Flow Index ($LFI_{material}$):** material specific
- **Utility Factor ($UF_{product}$):** utilisation specific
  - Intensitity of use: e.g. different payloads
  - Lifetime: e.g. different lifetimes of vehicle (12a) & energy supply (30 a)
- **Material Circularity Index (MCI)**
  - Application product specific (e.g. battery, bus, power plant)
  - $MCI = LFI_{materials} * UF_{product}$




Example: New EU Battery Regulation

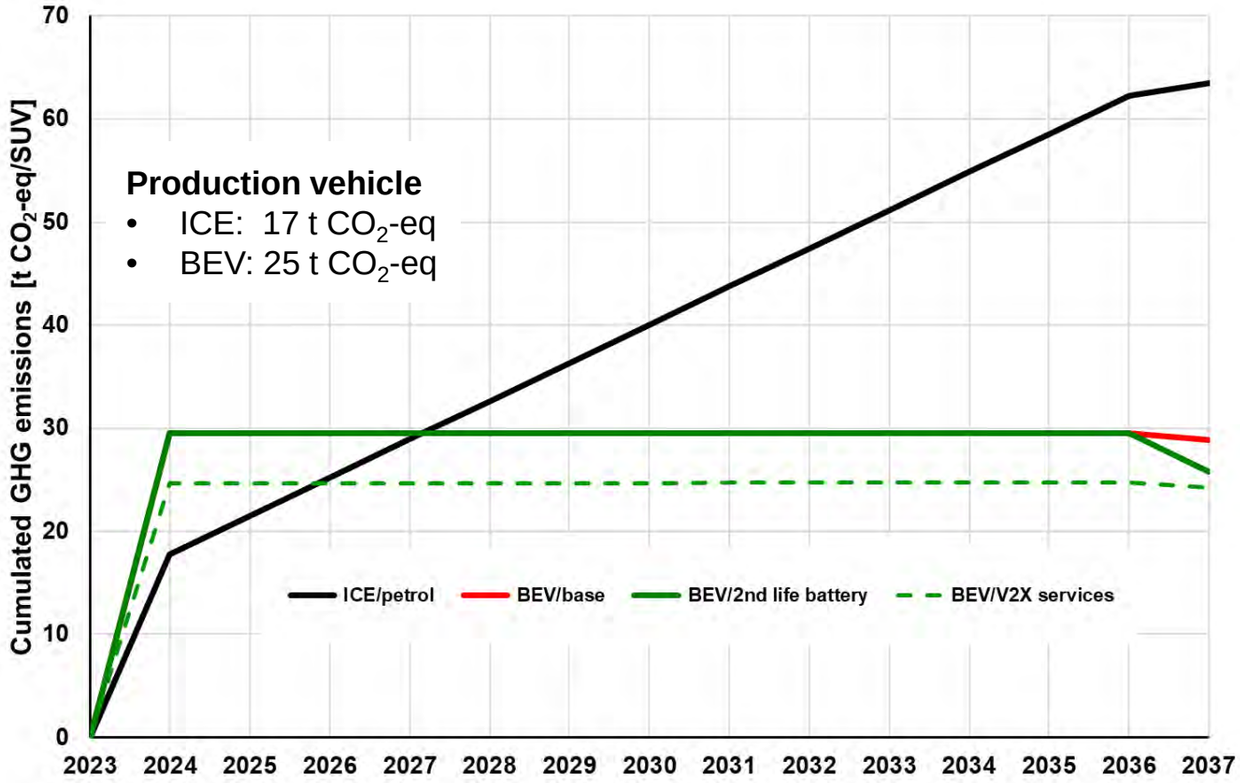


# LCA Case Studies – SUV and Buses

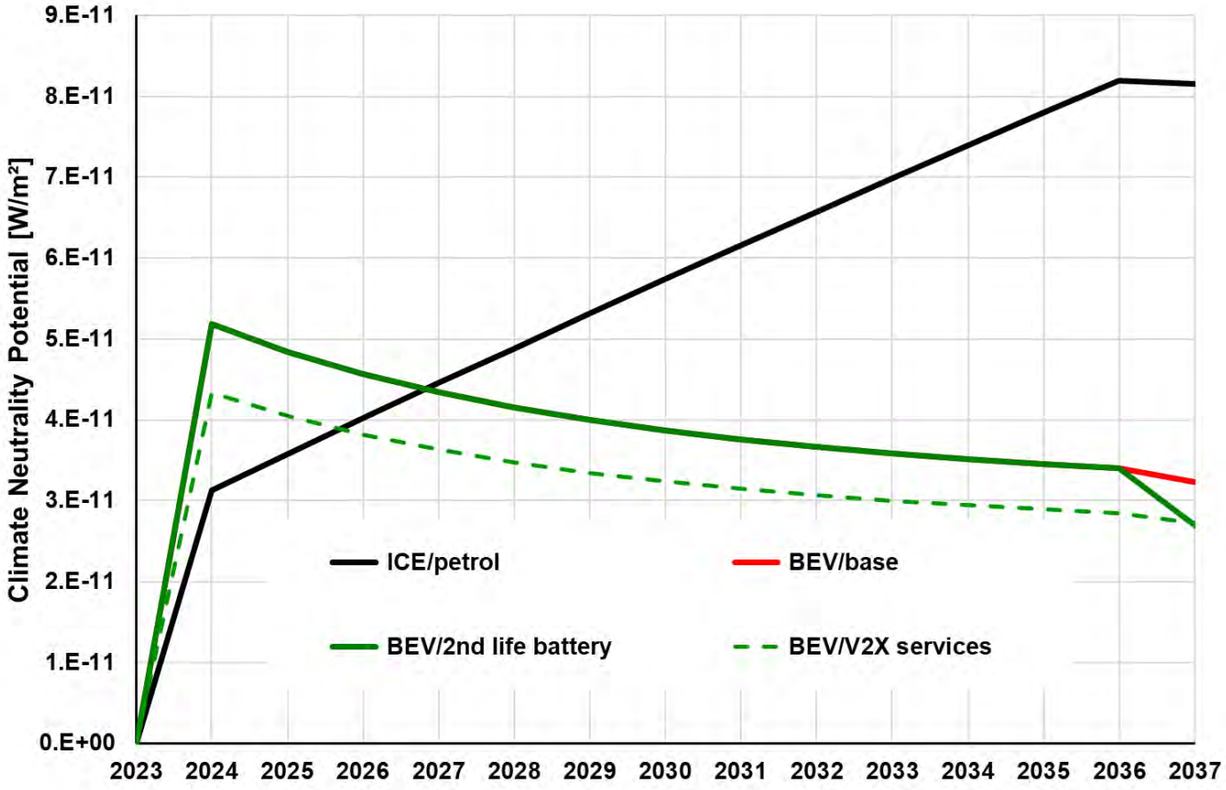



# *Climate Impacts of SUV – BEV with V2X-Services*

## GHG Emissions

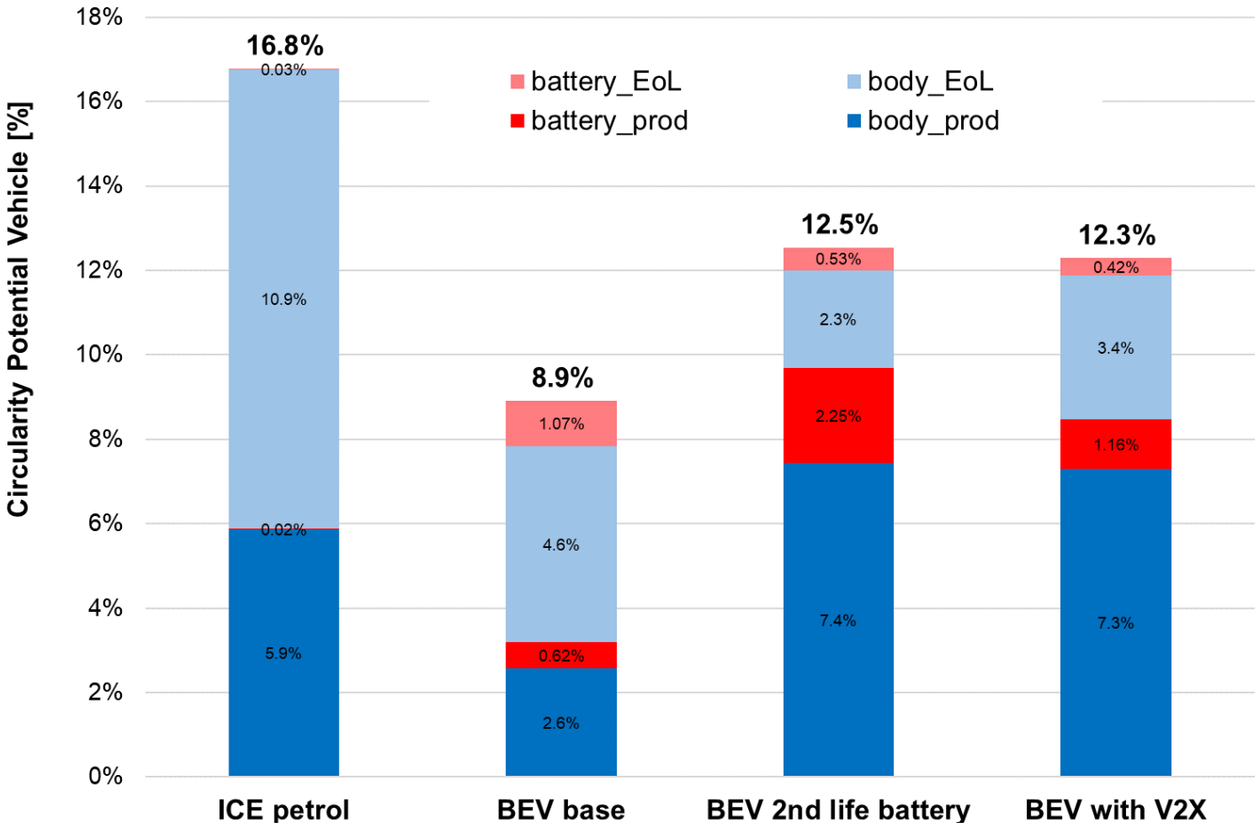



## Climate Neutrality Potential

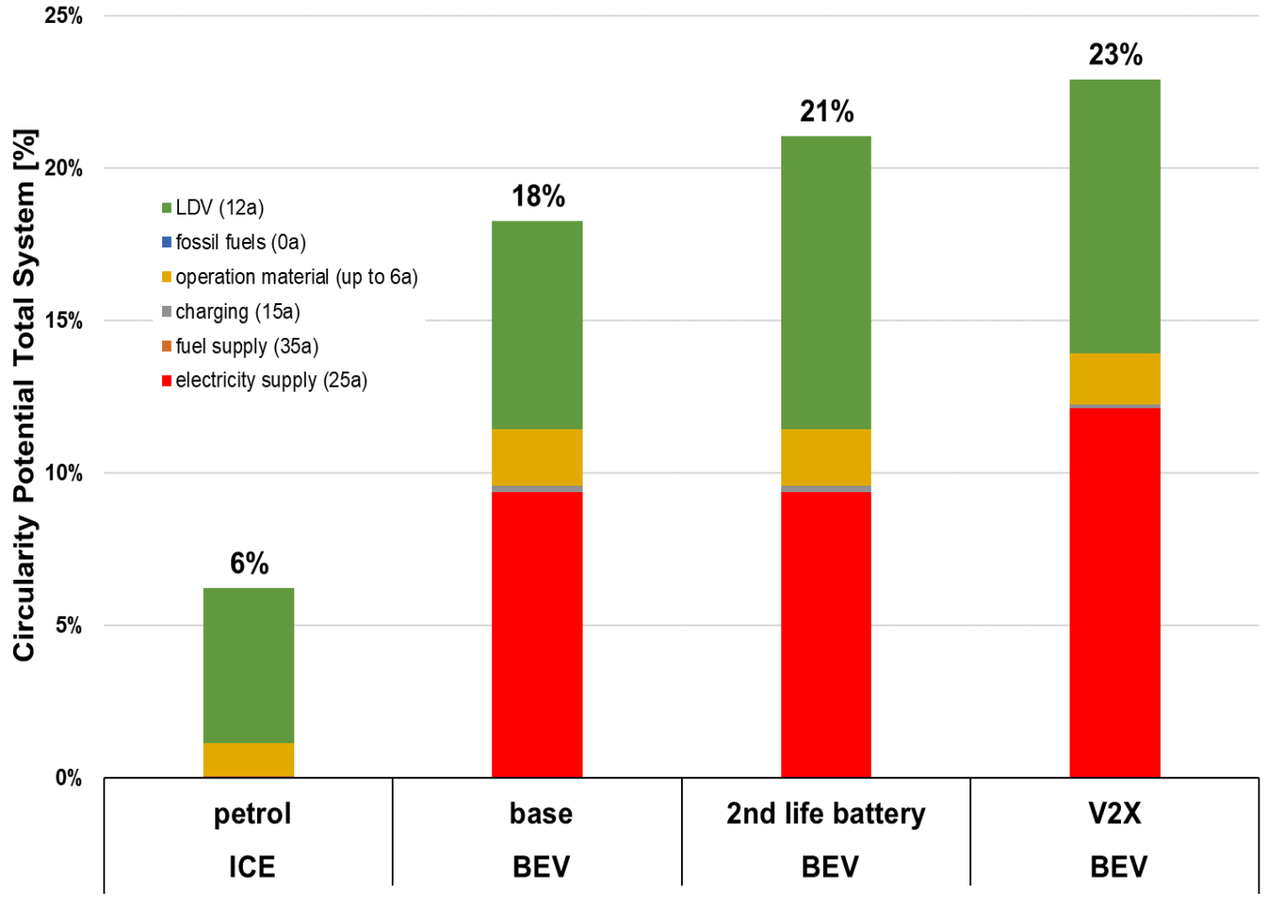


# Circularity Potential of SUV

## Vehicle only




## Total system (incl. energy supply)



# *IEA EV Task 46: LCA of Electric Trucks, Other Vehicles and V2X-Services*

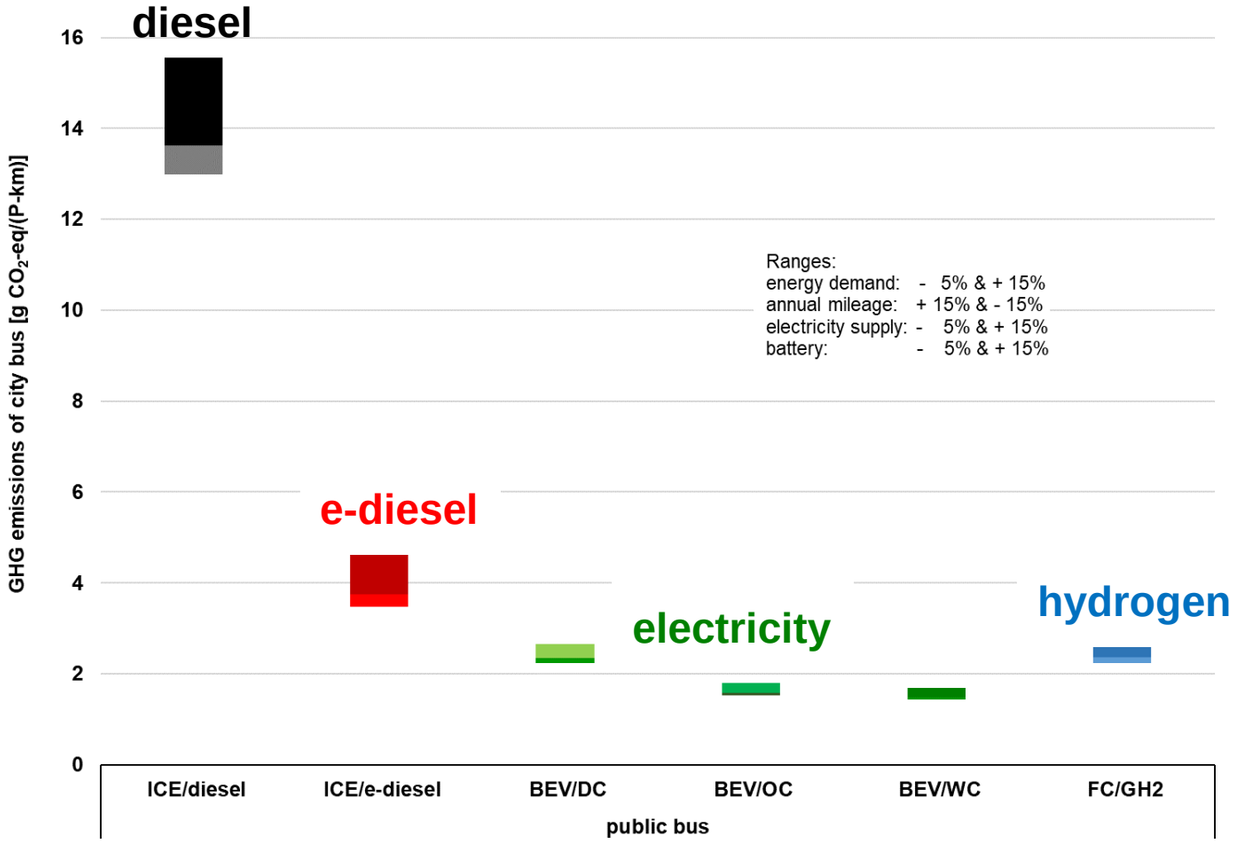
- **Frame: Technology Cooperation Programm (TCP) of International Energy Agency (IEA) with 20 countries**
- **12 Participants in LCA Task**
  - **Argonne (US):** Jarod Kelly
  - **DLR (DE):** Simone Ehrenberger, Janna Ferdouse
  - **European Commission:** Guido Sacchetto (DG R&I), Dina Silina (DG CLIMA), Carlo de Grandis (DG R&I),
  - **Government of The Netherlands (NL):** Wilco Fiechter, Yvonne Boesten
  - **IREC (ES):** Víctor José Ferreira Ferreira
  - **JOANNEUM RESEARCH (AT):** Gerfried Jungmeier
  - **University of Waterloo (CA):** XiaoYu Wu
  - **Norwegian Centre for Transport Research (NO):** Linda Ager-Wick Ellingsen
  - **Ricardo Energy & Environment (UK):** Nikolas Hill, Marco Raugei
  - **PSI (CH):** Christian Bauer
  - **Univercity of Ulsam (KR):** Ocktaeck Lim
  - **TCP AMF (finished)**
    - **„Task 64 - E-fuels and End-use Perspective“:** Zoe Stadler
    - **„Trucks/buses“:** Petri Söderena
- **2 Observers**
  - **Sabanci Universitesi (TR):** Tugce Yuksel
  - **Transport Energy/Emission Research (AUS)**: Robin Smit
- **Task Manager**
  - **Gerfried Jungmeier**, JOANNEUM RESEARCH, AT
  - **Simone Ehrenberger**, DLR (vice), DE

*Austrian participation financed by*

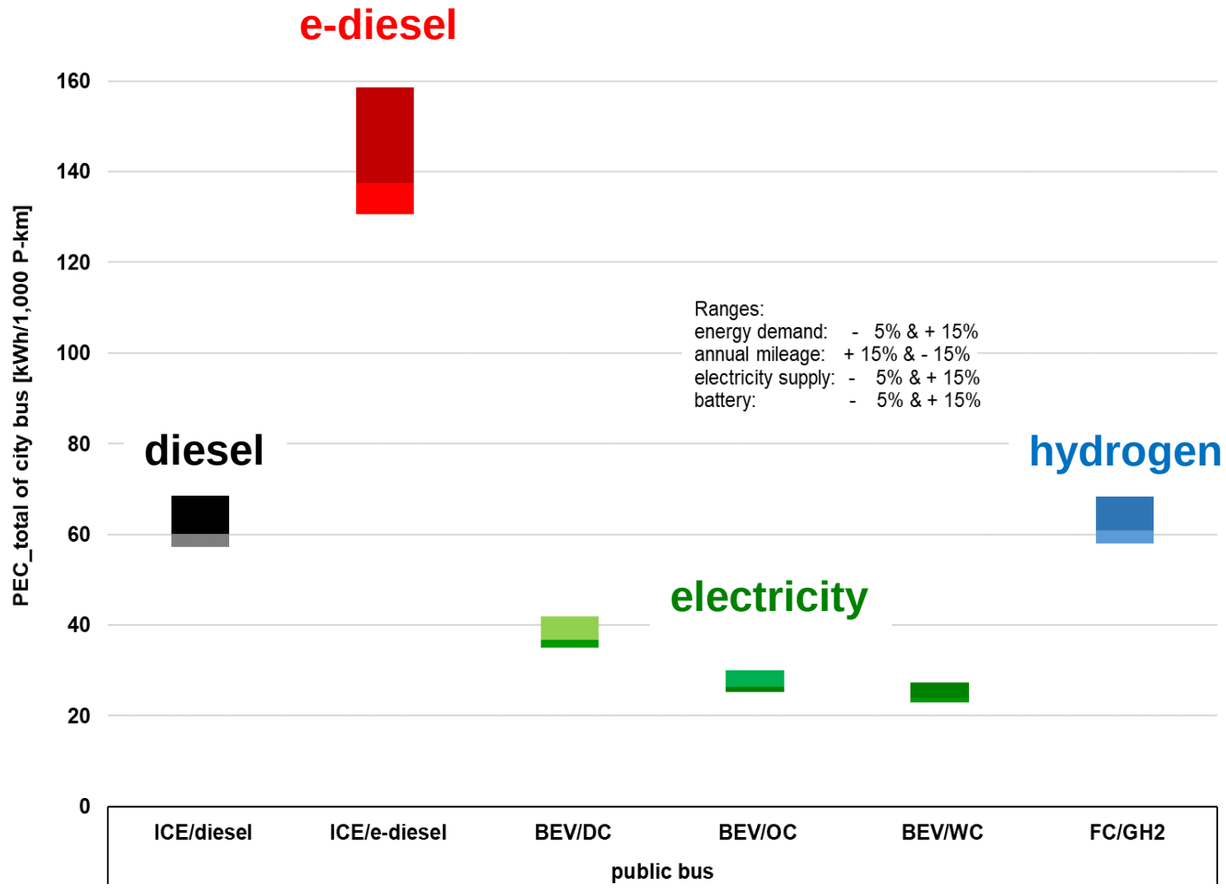
https://evtcp.org/task/task-46/

# *Impacts of City Buses*

## GHG emissions

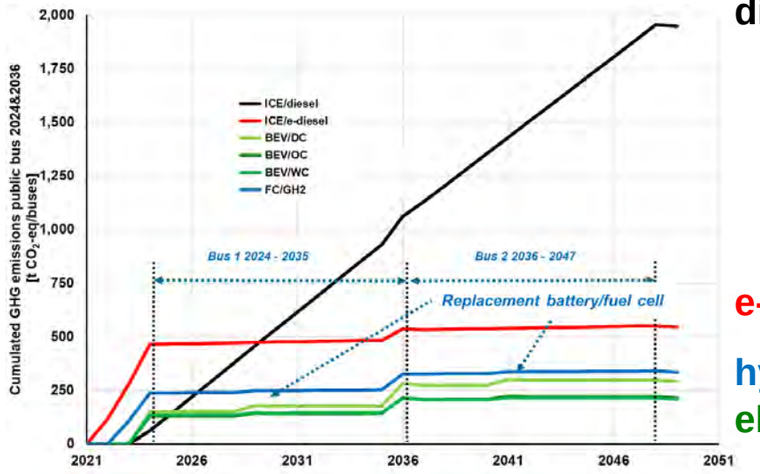



## Primary energy



# Results of dynamic LCA of Buses

## GHG Emissions



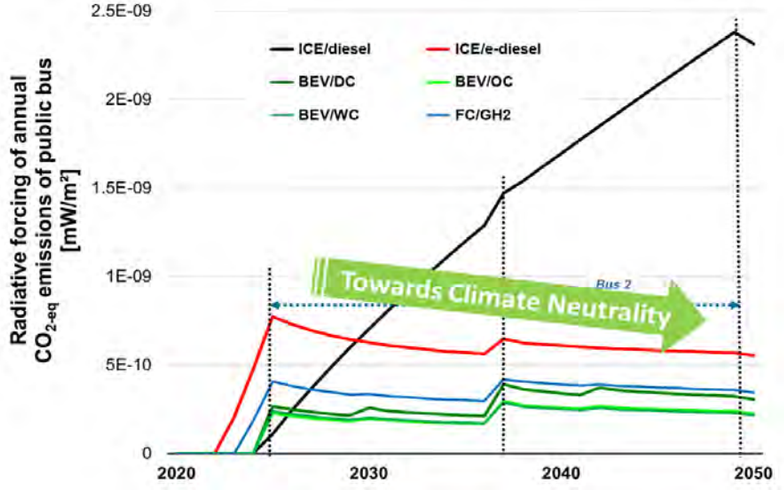

diesel

e-diesel

hydrogen

electricity

## Climate Neutrality Potential 2050



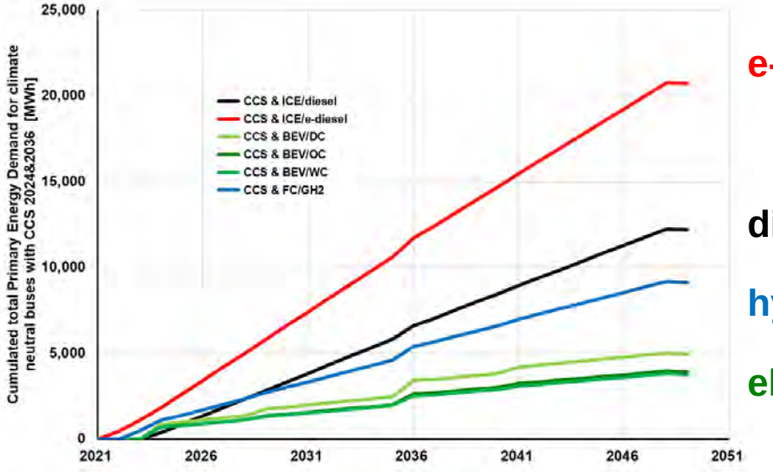

diesel

e-diesel

hydrogen

electricity

## Primary Energy Demand



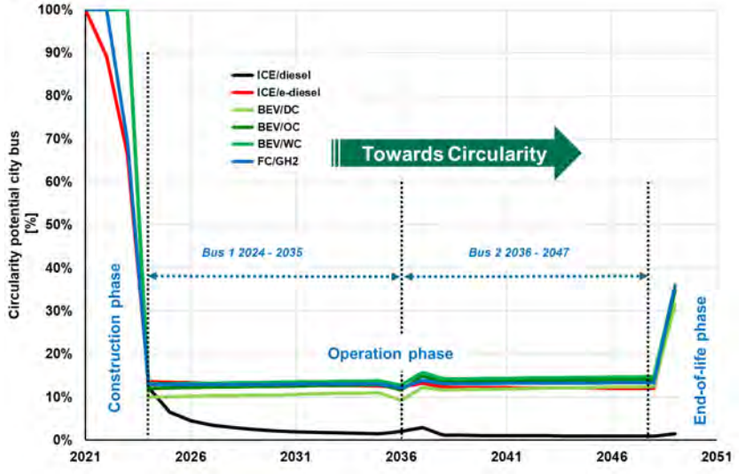

e-diesel

diesel

hydrogen

electricity

## Circularity Potential



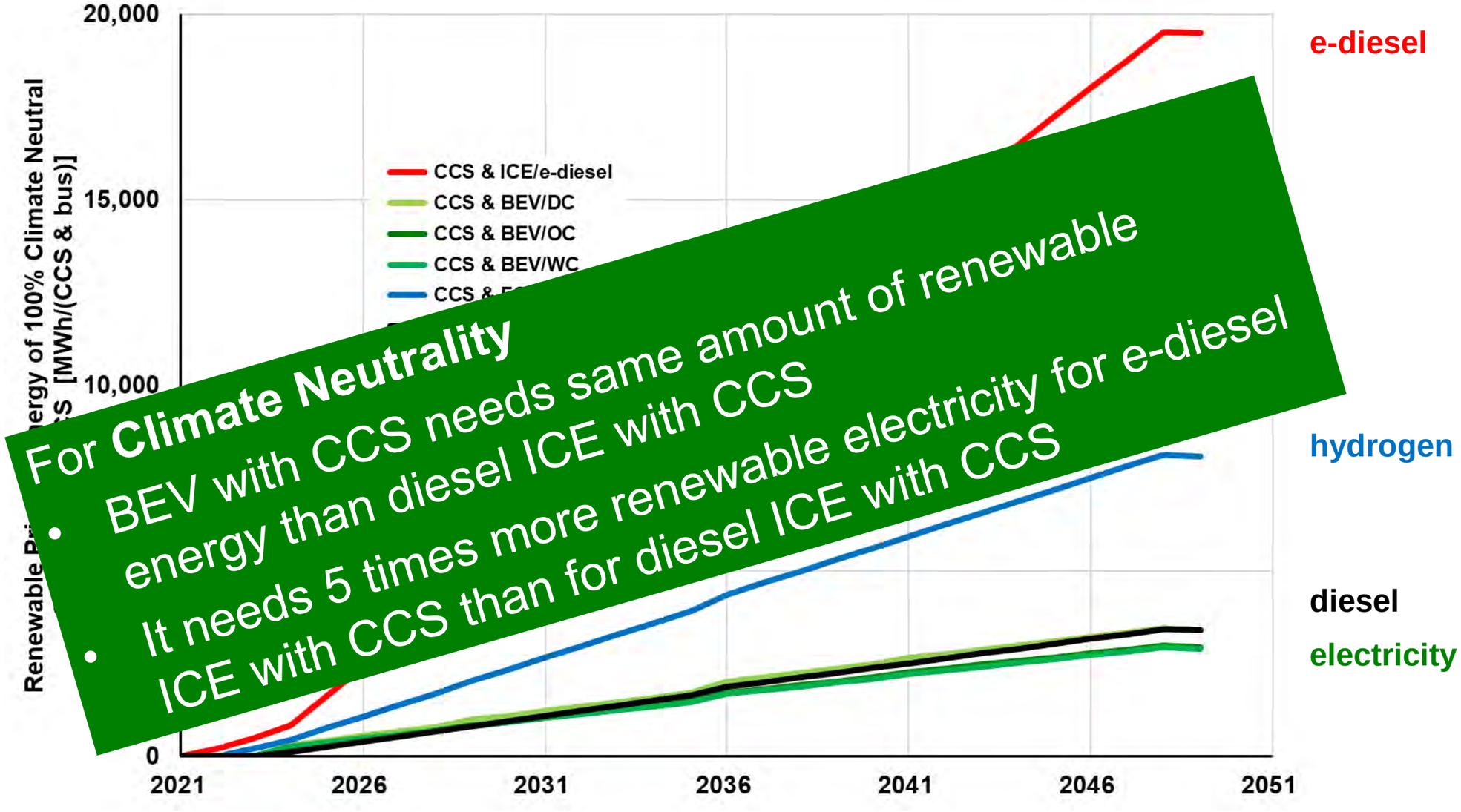

electricity

hydrogen

e-diesel

diesel

# *Renewable Primary Energy of „100% Climate Neutral“ Buses with CCS*

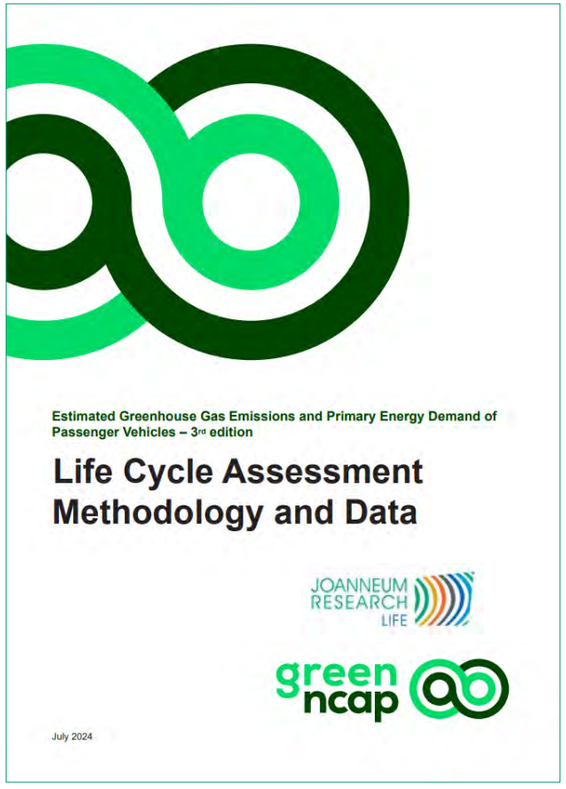



For **Climate Neutrality**

- BEV with CCS needs same amount of renewable energy than diesel ICE with CCS
- It needs 5 times more renewable electricity for e-diesel ICE with CCS than for diesel ICE with CCS

# Transparency in LCA is Key!

## Online LCA Tool for more than 30,000 Passenger Vehicles in Europe



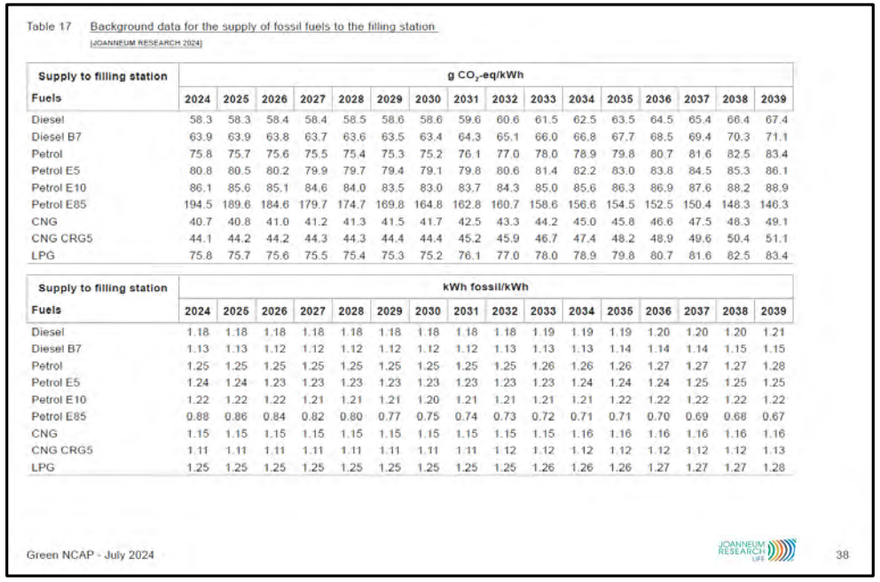
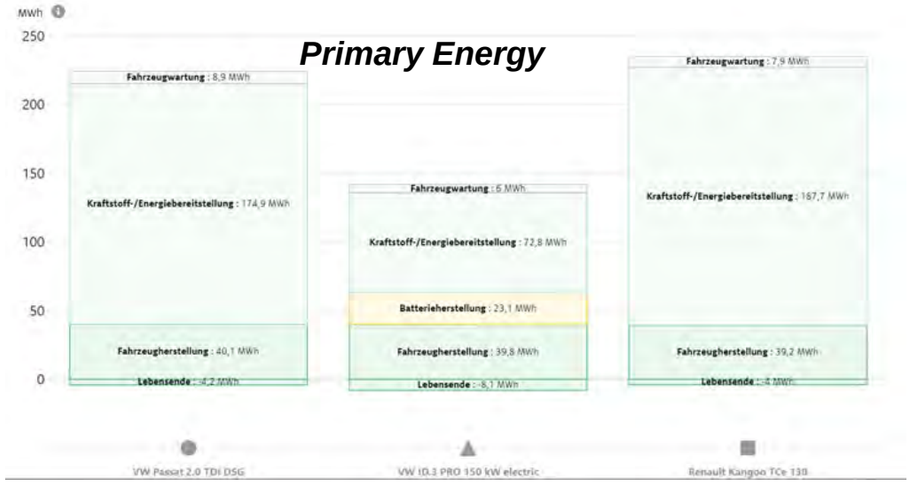



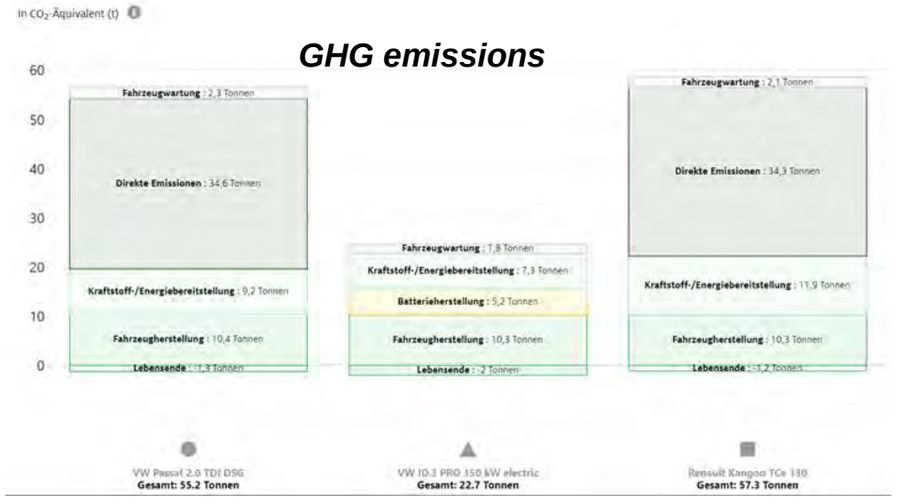
Table 17 Background data for the supply of fossil fuels to the filling station
[JOANNEUM RESEARCH 2024]

| Supply to filling station | g $CO_2$-eq/kWh | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fuels | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 |
| Diesel | 58.3 | 58.3 | 58.4 | 58.4 | 58.5 | 58.6 | 58.6 | 59.6 | 60.6 | 61.5 | 62.5 | 63.5 | 64.5 | 65.4 | 66.4 | 67.4 |
| Diesel B7 | 63.9 | 63.9 | 63.8 | 63.7 | 63.6 | 63.5 | 63.4 | 64.3 | 65.1 | 66.0 | 66.8 | 67.7 | 68.5 | 69.4 | 70.3 | 71.1 |
| Petrol | 75.8 | 75.7 | 75.6 | 75.5 | 75.4 | 75.3 | 75.2 | 76.1 | 77.0 | 78.0 | 78.9 | 79.8 | 80.7 | 81.6 | 82.5 | 83.4 |
| Petrol E5 | 80.8 | 80.5 | 80.2 | 79.9 | 79.7 | 79.4 | 79.1 | 79.8 | 80.6 | 81.4 | 82.2 | 83.0 | 83.8 | 84.5 | 85.3 | 86.1 |
| Petrol E10 | 86.1 | 85.6 | 85.1 | 84.6 | 84.0 | 83.5 | 83.0 | 83.7 | 84.3 | 85.0 | 85.6 | 86.3 | 86.9 | 87.6 | 88.2 | 88.9 |
| Petrol E85 | 194.5 | 189.6 | 184.6 | 179.7 | 174.7 | 169.8 | 164.8 | 162.8 | 160.7 | 158.6 | 156.6 | 154.5 | 152.5 | 150.4 | 148.3 | 146.3 |
| CNG | 40.7 | 40.8 | 41.0 | 41.2 | 41.3 | 41.5 | 41.7 | 42.5 | 43.3 | 44.2 | 45.0 | 45.8 | 46.6 | 47.5 | 48.3 | 49.1 |
| CNG CRG5 | 44.1 | 44.2 | 44.2 | 44.3 | 44.3 | 44.4 | 44.4 | 45.2 | 45.9 | 46.7 | 47.4 | 48.2 | 48.9 | 49.6 | 50.4 | 51.1 |
| LPG | 75.8 | 75.7 | 75.6 | 75.5 | 75.4 | 75.3 | 75.2 | 76.1 | 77.0 | 78.0 | 78.9 | 79.8 | 80.7 | 81.6 | 82.5 | 83.4 |

| Supply to filling station | kWh fossil/kWh | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fuels | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 |
| Diesel | 1.18 | 1.18 | 1.18 | 1.18 | 1.18 | 1.18 | 1.18 | 1.18 | 1.18 | 1.19 | 1.19 | 1.19 | 1.20 | 1.20 | 1.20 | 1.21 |
| Diesel B7 | 1.13 | 1.13 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 | 1.13 | 1.13 | 1.13 | 1.14 | 1.14 | 1.14 | 1.15 | 1.15 |
| Petrol | 1.25 | 1.25 | 1.25 | 1.25 | 1.25 | 1.25 | 1.25 | 1.25 | 1.25 | 1.26 | 1.26 | 1.26 | 1.27 | 1.27 | 1.27 | 1.28 |
| Petrol E5 | 1.24 | 1.24 | 1.23 | 1.23 | 1.23 | 1.23 | 1.23 | 1.23 | 1.23 | 1.23 | 1.24 | 1.24 | 1.24 | 1.25 | 1.25 | 1.25 |
| Petrol E10 | 1.22 | 1.22 | 1.22 | 1.21 | 1.21 | 1.21 | 1.20 | 1.21 | 1.21 | 1.21 | 1.21 | 1.22 | 1.22 | 1.22 | 1.22 | 1.22 |
| Petrol E85 | 0.88 | 0.86 | 0.84 | 0.82 | 0.80 | 0.77 | 0.75 | 0.74 | 0.73 | 0.72 | 0.71 | 0.71 | 0.70 | 0.69 | 0.68 | 0.67 |
| CNG | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 | 1.16 | 1.16 | 1.16 | 1.16 | 1.16 | 1.16 |
| CNG CRG5 | 1.11 | 1.11 | 1.11 | 1.11 | 1.11 | 1.11 | 1.11 | 1.11 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 | 1.13 |
| LPG | 1.25 | 1.25 | 1.25 | 1.25 | 1.25 | 1.25 | 1.25 | 1.25 | 1.25 | 1.26 | 1.26 | 1.26 | 1.27 | 1.27 | 1.27 | 1.28 |

Green NCAP - July 2024 38

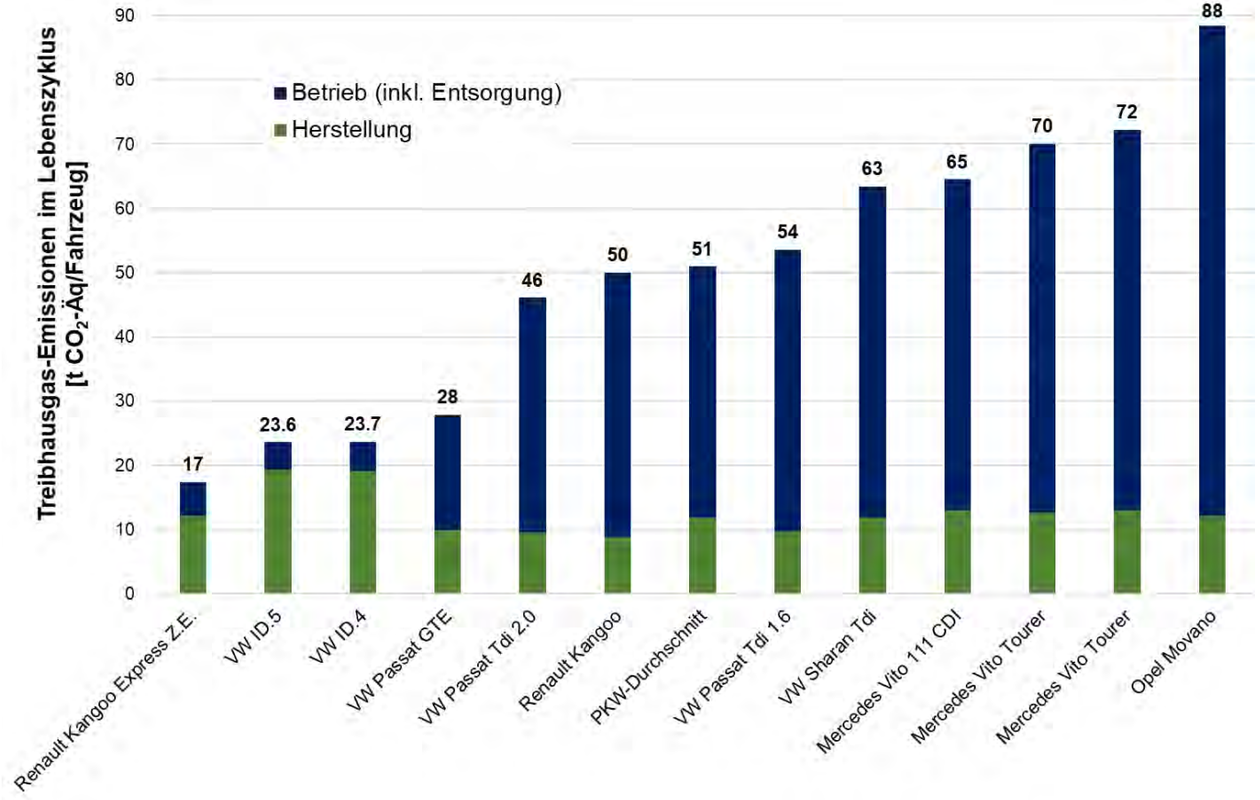


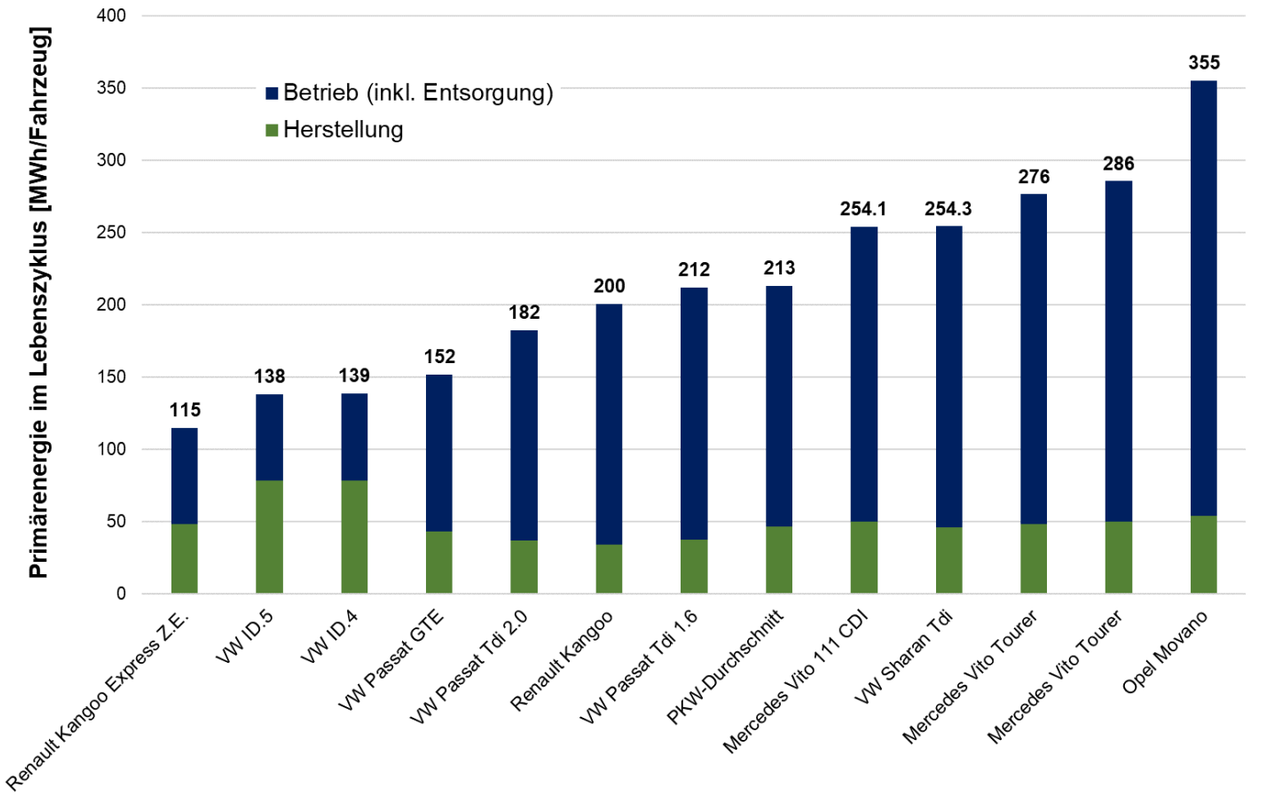

*Englisch: https://www.greenncap.com/lca-tool/*
*Deutsch: https://www.greenncap.com/lca-german.php*
*Italienisch: https://www.greenncap.com/lca-italian.php*

# *LCA is for Decision Making: The Vehicles of JOANNEUM RESEARCH*

## GHG emissions
## 17 – 88 t $CO_2$-eq/vehicle




## Primary energy
## 115 – 355 MWh/vehicle



# Conclusions


- **Climate Neutrality Potential** & **Circularity Potential** assed in dynamic Life Cycle Assessment (LCA)
- **Key Impacts** in LCA: GHG emissions, primary energy, Climate Neutrality & Circularity Potentials
- **LCA Case Studies:** SUV and city buses using wind electricity, petrol, diesel, hydrogen & e-fuel
- Only systems using renewable energy have the potential **towards Climate Neutrality & Circularity**
- **Circularity Potential**
  - City buses higher than SUV
  - Battery: 7 – 10%
  - Supply of wind electricity: 50 – 55%
  - Battery electric vehicle (BEV using wind): 18 - 36% (similar for e-fuel and hydrogen using wind)
  - Internal combustion engine (ICE using petrol/diesel): 1.5 - 6%
- **Climate Neutrality**
  - **Only in combination with Carbon Capture & Storage (CCS)** systems might be *“100% climate neutral”*
  - For **100% Climate Neutrality** (example city bus)
    - *BEV with CCS needs same amount of renewable energy than diesel ICE with CCS*
    - *It needs 5 times more renewable electricity for e-diesel ICE with CCS than for diesel ICE with CCS*

# *Contact*

**Gerfried JUNGMEIER**

JOANNEUM RESEARCH
Forschungsgesellschaft mbH

LIFE – Institute for Climate, Energy Systems and Society

Science Tower
Waagner-Biro-Straße 100, 8020 Graz
Tel. +43 316 876-7630
gerfried.jungmeier@joanneum.at

**www.joanneum.at/life**