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Circularity and Climate Neutrality Potentials in the LCA of Vehicles

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Institute for
Climate, Energy Systems and Society

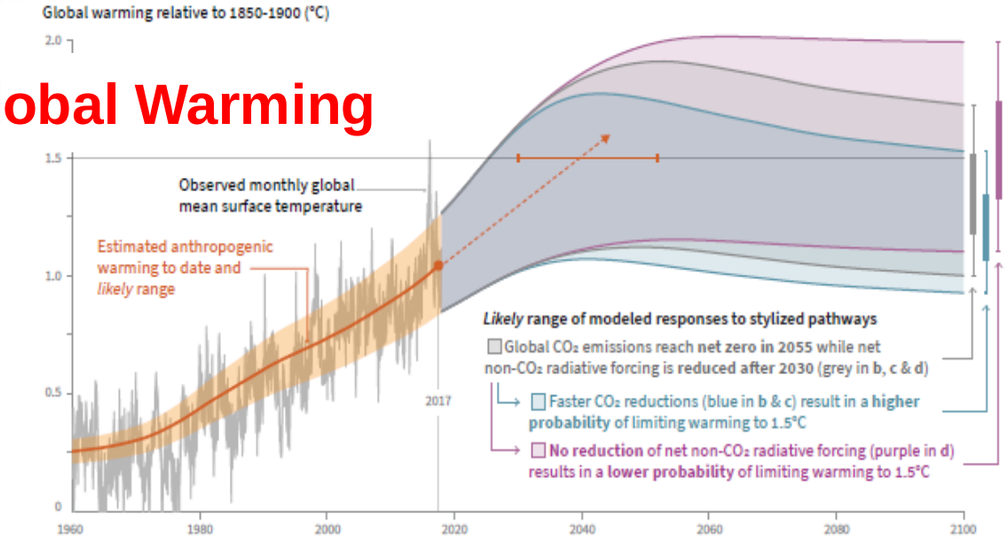
Research Area:
Climate Neutral Energy Systems and Lifestyles

LCA Case Study Buses - Conclusions

- **Climate Neutrality Potential** & **Circularity Potential** are additional environmental impacts in dynamic LCA
- Systems using renewable energy have the potential **towards Climate Neutrality & Circularity**
- In **combination with CCS** all buses have zero GHG emissions and can be *“100% climate neutral”*
- **Circularity Potential** of electric (57 – 58%), hydrogen (55%) and e-diesel buses (48%) are quite similar due to renewable electricity use, for diesel very low (3%) due to diesel use
- Diesel bus has **highest environmental impacts**, except primary energy demand lower than e-diesel
- **For Climate Neutrality**
  - **“e-bus with CCS needs same amount of additional renewable energy than diesel bus with CCS”**
  - **“it needs less additional renewable electricity to use fossil diesel with CCS than making e-diesel with CCS”**

The LCA Approach to Face the Challenges

Global Warming



Circularity

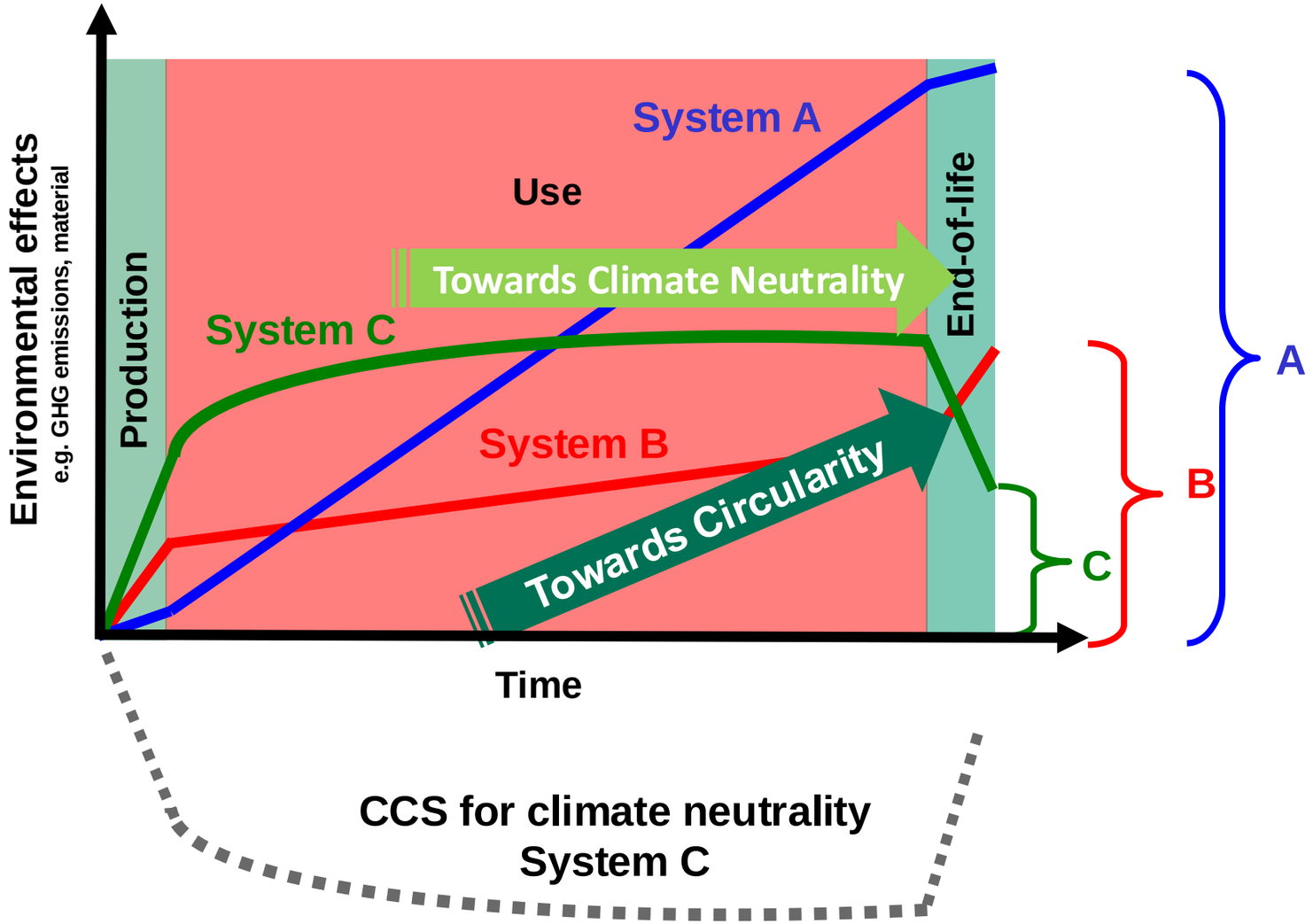
Dynamic LCA

- ✓ 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

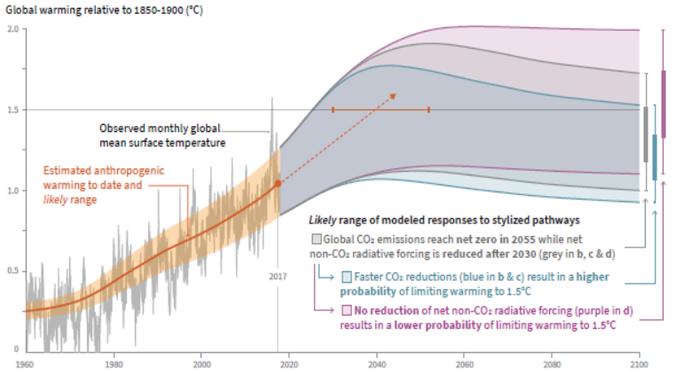
The Three Phases in Life Cycle

Dynamic LCA considers time of environmental effects



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 *(reuse index)*
    - secondary/recycled material *(recycled content)*
    - renewable energy
  - **makes**
    - zero waste and
    - zero GHG emissions



- **Indicators for assessment**
  - **Circularity Potential**
    - based on data of Inventory Analysis
    - Material Circularity Index (MCI) based on mass flows over lifetime: **0% = linear** and **100% = circular**
  - **Climate Neutrality Potential**
    - based on GHG emissions from Impact assessment
    - total radiative forcing at top-of atmosphere based on GHG emissions over lifetime at end-of-life: **$W_{year}/m^2 = 0$**
    - „Towards“ climate neutrality“: Zero GHG emissions in operation phase

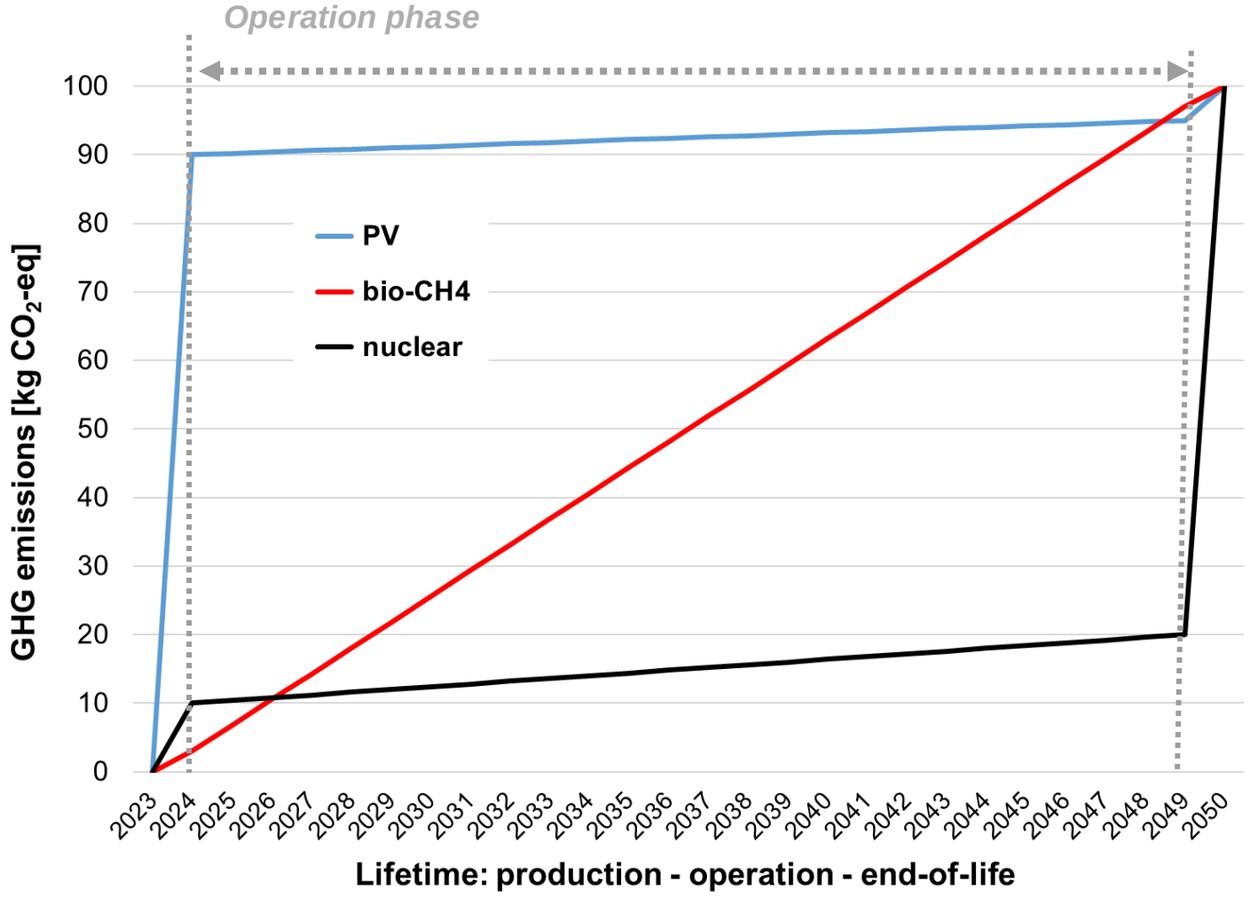
- **Concluding**
  - *Climate Neutrality* and *Circularity* are visionary and long term targets
  - **BUT**: future products and services must be developed and assessed ***„towards“*** *Climate Neutrality* and *Circularity*

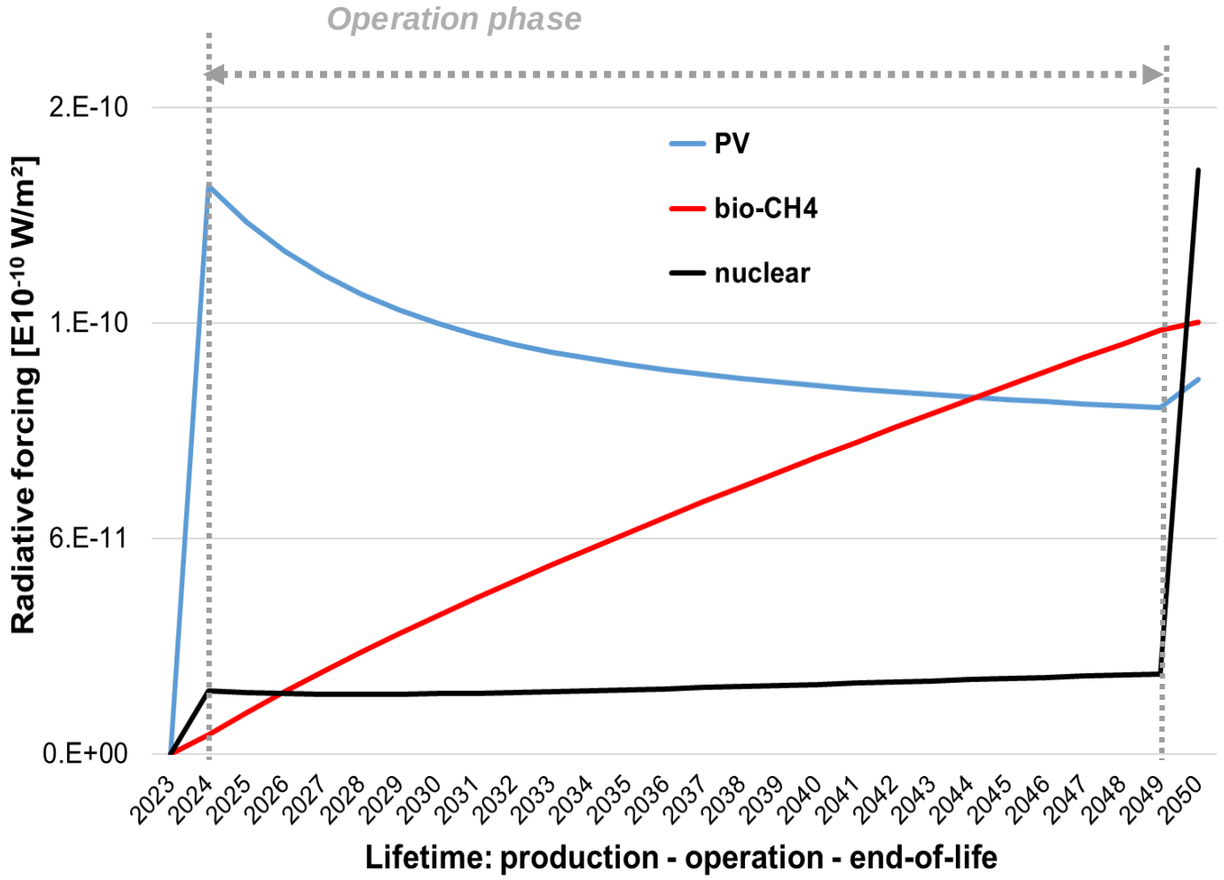
Same GHG Emissions but Different Climate Neutrality Potential!

GHG emissions

Climate Neutrality Potential

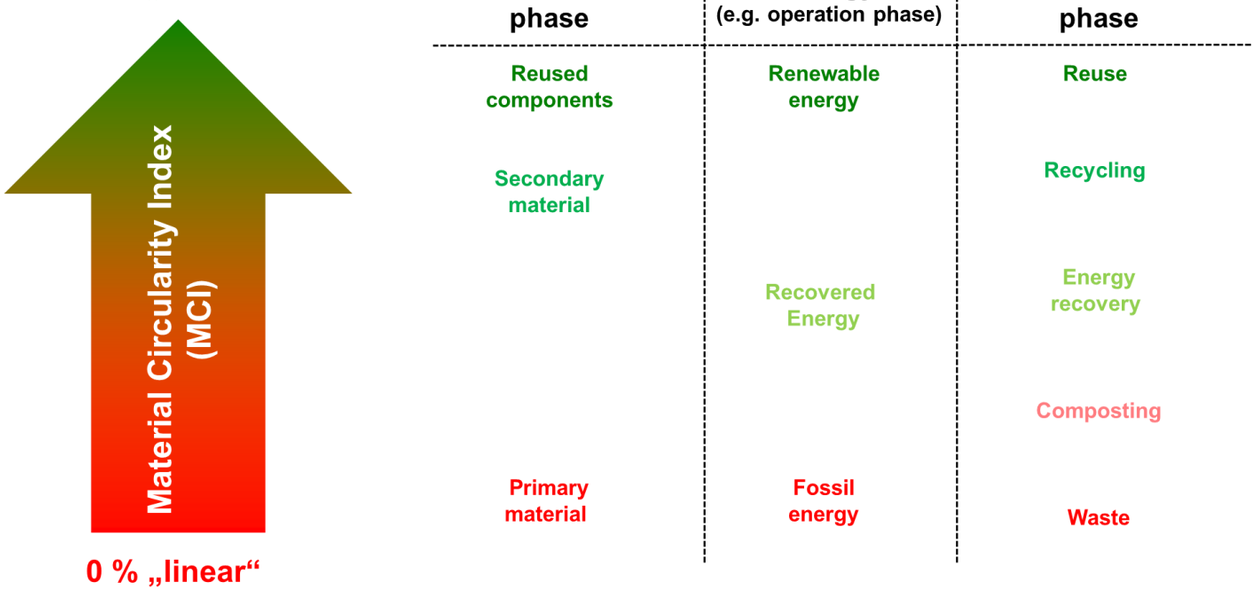
Same service and lifetime

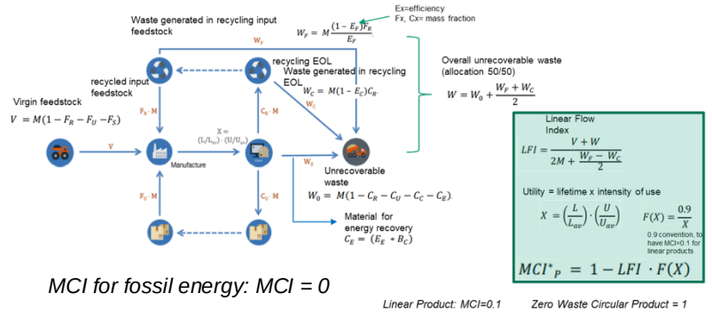




The Circularity Potential

- **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 = $LFI_{materials}$ * $UF_{product}$

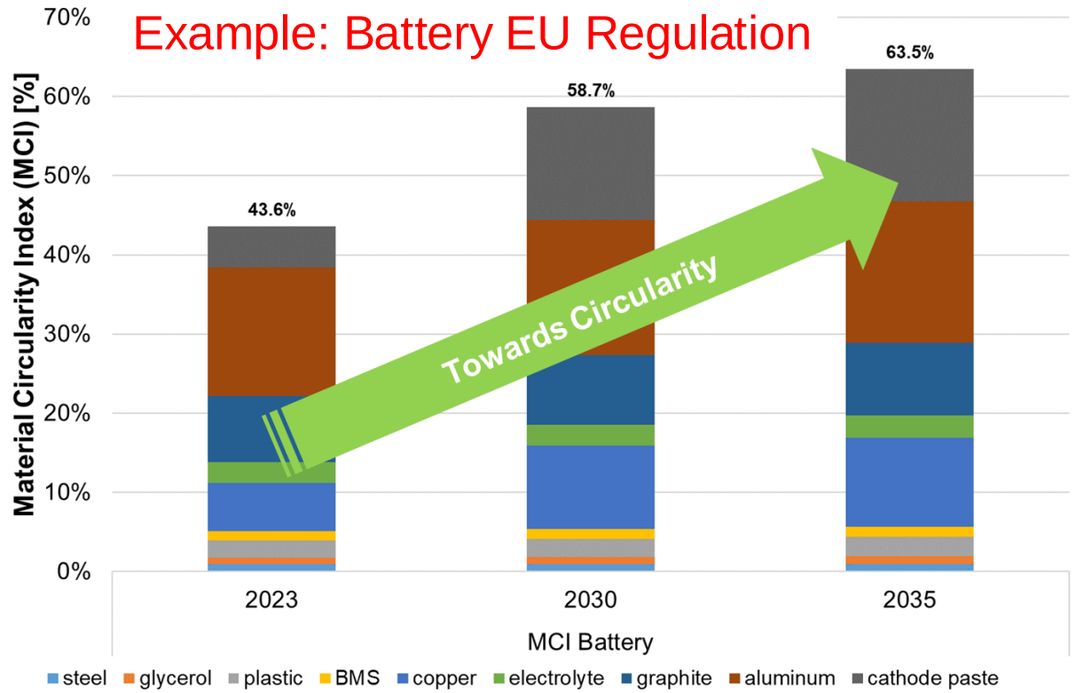




MCI for fossil energy: MCI = 0

Linear Product: MCI=0.1 *Zero Waste Circular Product = 1*

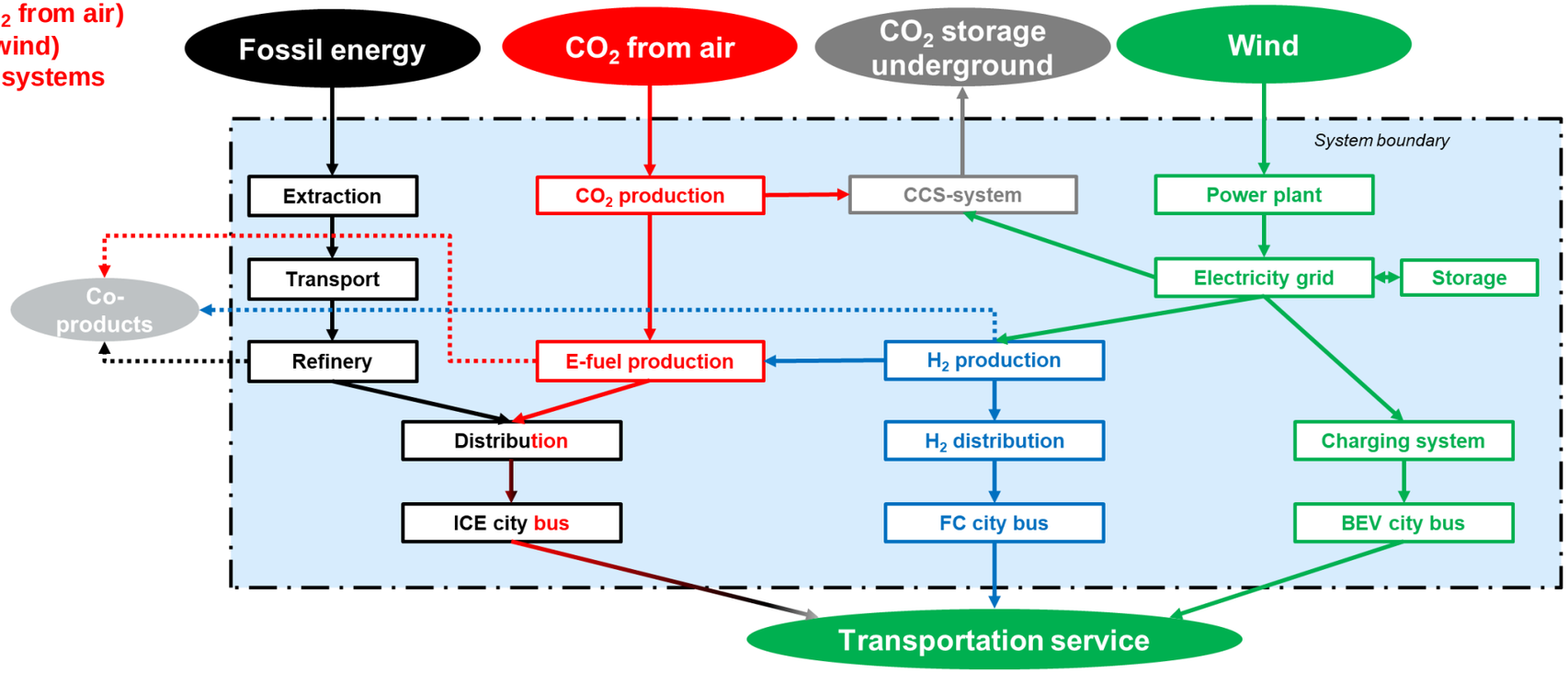
Source: Calculation of „Circularity Indicators“ of Ellen MacArthur Foundation



Example: LCA Case Study Buses

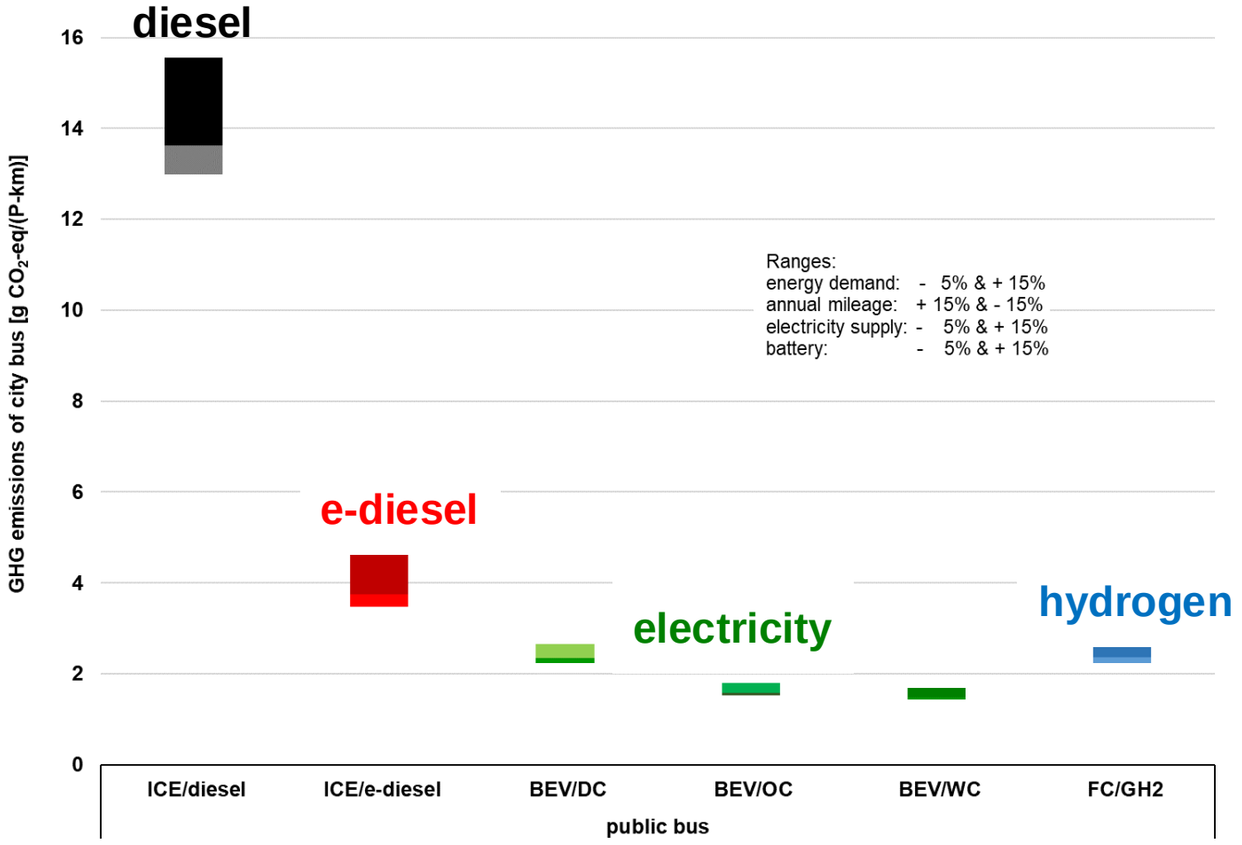
- **Aim**
  - Identify significant differences of environmental effects of buses with different propulsion system/fuel for current (2024) and future state (2036) of technology
  - **Usage of electricity from newly built wind power plants**
  - Analysing the effects and limits of using Carbon Capture and Storage (CCS) for Climate Neutrality
- **Methodology**
  - Dynamic LCA using generic global LCA data
- **Systems**: public city bus 12 m
  - **Diesel ICE**
  - **E-diesel ICE (from wind electricity and CO_2 from air)**
  - **Hydrogen FC (@ 700 bar, electricity from wind)**
  - **BEV electricity from wind with 3 charging systems**
    - Depot charging (DC)
    - Opportunity charging pantograph (OC)
    - Wireless opportunity charging (WC)
- **Functional units**
  - per passenger-km and per lifetime
- **Impacts**
  - GHG emissions
  - Climate Neutrality Potential: W2100/m²
  - Primary energy demand
  - Circularity Potential

- **Specialities**
  - Further **development of approach** for
    - "Climate Neutrality Potential" and
    - "Circularity Potential"
    - Possibilities to include criticality aspects in Circularity
  - Battery and fuel cell **change after 6 years**
  - Consideration over **lifetime of 2 buses** for 24 years, same lifetime as wind power plant
  - **Duration of system construction:**
    - e-fuel= 3 years, H_2 = 2 years and BEV = 1 year
  - **"Climate Neutrality" of all systems in combination with Carbon Capture & Storage (CCS) of CO_2 from air with wind power**
    - Calculated based on CO_2eq also covering CH_4 and N_2O

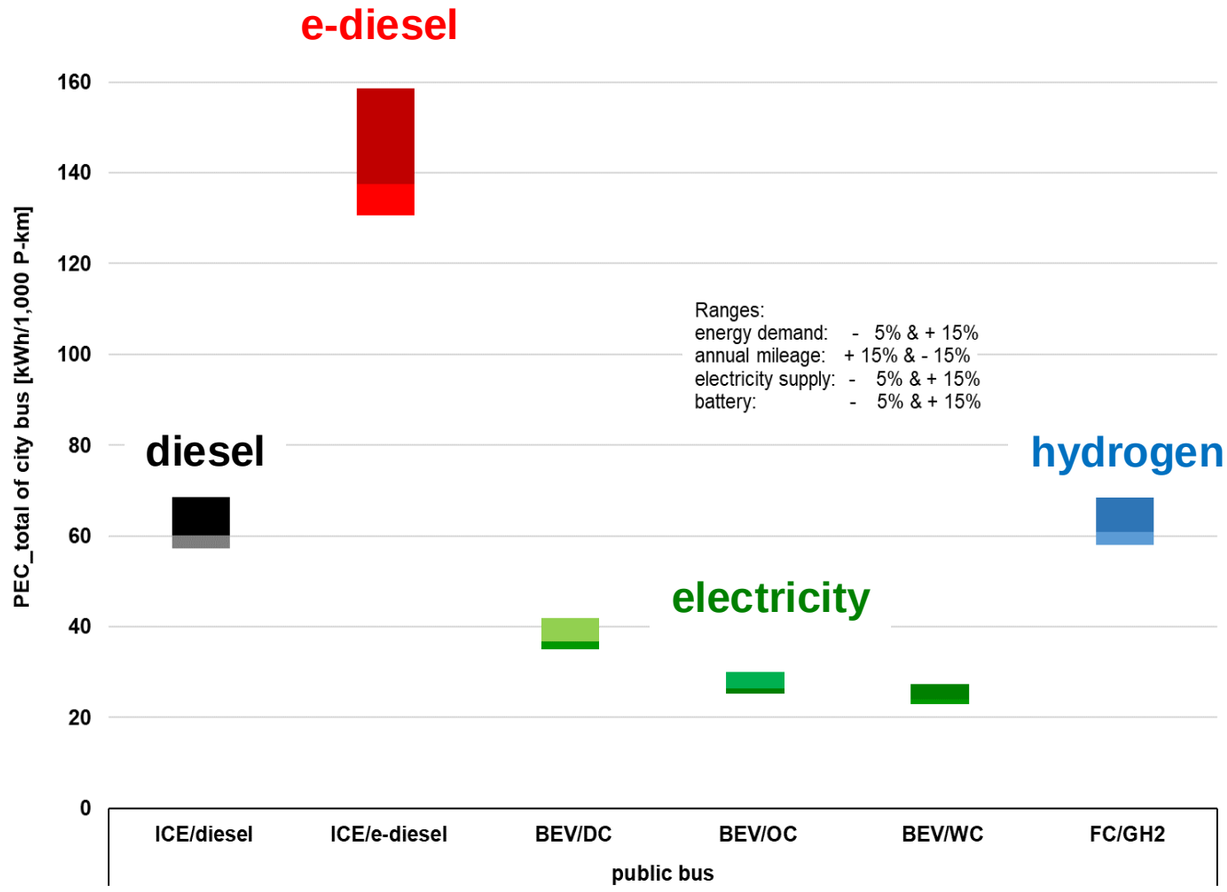


Results of LCA on Buses

GHG emissions

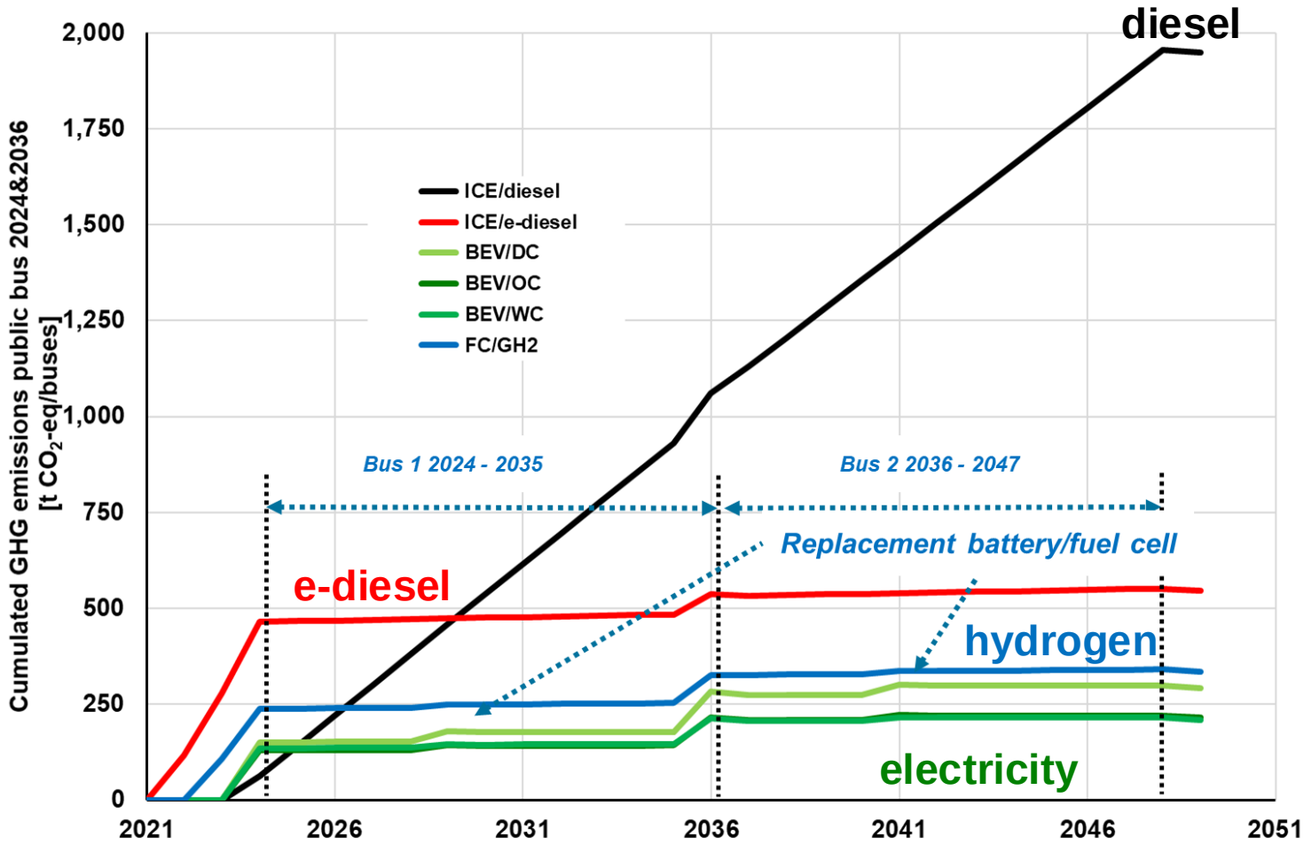


Primary energy

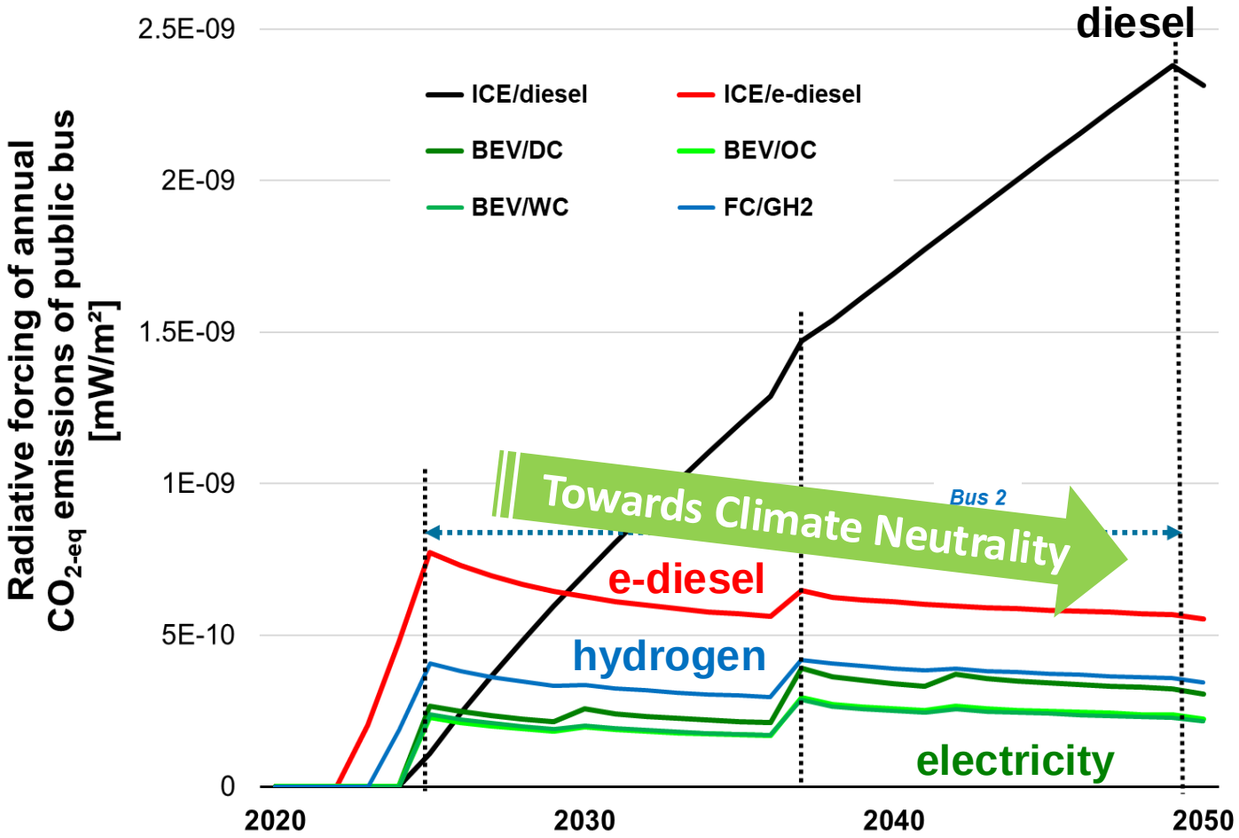


Results of "dynamic" LCA of Buses

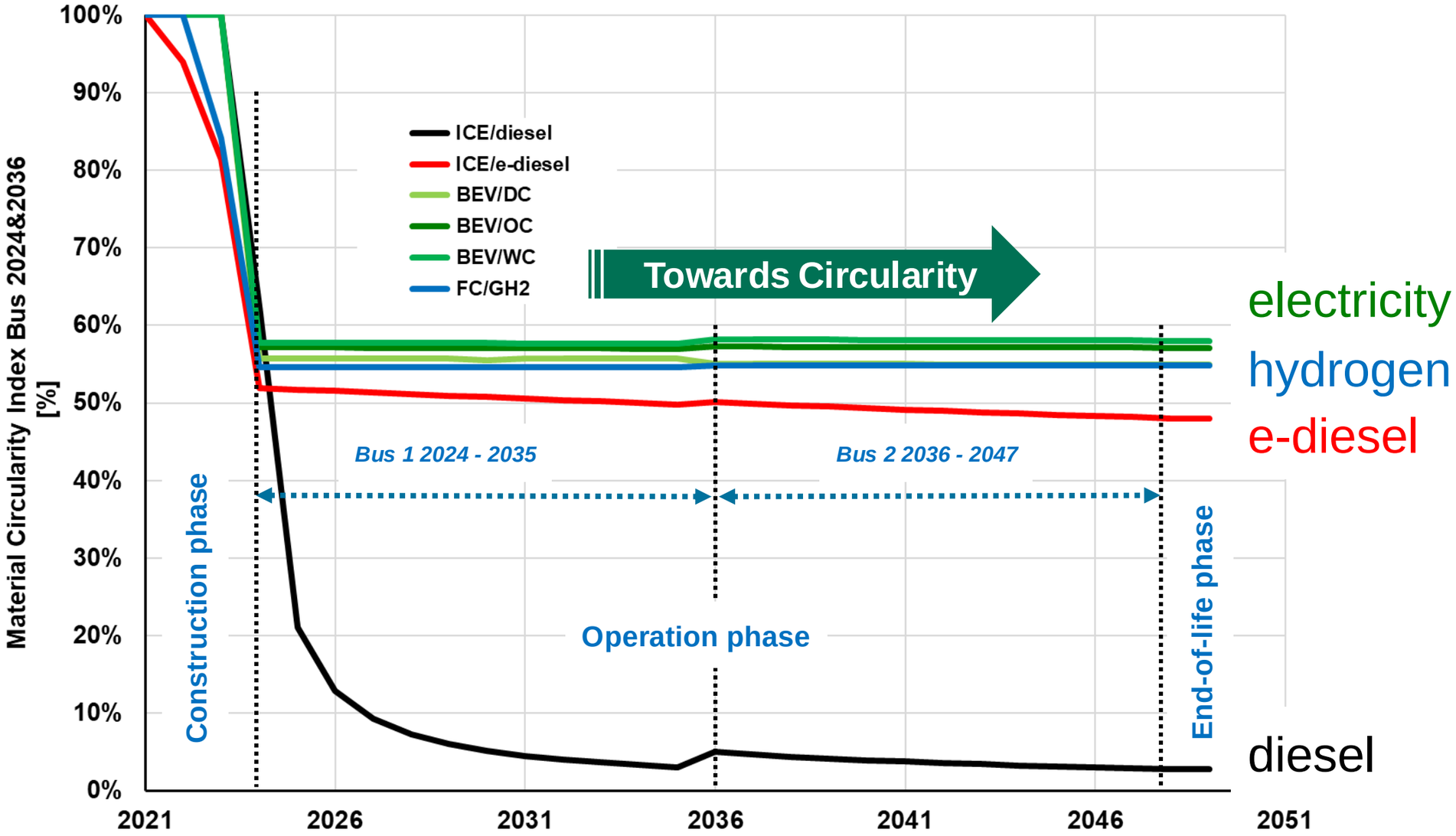
GHG Emissions



Climate Neutrality Potential 2050



Circularity Potential of Buses (2024 & 2036)



electricity

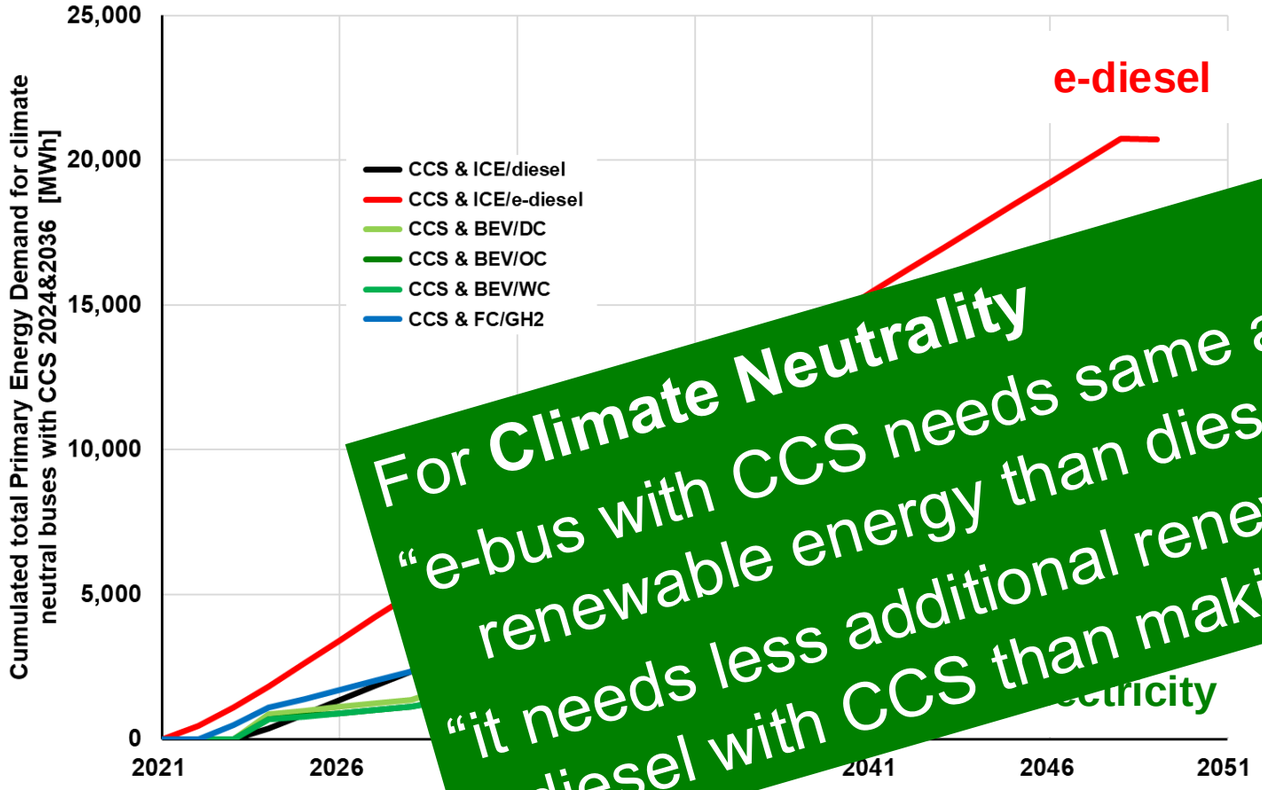
hydrogen

e-diesel

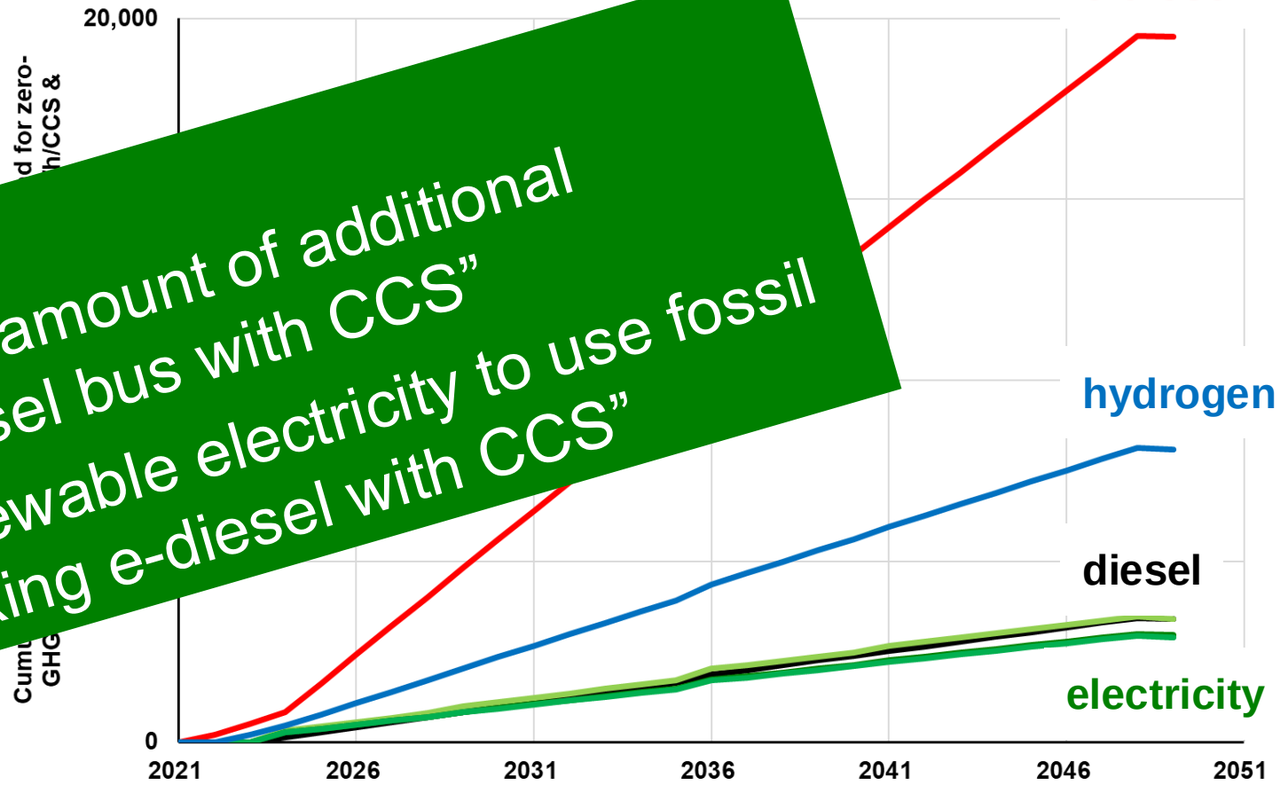
diesel

Cumulated Primary Energy of „100% Climate Neutral“ Buses with CCS (2024 & 2036)

Total primary energy



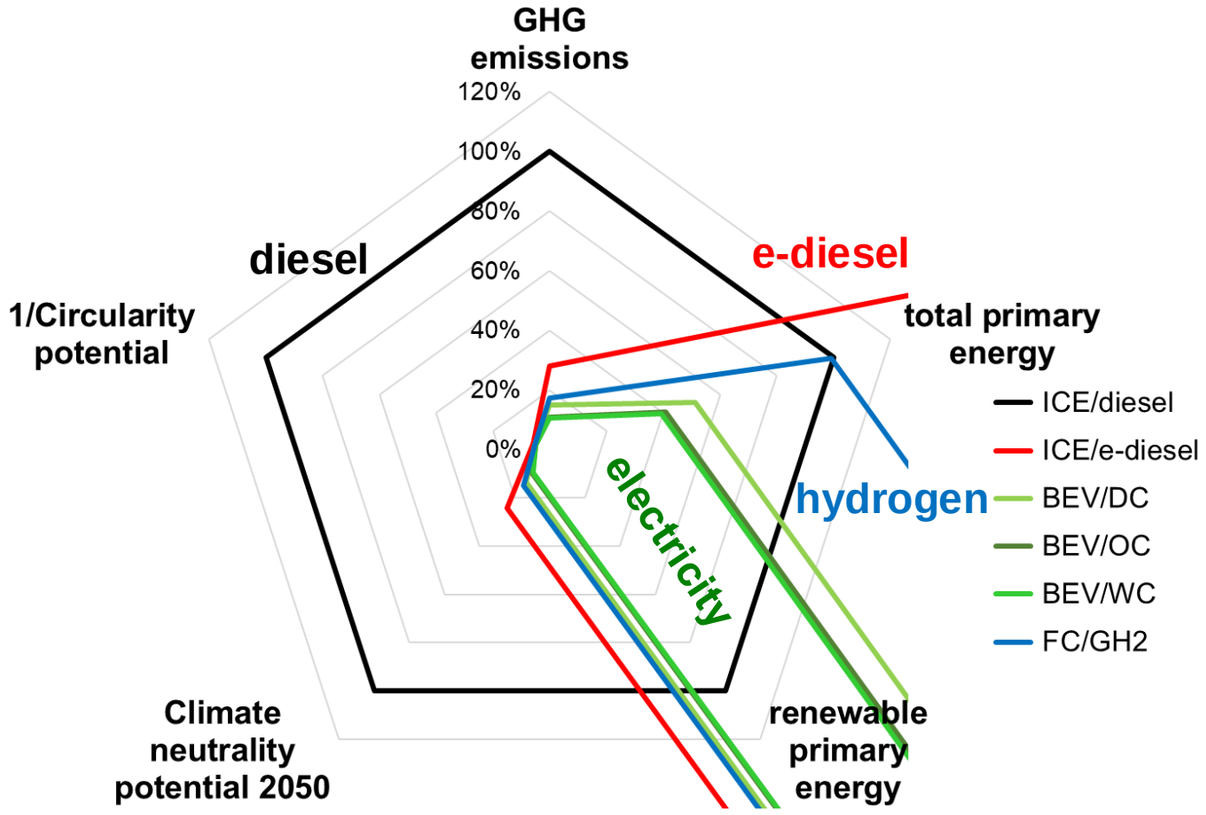
Renewable primary energy



For **Climate Neutrality**
“e-bus with CCS needs same amount of additional renewable energy than diesel bus with CCS”
“it needs less additional renewable electricity to use fossil diesel with CCS than making e-diesel with CCS”

Overall Summary: ICE/diesel = 100%

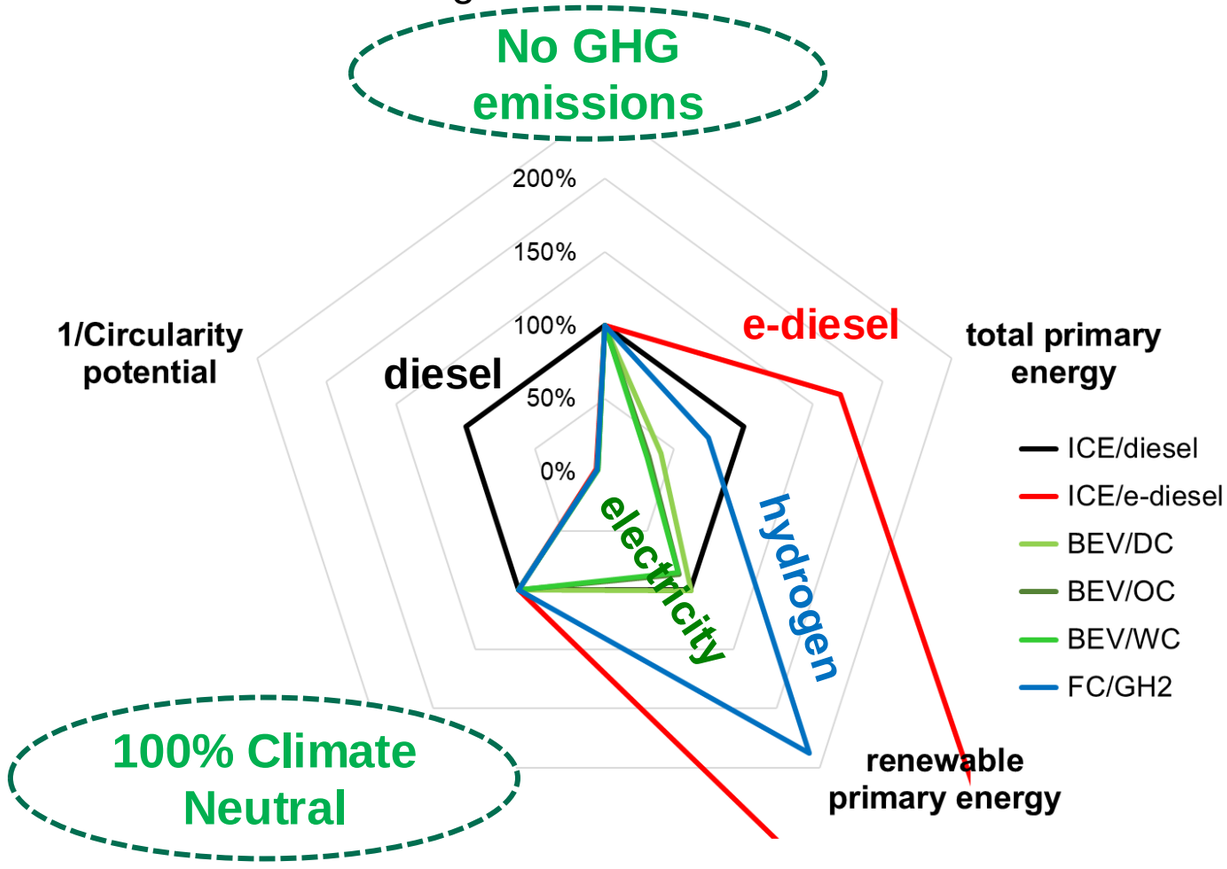
Buses without CCS



"100% Climate Neutral" Buses with CCS

over lifetime of buses

- GHG emissions: 0 t CO_2-eq for all buses
- Radiative forcing: 0 W/m²



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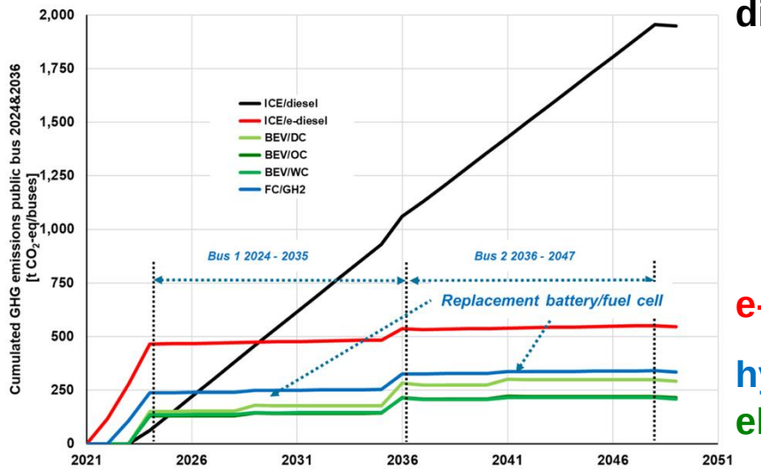


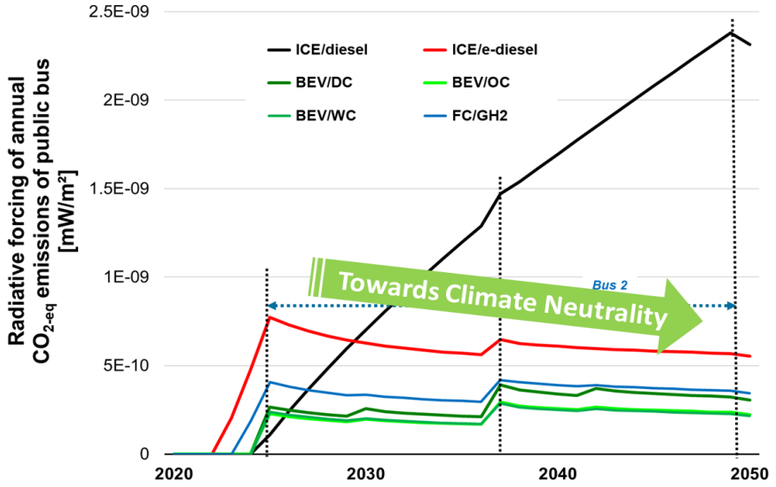
diesel

e-diesel

hydrogen

electricity

Climate Neutrality Potential 2050



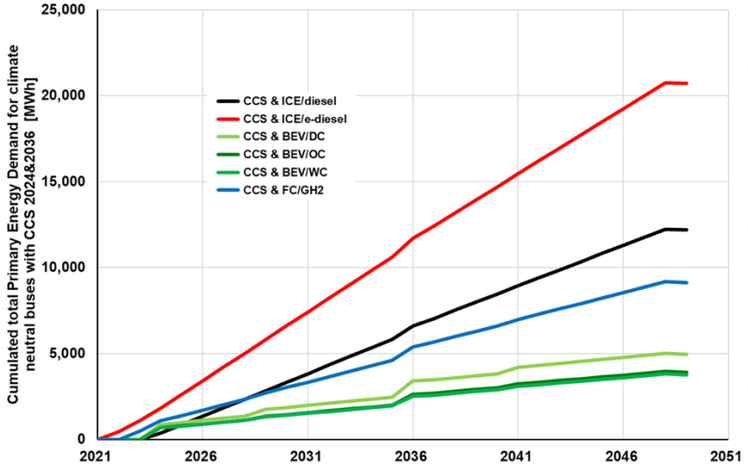
diesel

e-diesel

hydrogen

electricity

Primary Energy Demand



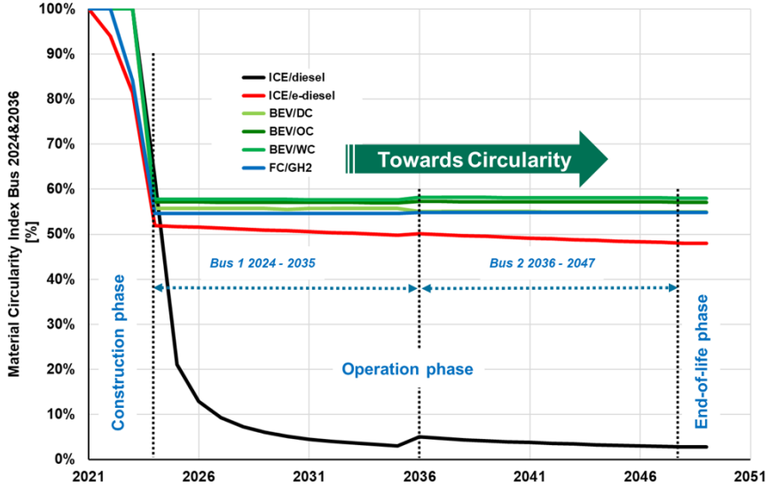
e-diesel

diesel

hydrogen

electricity

Circularity Potential



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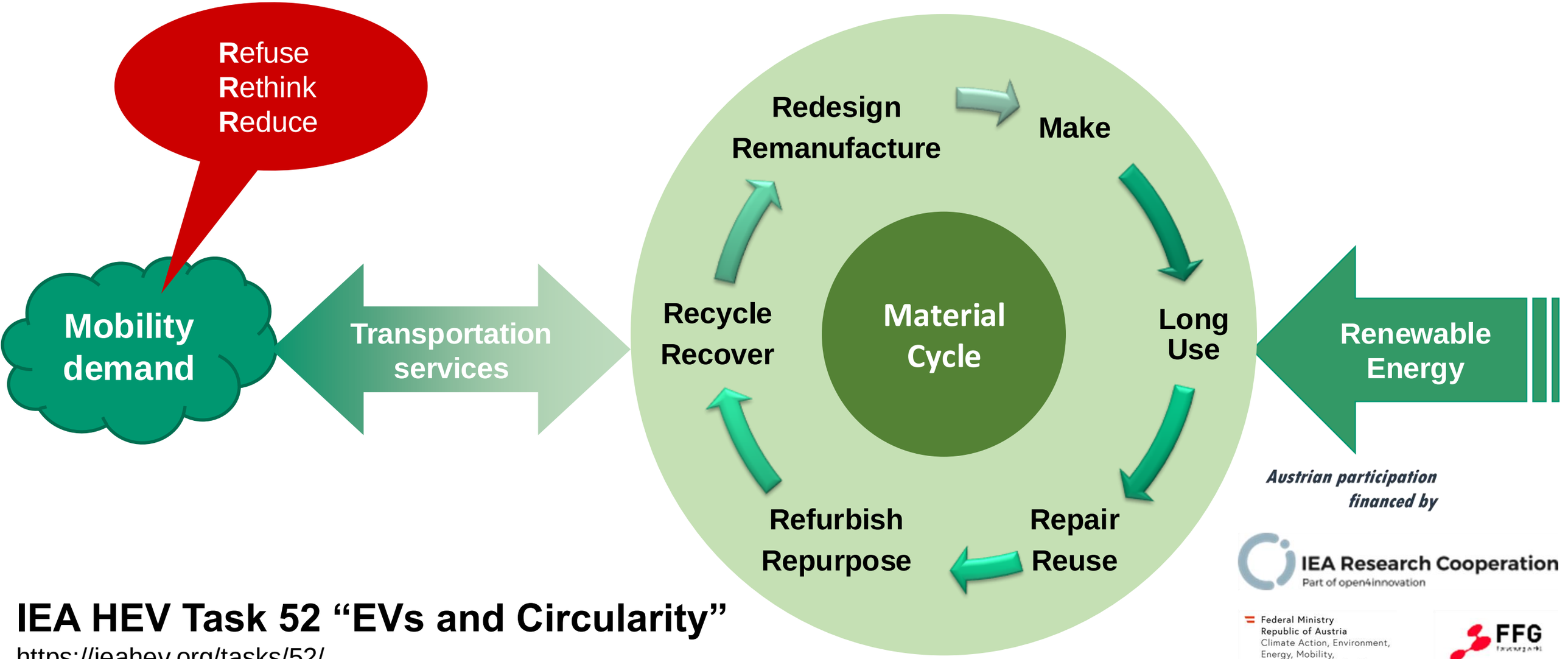
Circularity and Transportation Services



IEA HEV Task 52 "EVs and Circularity"

https://ieahev.org/tasks/52/

Austrian participation financed by

IEA Research Cooperation
Part of open4innovation

Federal Ministry
Republic of Austria
Climate Action, Environment, Energy, Mobility, Innovation and Technology

FFG

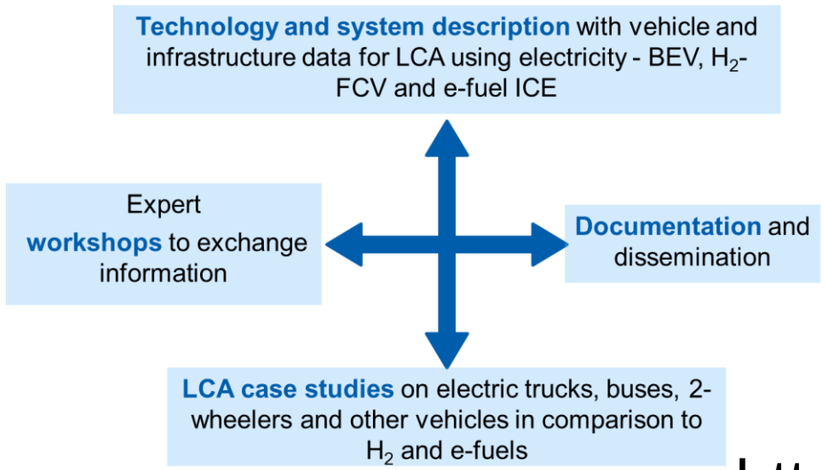
Further Information

- **Webinar 1: "*LCA of BEV – Basics*": November 21, 2024 3 – 4 pm (CET)**
  - Intro. IEA HEV and Task 46 (**Gerfried** Jungmeier – JOANNEUM RESEARCH, AT)
  - LCA Methodology & Application for Electric Vehicles (**Jarod** Kelly - ARGONNE, US and **Nick** Hill - Ricardo, UK (Joint presentation/storyline)
  - Q&A via chat with audience
- **Webinar 2: "*LCA of BEV – Developments*" January 21, 2025 3 – 4 pm (CET)**
  - Intro: IEA HEV and Task 46 (**Gerfried** Jungmeier – JOANNEUM RESEARCH, AT)
  - Climate Neutrality & Circularity Assessment of EVs – Results of Task 46 (**Gerfried** Jungmeier – JOANNEUM RESEARCH, AT)
  - Specialities of BEV-LCA (**Robin** Smit - Transport Energy/Emission Research, AUS)
  - Q&A via chat with audience
- In-person Workshop **"LCA of EVs - Steps Towards Circularity & Climate Neutrality"**, May 15 – 16, 2025, Vienna, Austria

IEA HEV Task 46: LCA of Electric Trucks, Other Vehicles and V2X-Services (2022 – 2025)

Analyse, Discuss and Document the **Environmental Impacts** based on **Life Cycle Assessment**

- of electric (UNECE class)
  - Buses (M)
  - Trucks (N)
  - Two-wheelers (L) and
  - Other vehicles e.g. mining, agriculture, train
- in **comparison** to
  - **Conventional fuels** e.g. diesel, petrol, natural gas
  - **Renewable hydrogen** and
  - **E-fuels** made from CO_2 and renewable electricity



- **12 Participants**
  - **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:** Wilco Fiechter, Yvonne Boesten
  - **IREC (ES):** Víctor José Ferreira Ferreira, Luis Alberto López
  - **JOANNEUM RESEARCH (AT):** Gerfried Jungmeier
  - **National Research Council Canada (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
  - **Simone Ehrenberger**, DLR (vice)

Task manager and Austrian participation financed by

https://ieahev.org/tasks/46/

Contact

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