Assessing Circularity and Climate Neutrality as Two New Impact Categories in LCA

–

A Case Study on Heating Systems

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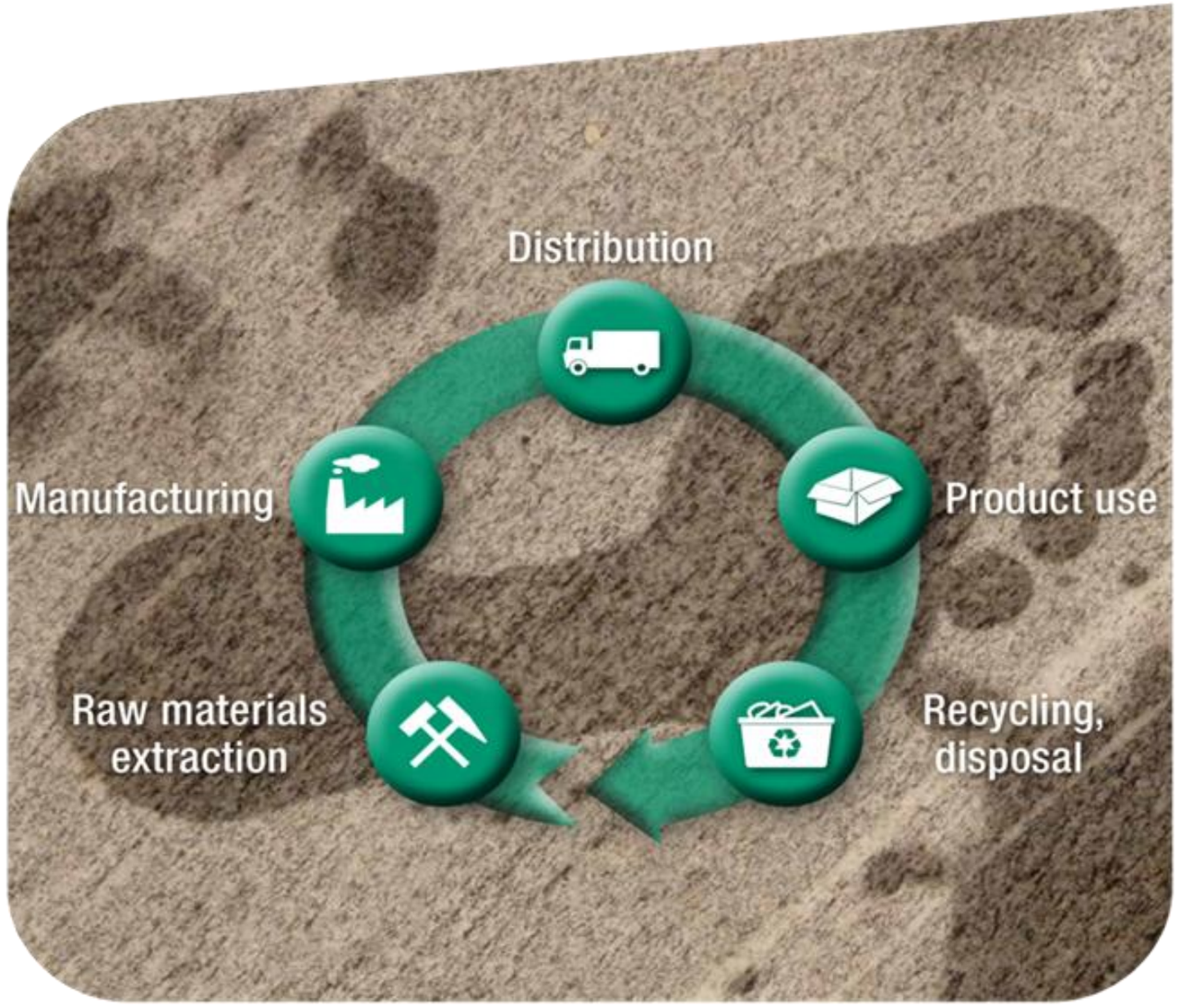
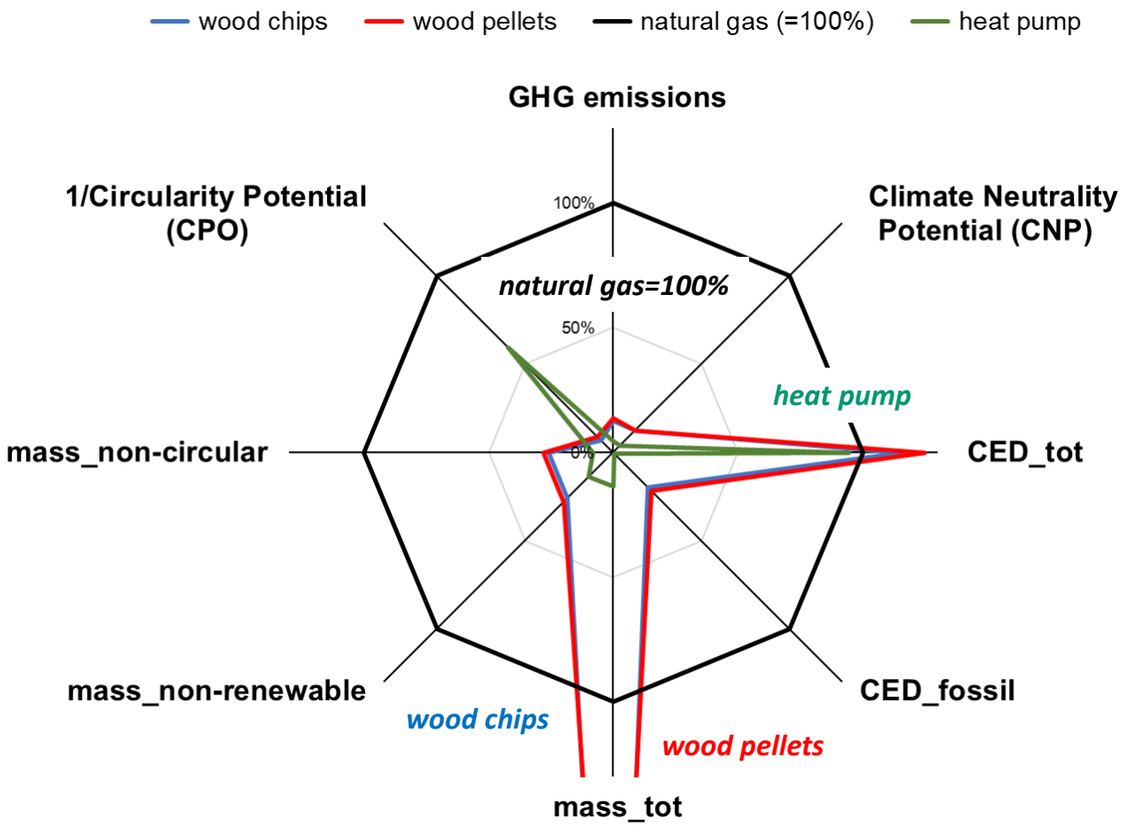


Take Home Message

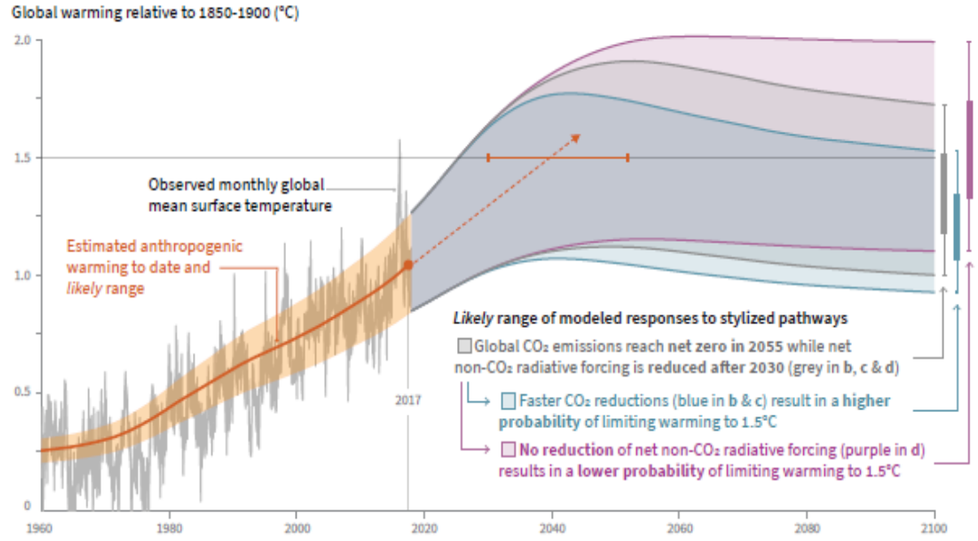
- Definition essential for **“Circularity Potential”** and **“Climate Neutral Potential”**
- Climate Neutrality Potential and Circularity Potential are **two new impact categories** not yet covered in LCA.
  - Non-circular mass, renewable-circular mass and total mass of an energy service are additional indicators to assess circularity
  - Climate Neutrality Potential gives additional information about the timing of the GHG emissions in lifecycle and its effects on temperature
- **Comparison** of heating systems
  - Heat pump using ambient air and renewable electricity
    - highest Climate Neutrality Potential (2.1 E-11 W/m²)
    - lowest GHG emissions (12 g CO2-eq/kWh)
    - lowest non-circular mass (7 g/kWh) and
    - lowest primary energy demand (1.2 kWh/kWh).
  - Biomass heating systems
    - highest Circularity Potential due to the use of renewable biomass
    - highest total amount of mass
  - Natural gas heating system is worst in all impacts



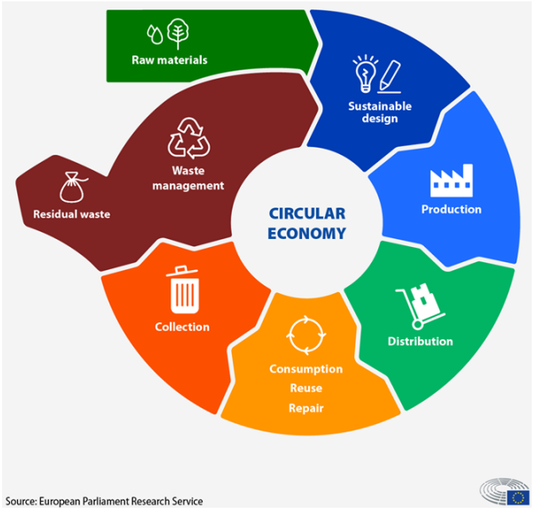
Impact		Heating system 50 kW			
	per kWh_useful heat	wood chips	wood pellets	natural gas	heat pump
GHG emissions	[g/kWh]	34	36	267	12
Climate Neutrality Potential (CNP)	[W/m²]	6.5E-11	6.6E-11	5.3E-10	2.1E-11
primary energy (CED_tot)	[kWh_primary energy/kWh]	1.5	1.6	1.3	1.2
fossil primary energy (CED_fos)	[kWh_fossil primary energy/kWh]	0.3	0.3	1.3	0.01
mass_tot	[g/kWh]	309	261	85.4	12
mass_non-renewable	[g/kWh]	22	24	85.4	12
mass non-circular	[g/kWh]	22	24	85.2	7
Circularity Potential (CPO)	[%]	93%	91%	0.2%	41%

The LCA Approach to Face the Challenges

Global Warming



Circularity

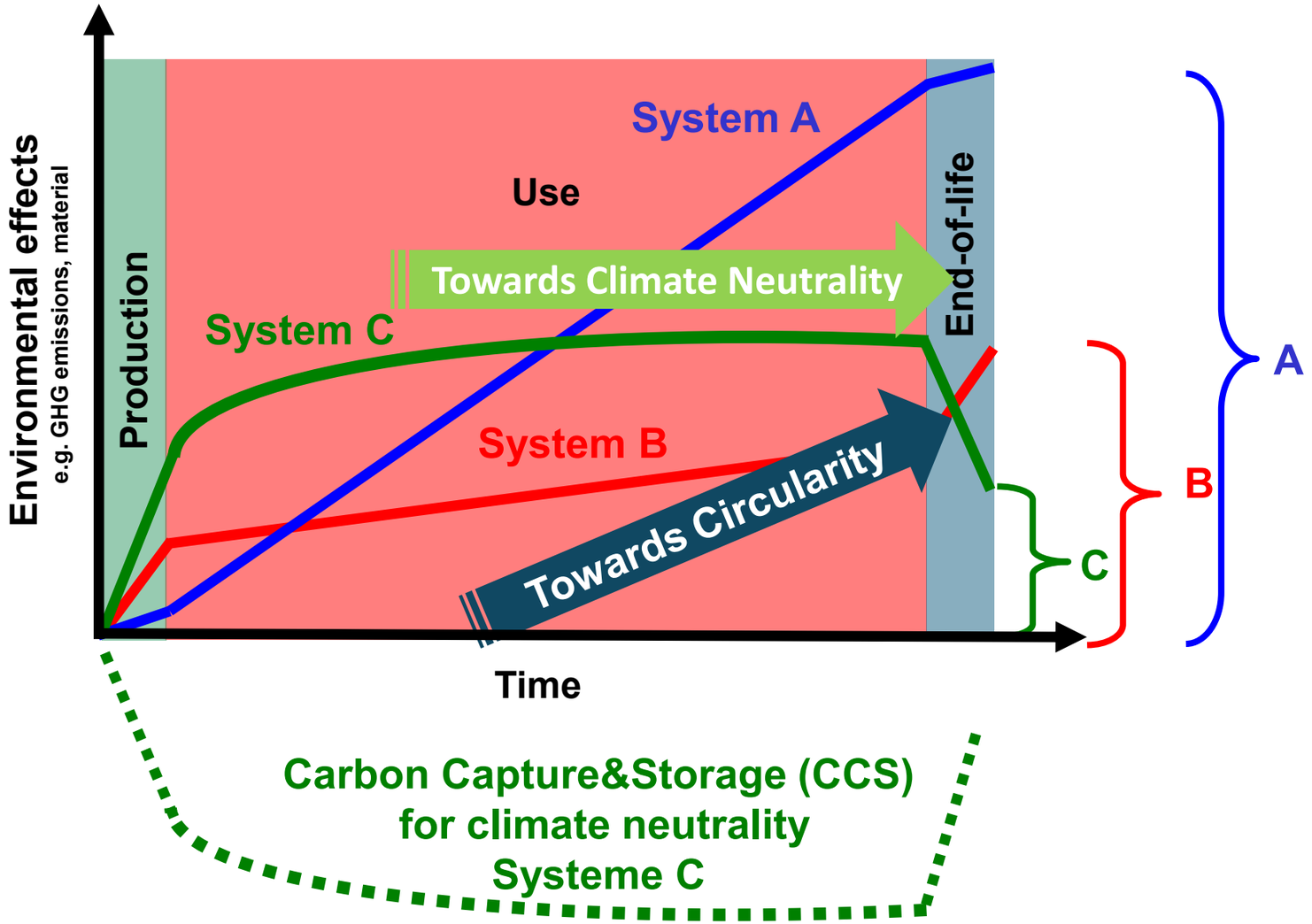


Life Cycle Assessment (LCA)

- ✓ Environmental effects of products & services must be analysed with **Life Cycle Assessment (LCA)** covering production, use & end-of-life
- ✓ **"Climate Neutrality"** and **"Circularity"** are
  - ➢ yet not covered in LCA impact categories
  - ➢ 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 Dynamic Life Cycle Assessment



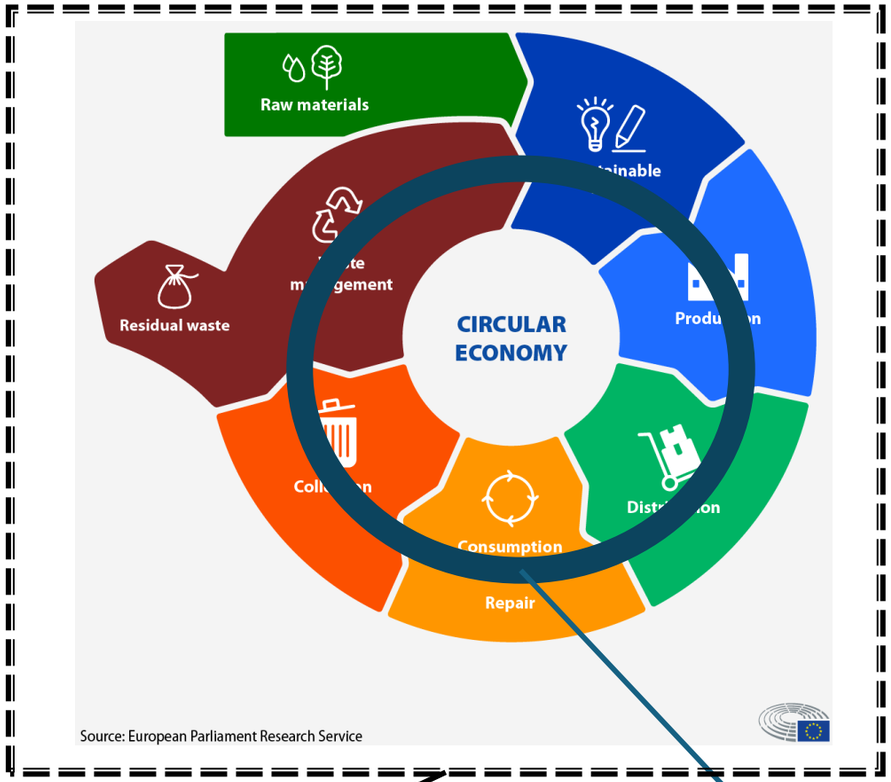
What is Circularity?

(1) Circularity (%) = circular mass / total mass

(2) Mass per product/service

Remarks

- ***Mass*** *is the sum of all materials in the total lifecycle*
- ***Primary energy*** *is counted as material (e.g. conversion from energy units in mass units using heating value of energy carriers)*
- *Total mass should be* ***minimized***
- ***Circular mass*** *should be increased*
- ***Non-circular mass*** *should must be reduced*

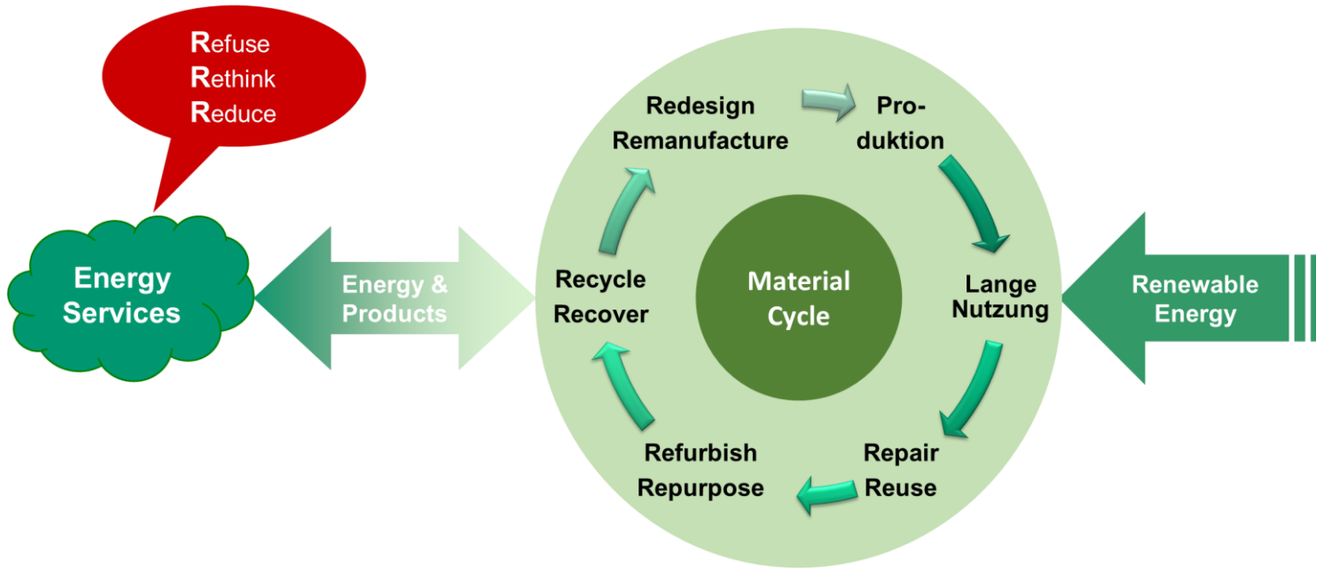


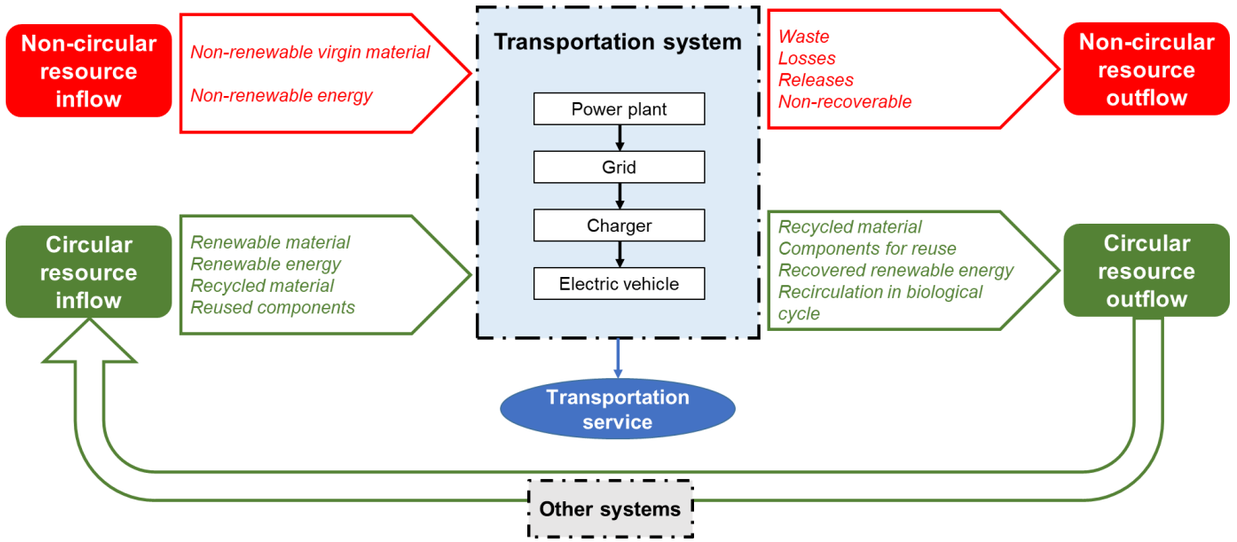
Total mass

Circular mass

Definition and Assessment of Circularity Potential and Climate Neutrality Potential in dLCA

- An energy service is **"100% circular and climate neutral "**, if in the whole life cycle - production, operation & end-of-life
  - the total mass only of **reused components, recycled and renewable/bio-based materials and primary renewable energy**
  - whereas no waste and **no GHG emissions** occur.
- **Indicators for assessment**
  - **Circularity Potential (CPO)**
    - based on mass balance in lifetime
    - Assessing circular/renewable and non-circular mass flows
    - Including primary energy
    - Material specific and utilisation factors
    - Circularity Potential: circular mass / total mass: **0% = linear** and **100% = circular**
  - **Climate Neutrality Potential (CNP)**
    - based on GHG emissions in lifetime
    - total radiative forcing at top-of atmosphere of GHG emissions: $\mathbf{W_{year\ of\ EoL}/m^2 = 0}$
    - "*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*





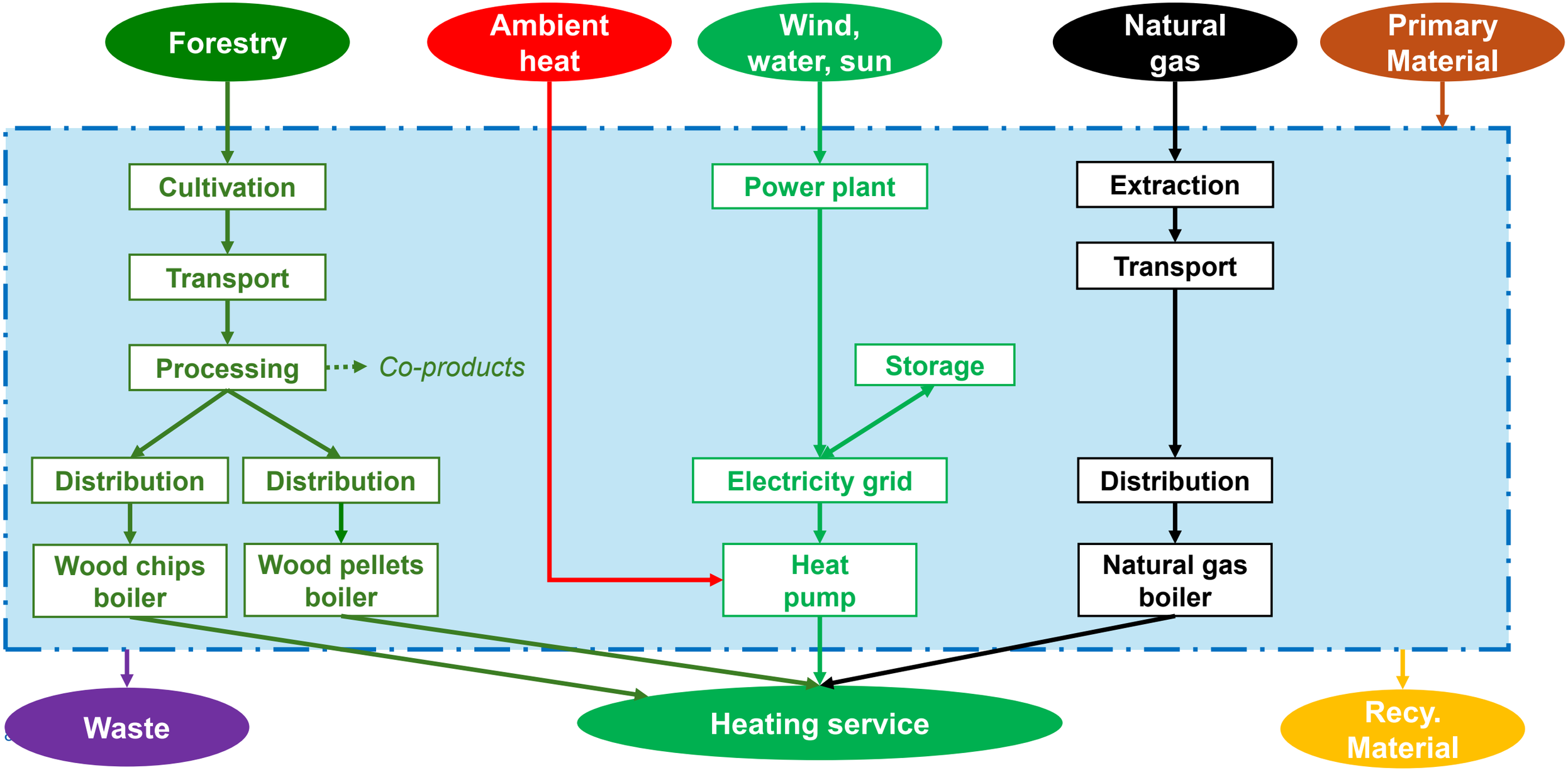
Identify Significant Differences of Environmental Impacts Between Heating Systems Using dLCA

- **Methodology**
  - Dynamic life cycle assessment using generic global production data for materials
- **Heating systems**
  - Wood chips
  - Wood pellets
  - Natural gas and
  - Heat pump using ambient air and renewable electricity (mix of 15% PV, 25% hydro & 60%wind)
- **Key data:**
  - Lifetime: 20 a
  - Heating power: 50 kW
  - Annual full load hours: 1,600 h/a
  - Annual heat demand: 80,000 kWh/a

- **Impacts**
  - Greenhouse gas (GHG) emission [g CO_2-eq covering CO_2, CH_4 and N_2O emissions]
  - Climate Neutrality Potential (CNP) [W/m² radiative forcing on top of atmosphere]
  - Cumulated Primary Energy demand (CED) [kWh covering fossil, renewable primary energy]
  - Circularity Potential (CPO) [%] and
  - Mass [g of (non-)circular and (non-)renewable mass]
- **Functional unit:** kWh of useful heat

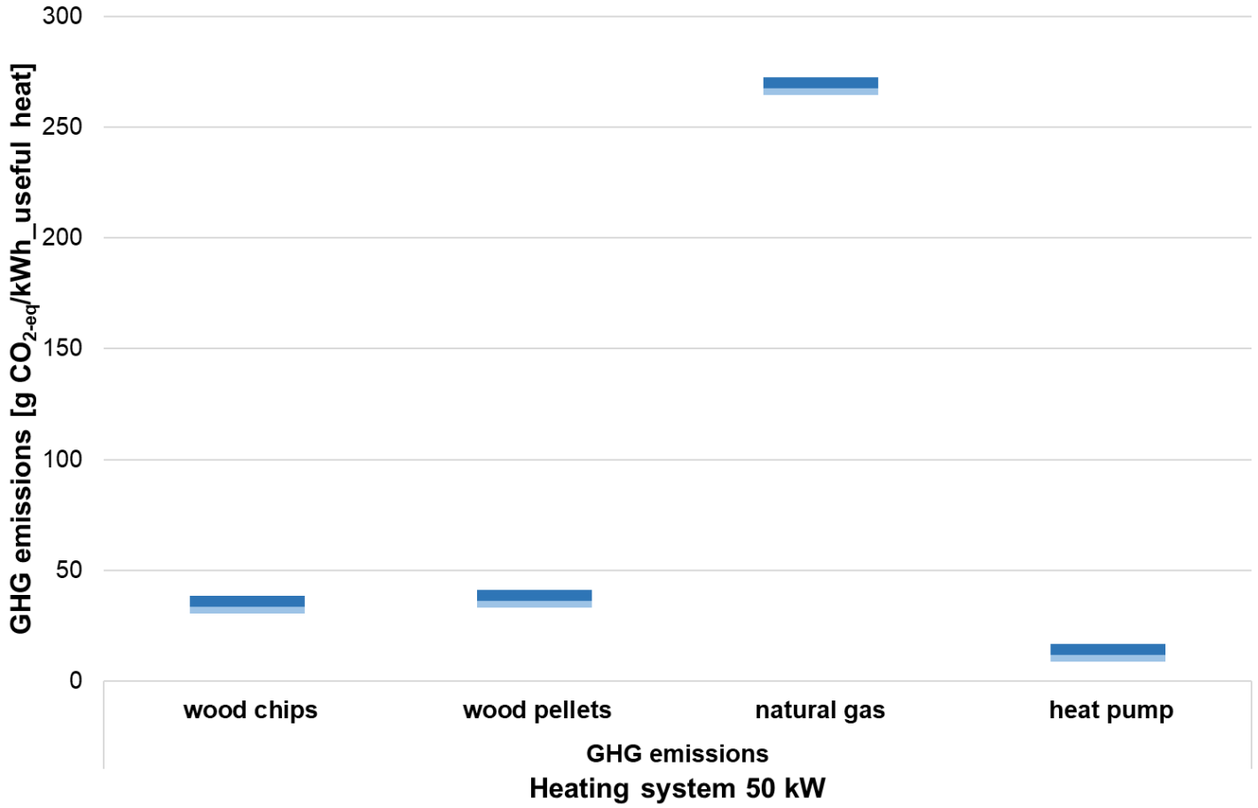
https://klimafreak.at/products/daikin-altherma-3-integrated-r32-8-0-kw-set?variant=13631842025577#&gid=1&pid=1
https://www.obadis.com/de/vaillant-vc-20cs-1-5-ecotec-plus-gas-wandheizgerat-0010043898-mit-brennwerttechnik.html
https://www.kwb.net/de-at/heizungen/hackschnitzelheizungen

System Boundaries of Heating Systems



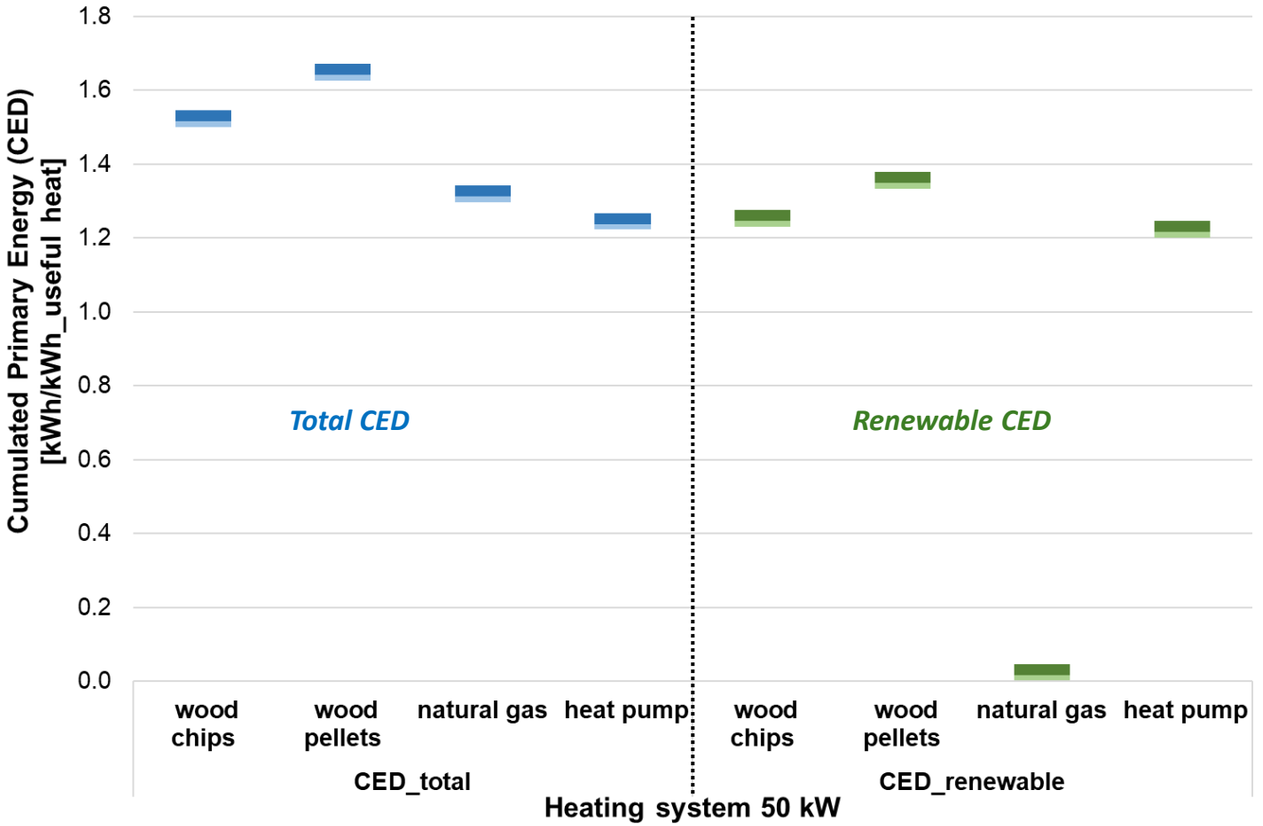
Results (I)

GHG emissions



- Wood chips: 34 g CO_2-eq/kWh
- Wood pellets: 36 g CO_2-eq/kWh
- Natural gas: 267 g CO_2-eq/kWh
- Heat pump: 12 g CO_2-eq/kWh

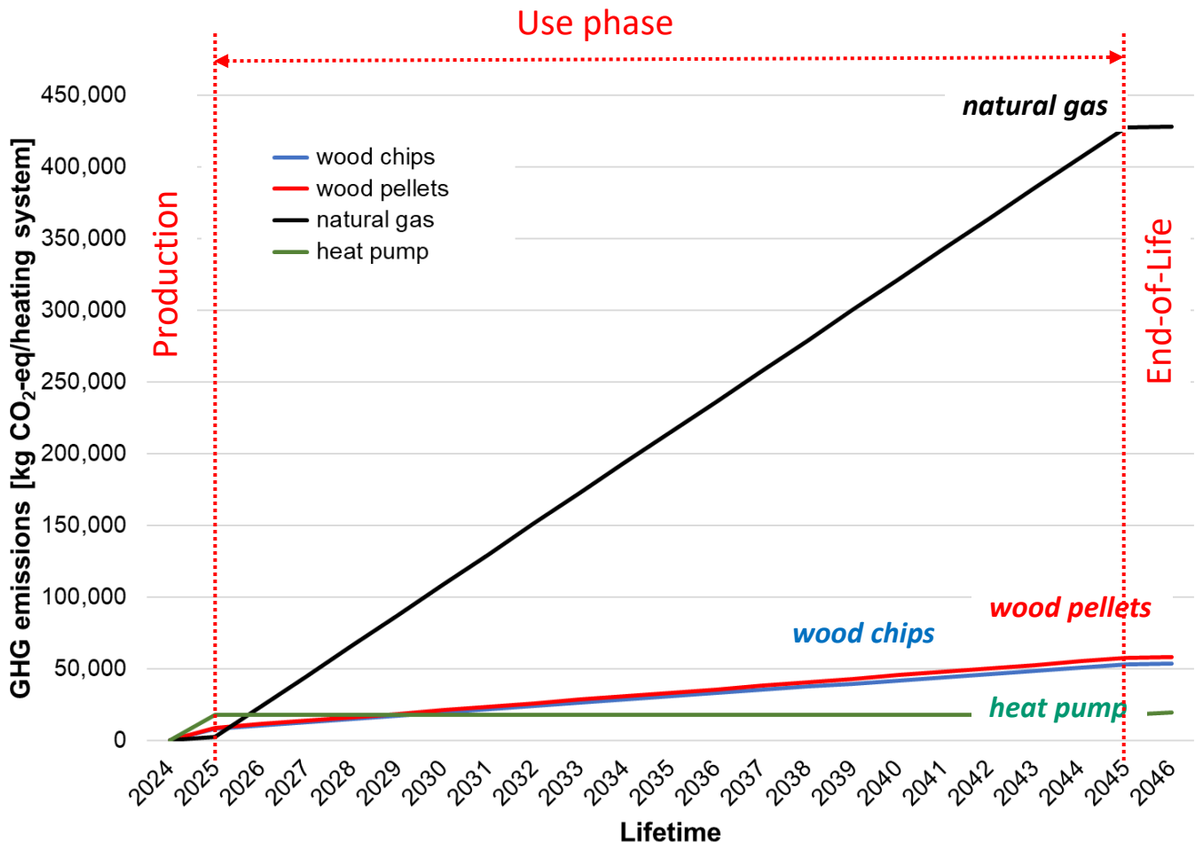
Primary Energy



- Wood chips: 1.5 kWh_tot/kWh with 0.3 kWh_fossil/kWh
- Wood pellets: 1.6 kWh_tot/kWh with 0.3 kWh_fossil/kWh
- Natural gas: 1.3 kWh_tot/kWh with 1.3 kWh_fossil/kWh²
- Heat pump: 1.2 kWh_tot/kWh with 0.01 kWh_fossil/kWh

Results (II): Climate Neutrality

GHG emissions



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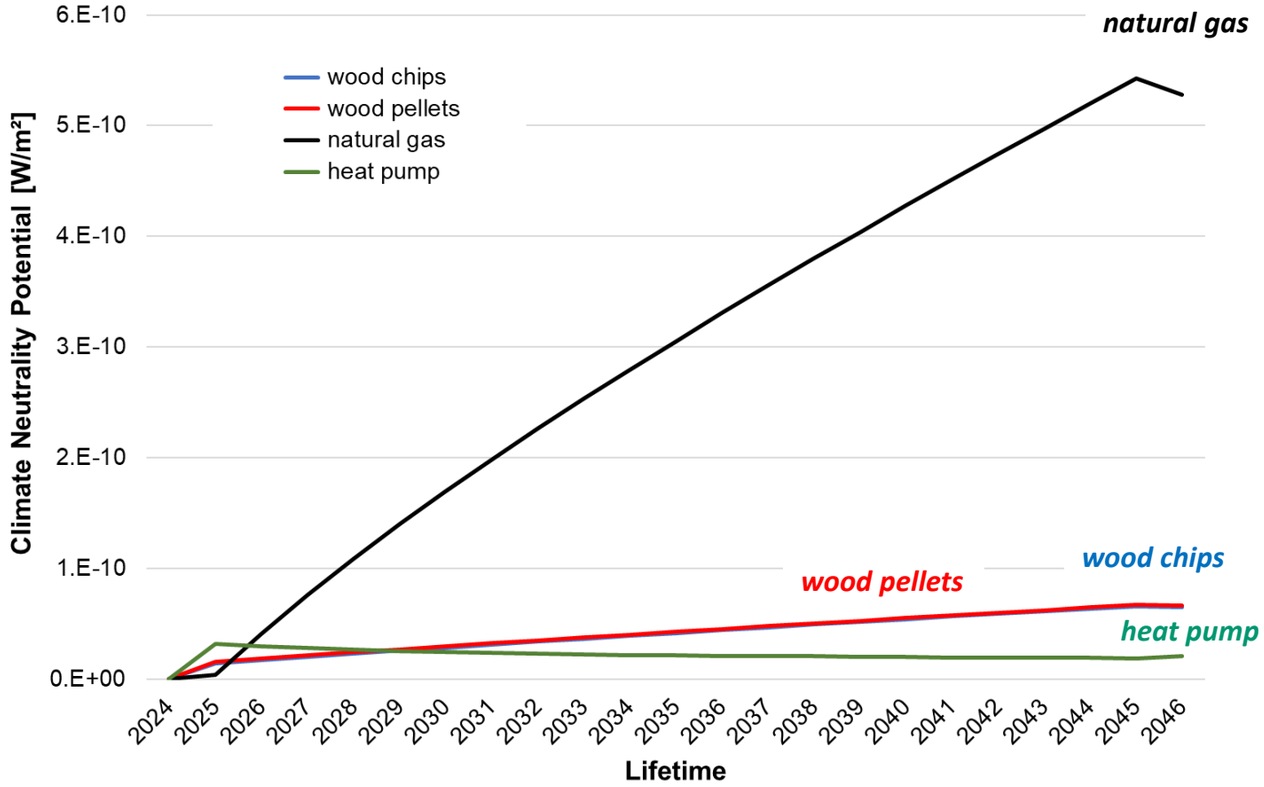
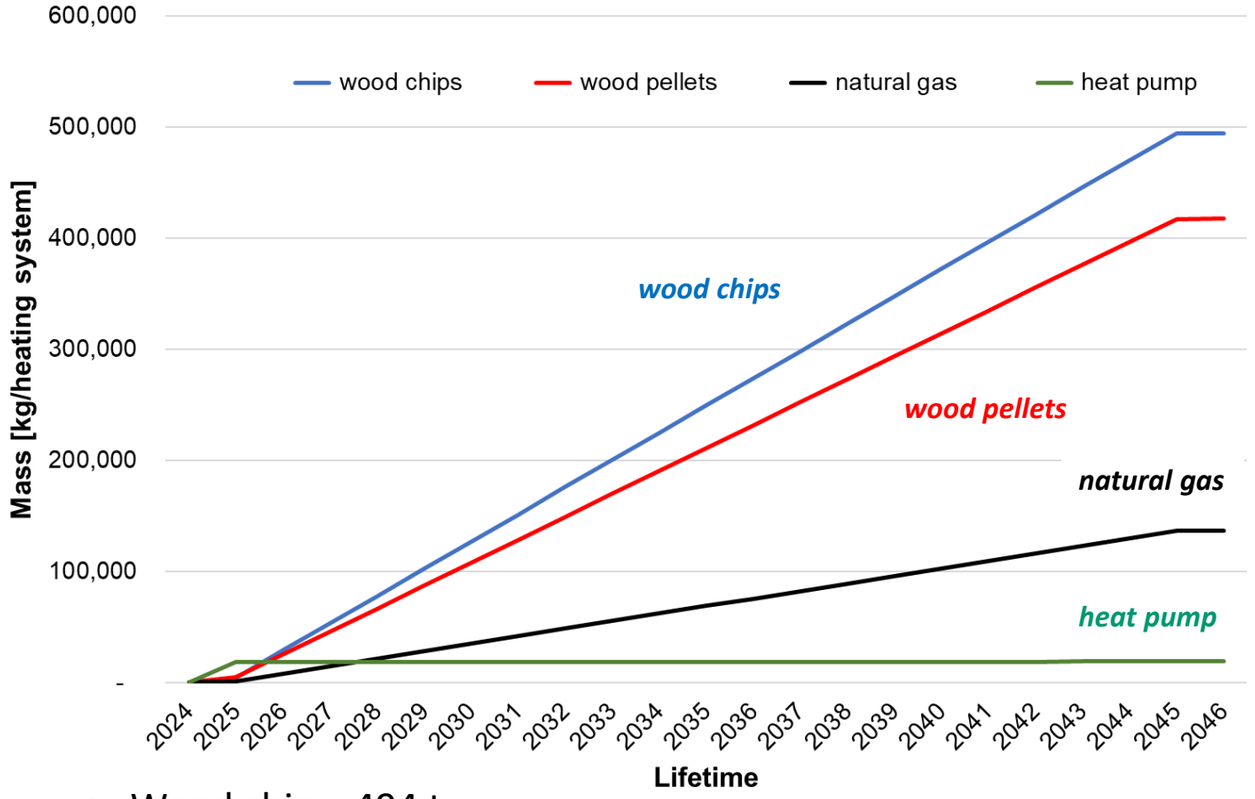
Climate Neutrality Potential



- Wood chips: 6.5E-11 W/m²
- Wood pellets: 6.6E-11 W/m²
- Natural gas: 5.3E-10 W/m²
- Heat pump: 2.1E-11 W/m²

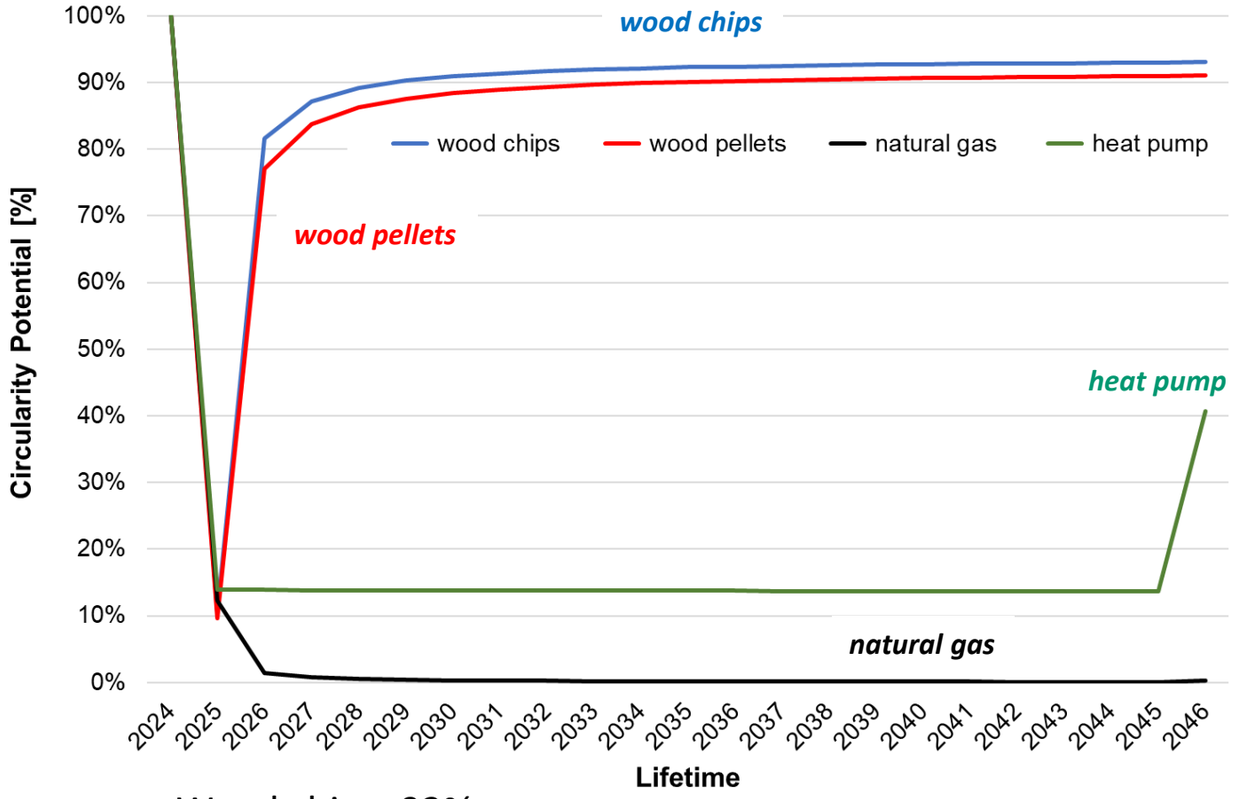
Results (III): Circularity

Mass



- Wood chips: 494 t
- Wood pellets: 417 t
- Natural gas: 137 t
- Heat pump: 19 t

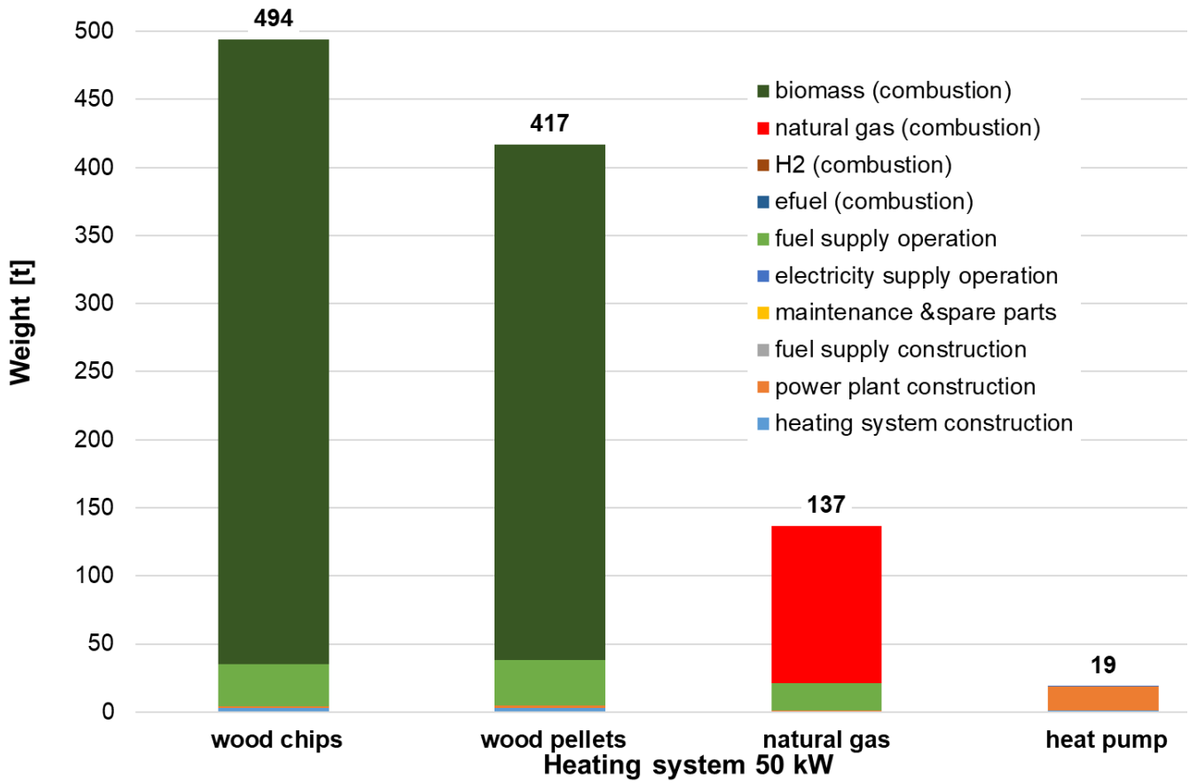
Circularity Potential



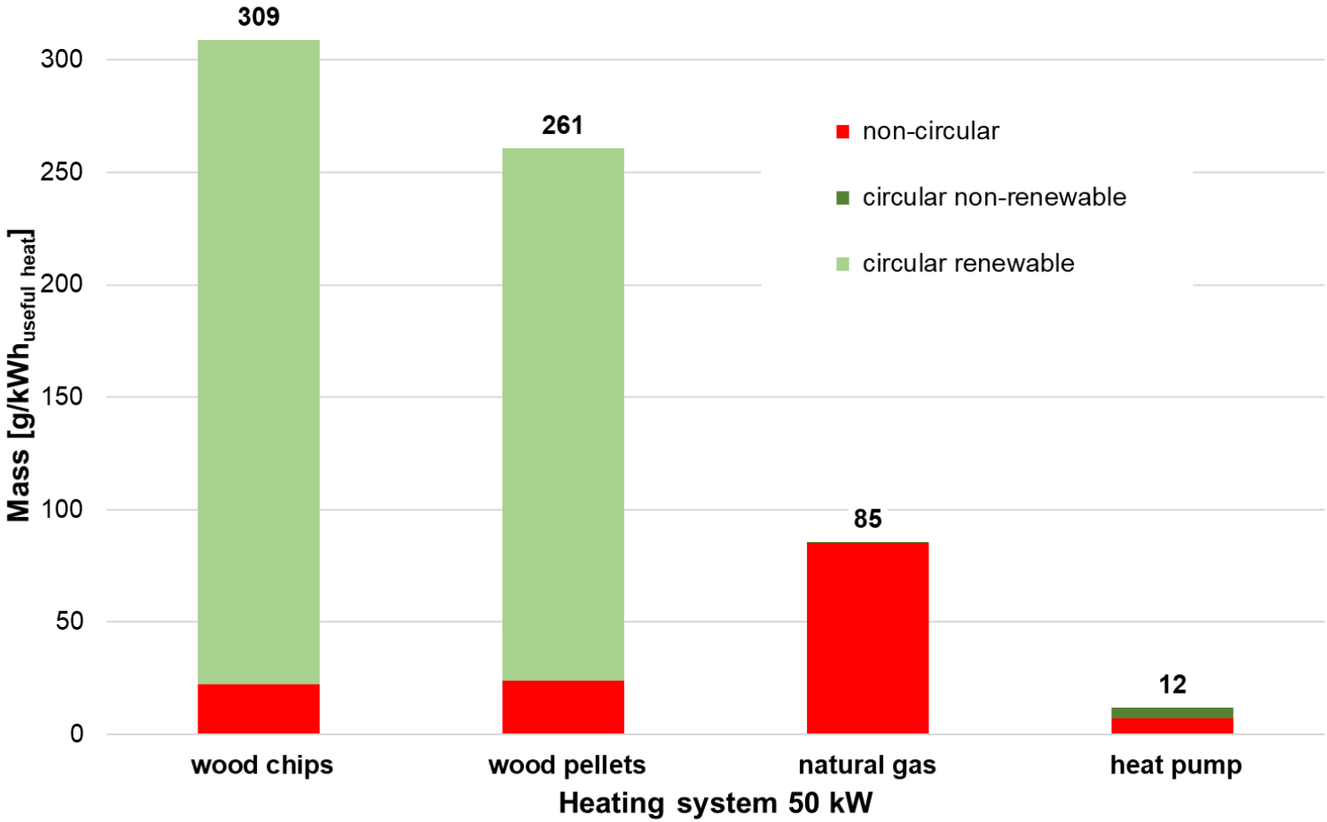
- Wood chips: 93%
- Wood pellets: 91%
- Natural gas: 0.2%
- Heat pump: 41%

Results (IV): Circular Mass

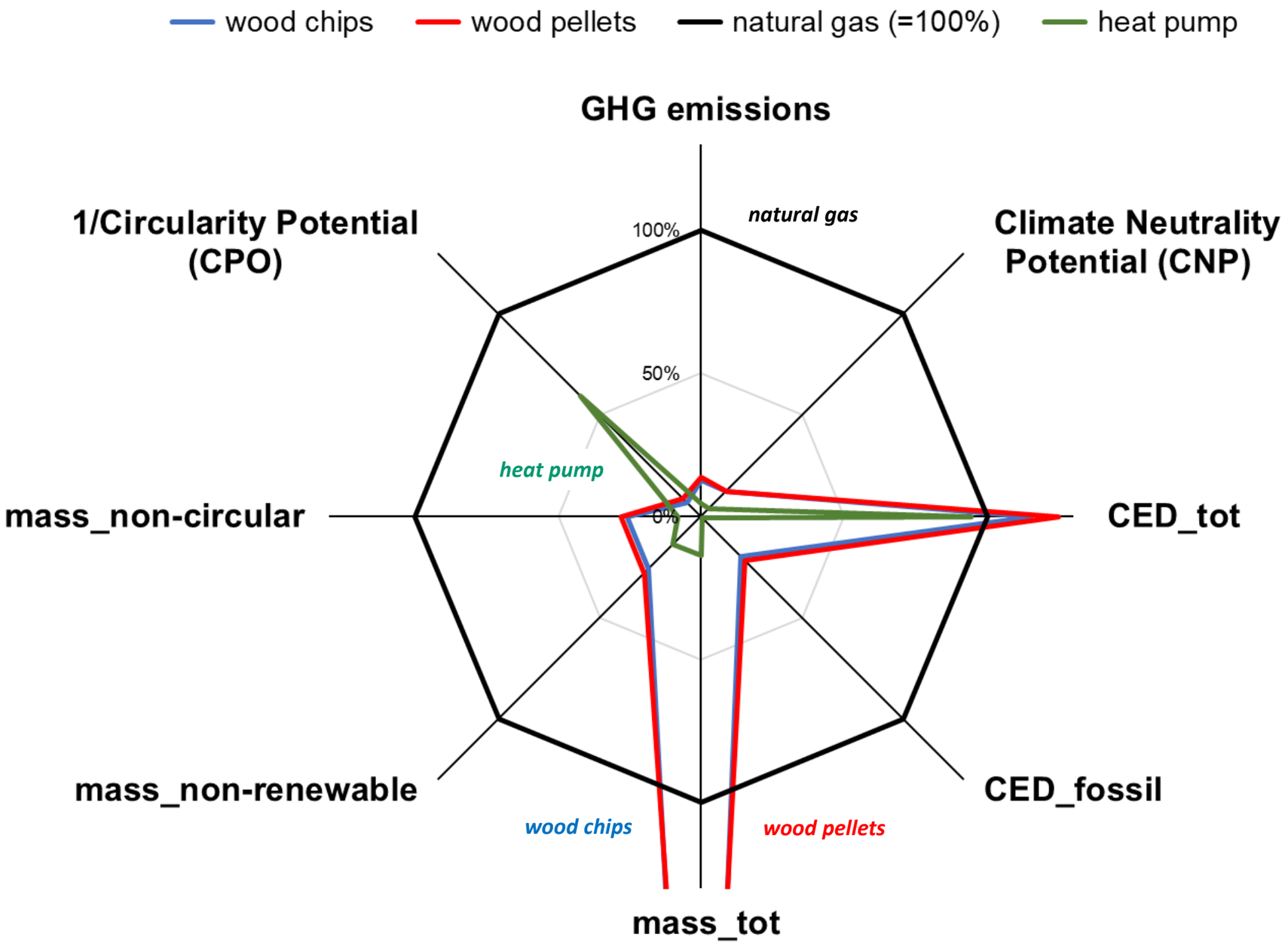
Total Mass



Specific Mass



Results (V): Total Assessment



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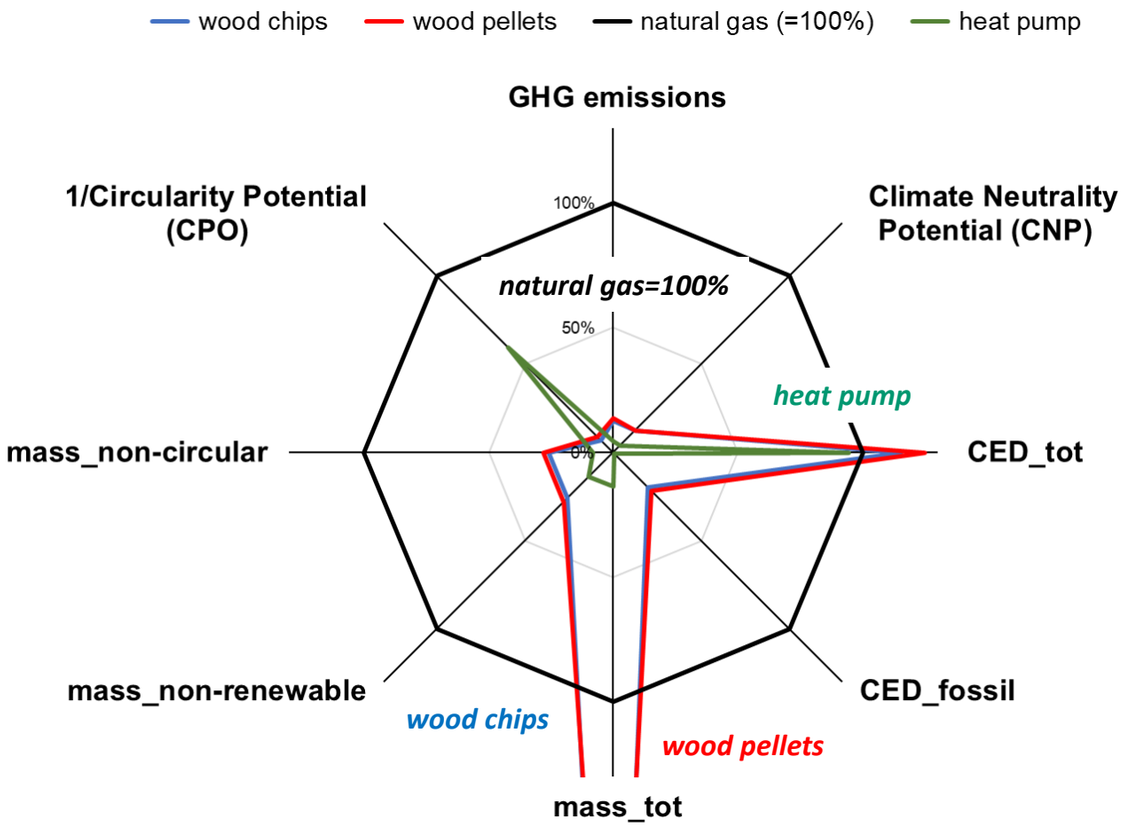

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Your Contact

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