

Global warming potential of bioenergy conversion pathways in Austria: A comparative life cycle assessment

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Which one is better?



Bild: KI-generiert (BESTAI)

Which one is better?



It depends on what function they provide, how we define the system, and what we use as a reference

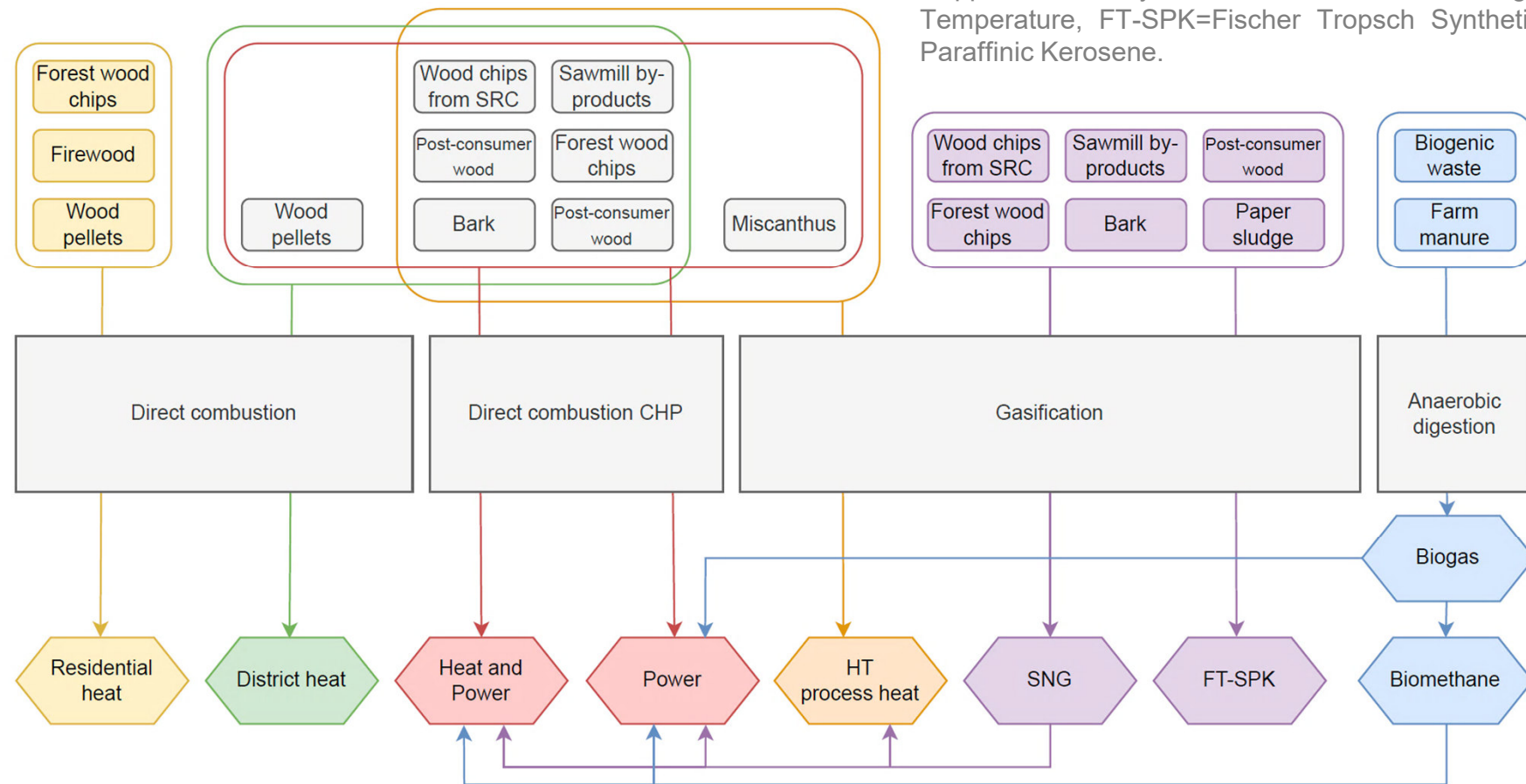


Bild: KI-generiert (BESTAI)

Bioenergy Pathways



Selected feedstocks, bioenergy conversion pathways and end-use, SRC=Short Rotation Coppice, SNG=Synthetic Natural Gas, HT=High Temperature, FT-SPK=Fischer Tropsch Synthetic Paraffinic Kerosene.



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Objective

1. Calculate the global warming potential (GWP) of each bioenergy pathway in Austria
2. Compare the GWP of bioenergy pathways with each other and their respective fossil-based alternatives/current energy mix

Why?

The GWP assessment, combined with a cost assessment, provided the basis for optimally allocating available biomass streams to bioenergy pathways in Austria

LCA Methodology – Study context Austria =



Standards & system boundaries

ISO 14040 & ISO 14044

Functional unit:
Bioenergy pathways:
1 MJ useful energy output

Cradle-to-grave approach for most pathways
Cradle-to-gate for SNG, FT-SPK & biomethane

Impact assessment

Focus on **Global Warming Potential (GWP)**

Results reported as **g CO₂-eq/MJ**

Characterization according to **EF3.1**

Life Cycle Inventory

Peer-reviewed literature

Upscaled data from **operational demonstration plants**

Reference plants located in **Austria**

ecoinvent background data adapted & updated to current state-of-the-art

LCA modelling

openLCA 2.0

ecoinvent v3.9

Austria specific-data

Allocation: “**cut-off by classification**”

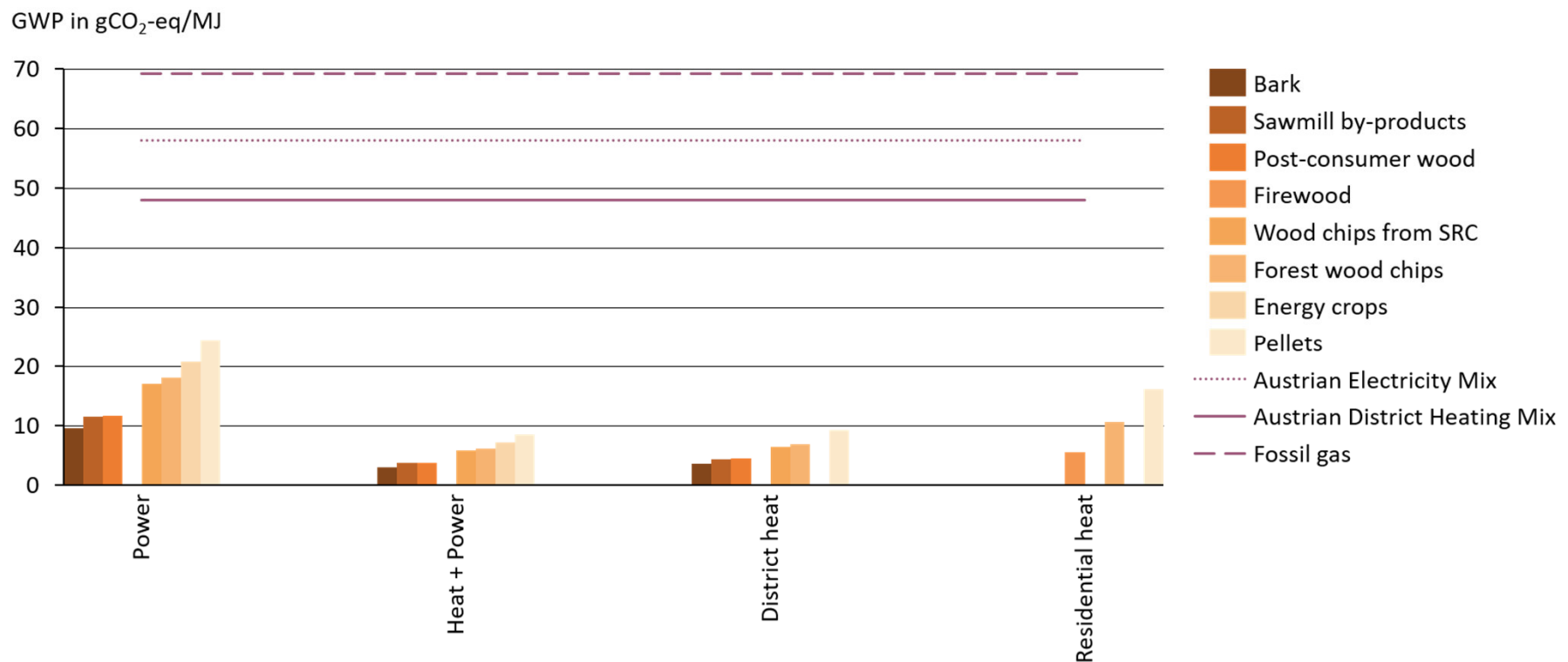
Credits for alternative emissions scenarios were not taken into account!



Consistent basis for comparing alternative bioenergy conversion pathways



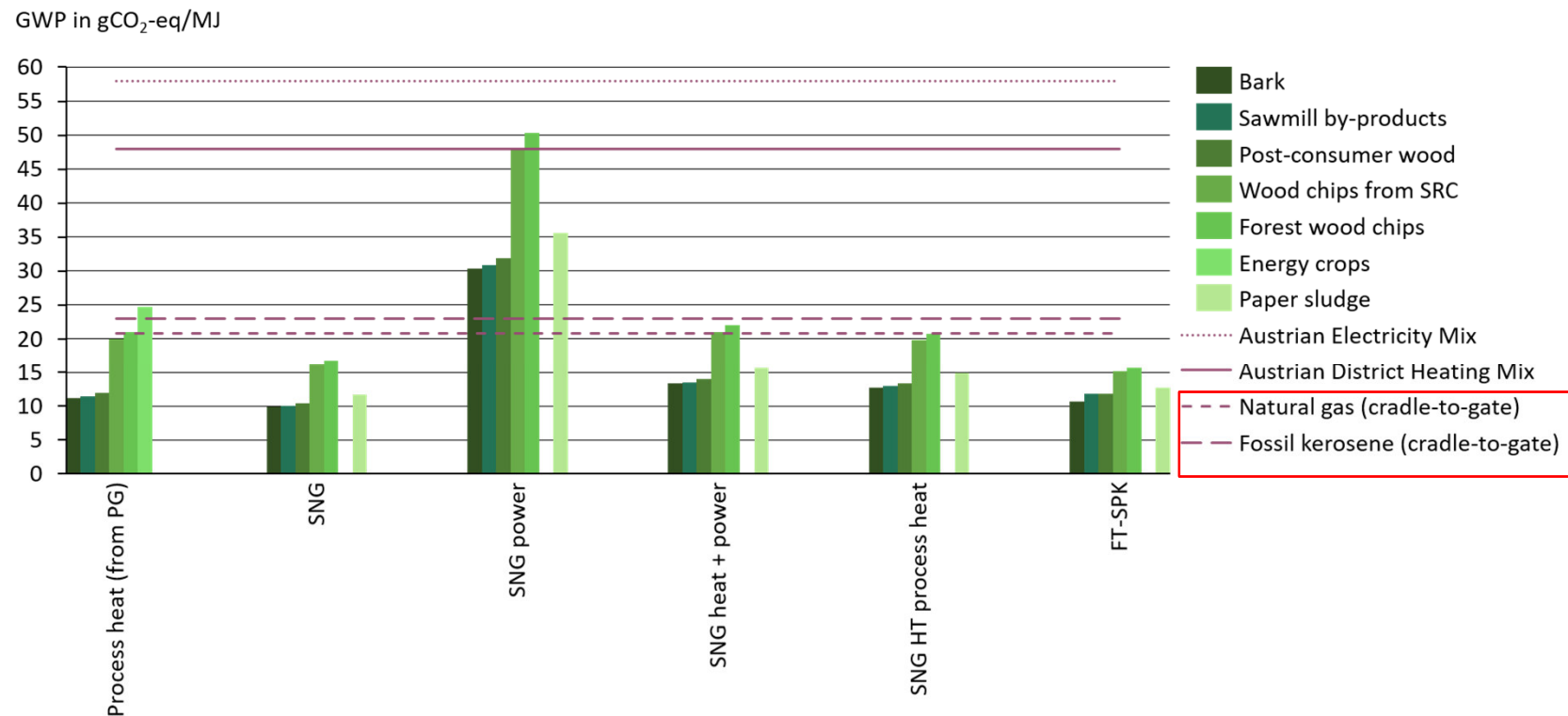
GWP thermo-chemical bioenergy conversion pathways providing heat and/or power



GWP given in gram CO₂-equivalent per MJ provided energy for each considered feedstock in relation to reference systems. SRC=Short Rotation Coppice



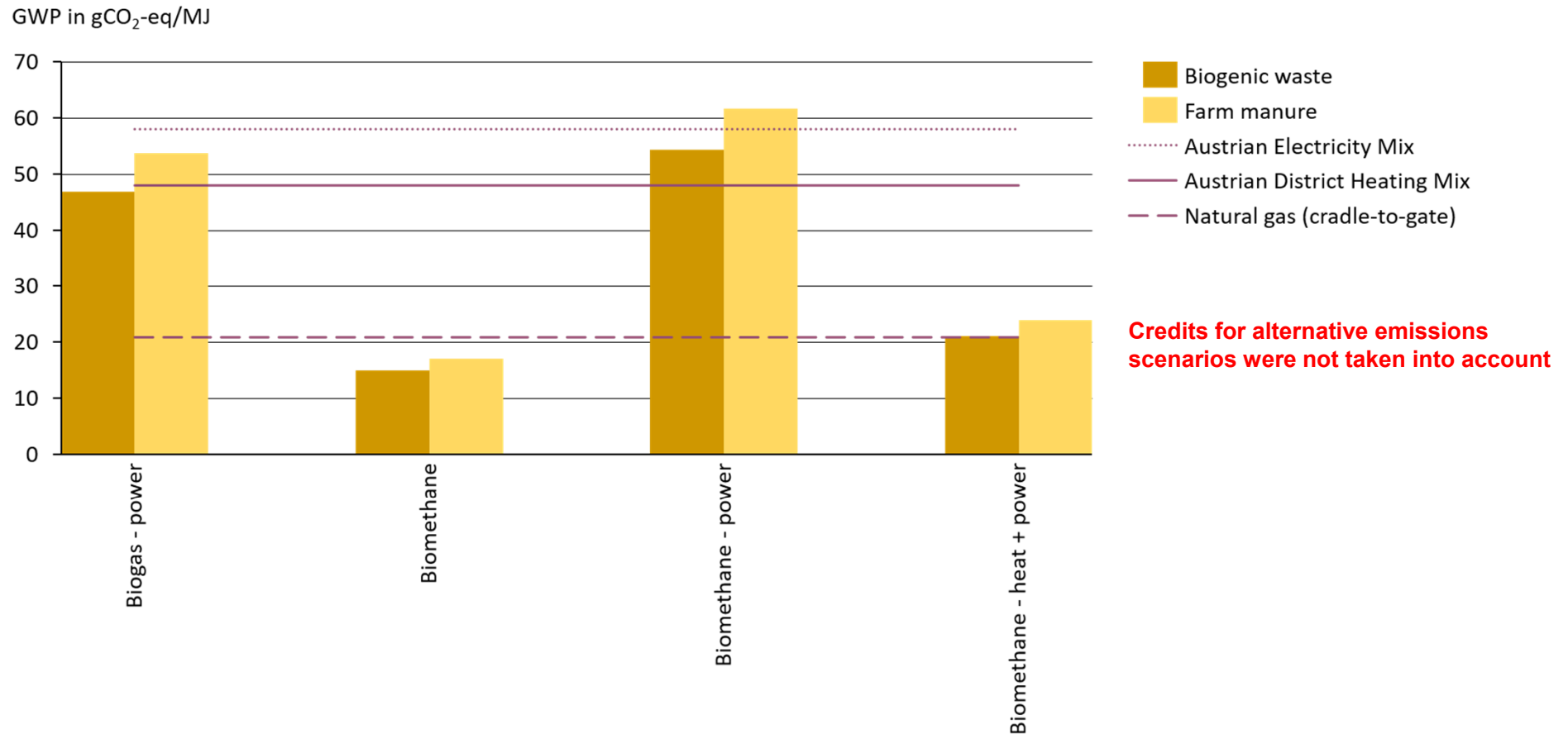
GWP of biomass gasification and different end use scenarios



GWP given in gram CO₂-equivalent per MJ provided energy for each considered feedstock. PG=Product Gas, SNG=Synthetic Natural Gas, HT=High Temperature, FT-SPK=Fischer Tropsch Synthetic Paraffinic Kerosene, SRC=Short Rotation Coppice



GWP of the bio-chemical pathways and different end use scenarios



GWP given in gram CO₂-equivalent per MJ provided energy for each considered feedstock



Sensitivity Analysis – Austrian electricity mix

Pathway	GWP reduction
Combustion	–1%
Anaerobic digestion + upgrading	–8%
Gasification + synthesis	–33%
Gasification + synthesis	13.3 → 8.9 g CO ₂ -eq/MJ

Renewable electricity has **limited impact on combustion**,
but **strong impact on gasification & synthesis**



Key Findings – GHG Mitigation Potential & Trade-offs

■ GHG mitigation potential

- Bioenergy pathways can reduce GHG emissions by **up to 92%** vs. fossil-based references & current energy mixes
- **Woody residues for heat & CHP**: lowest GWP at **3.4–4.4 g CO₂-eq/MJ**
- **Biomethane from farm manure**: up to **61.7 g CO₂-eq/MJ**
- **SNG from forest wood chips**: up to **50.3 g CO₂-eq/MJ**

■ Key drivers of climate performance

- **Feedstock supply chains** can strongly influence overall GWP
 - Residues → **low upstream emissions** due to minimal processing
 - Wood pellets → **higher upstream emissions** due to drying & pelletizing
- **Conversion efficiency & internal energy demand** are critical
- **Waste heat utilization** can improve overall system performance

■ Technology comparison & implications

- Enables comparison of **innovative thermo-chemical pathways** (e.g. gasification) with established technologies
- Highlights trade-offs between **efficiency, process complexity & GHG performance**
- Excluding avoided burdens/system credits ensures **harmonized comparison**
- Limited biomass availability → **diversified feedstocks & conversion technologies** are needed



Key Findings – GHG Mitigation Potential & Trade-offs

- **GHG mitigation potential**

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- **Take-home message:**

Low-GHG bioenergy depends on both low-emission feedstock supply and efficient conversion

- **Technology comparison & implications**

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Reference & Funding

- *Matschegg D., Kumpan K., Strasser C., Dißbauer C.: Global warming potential of bioenergy conversion pathways in Austria: A comparative life cycle assessment, Biomass and Bioenergy, Volume 216, 2027, 109750, ISSN 0961-9534, <https://doi.org/10.1016/j.biombioe.2026.109750>.*
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