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Life Cycle Assessment of Electricity and Heat Generation of a Biomass Gasification Plant including the District Heating Network

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Plant Description

Goal of the study is to assess the environmental impacts of the production of heat and electricity from a biomass gasification plant. All results are based on Käpplers master thesis [1]. Investigated is a floating fixed-bed gasifier with extra pyrolysis step and a gas engine for heat and electricity production (200 kW_{el}). The plant is located in the urban area of Dornbirn, Austria (see figure 1) and provides electricity to the grid and heat directly to consumers via a district heating grid.

Fig 1: Plant in Dornbirn, Austria.

Figure 3 shows the energy balance during the operating year 2016. Wood chips are dried with waste heat from a biogas plant from a water content of 40% to 15% and transported to the plant. In the gasification plant, the wood chips are converted to electricity (29.3%) and heat (55.2%). 10.1% of the wood chip heating value is found in the biochar, which is a by-product of the gasification process. Closing the energy balance, the thermal, mechanical and gas flare losses account for another 5.3%.

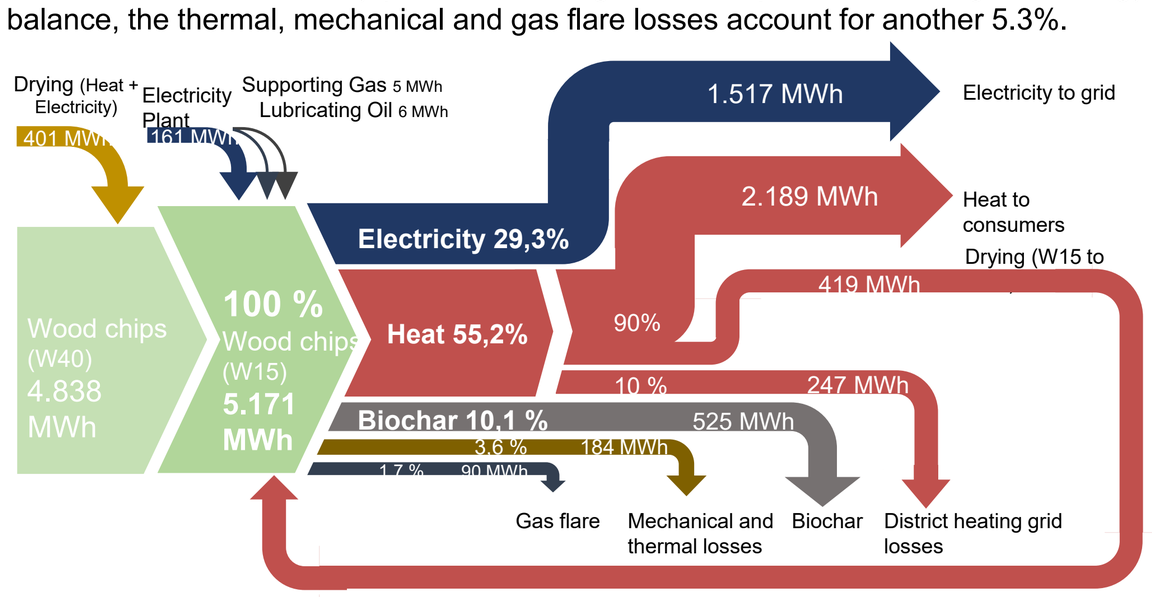

Fig 2: Energy Balance in the operating phase for 2016.

The main share of the heat (76.7%) is delivered to the customers through the district heating grid, while 10% distribution losses are accounted for. The remaining 14.7% of the heat is returned to the plant for drying the wood chips from 15% to 10% water content.

Inventory

Methods, scope and system of the Life Cycle Analysis

- Functional unit: 1 kWh delivered energy. For 2016 delivered energy is equal to electricity delivered to the grid (1517 MWh a^{-1}) and the heat delivered to customers (2189 MWh a^{-1}), as shown in figure 2.
- Scope: Cradle to Grave: Including the biomass supply chain, the heating grid and constructions
- Software/Data used: SimaPro 8.3.0.0, ReCiPe Midpoint (H) V1.13, EcoInvent
- Inventory (figure 3): all processes modelled with primary data, inputs mostly from database

INPUTS	PROCESSES	PHASE (OUTPUT PER FUNCTIONAL UNIT)
• Concrete, steel, … • Transport • Machine operation • Waste treatment	• Main building • Storage hall • Gasifier • Gas engine • District heating grid	**Construction** ($2.7*10^{-7}$ units)
• Transport • Machine operation	• Felling • Chidding • Skipping • Transport	**Biomass supply chain** (0.45 kg wood chips W40)
• Transport • Machine operation • Electricity from hydro • Heat from biogas • Emissions	• Wood Chip Processing: Drying, Handling, Transport • Plant operation: electricity, lubricating oil, supporting gas, emissions incl. biochar	**Operation** (1 kWh energy delivered: 59% heat, 41% electricity)

Fig 3: Scope and Processes in the life cycle inventory.

Results

Main results for category climate change (see figure 4 and 5):

- The operation phase has the biggest share (47%)
- If the carbon bound in the biochar is accounted for, the value is negative (-36.8 g_{CO_2eq} kWh^{-1})
- Handling of wood chips (operation phase) has the biggest share of all processes.
- Combustion of diesel for machine operation and transport is the main driver in all phases

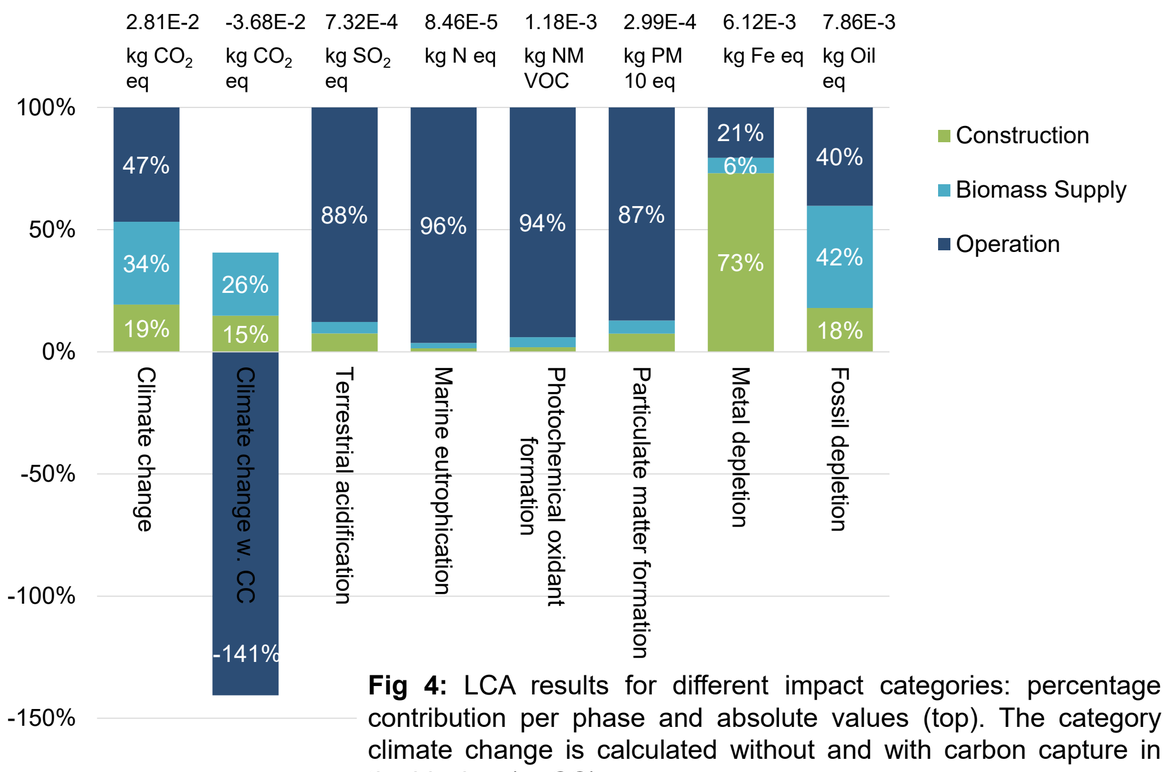

Fig 4: LCA results for different impact categories: percentage contribution per phase and absolute values (top). The category climate change is calculated without and with carbon capture in the biochar (w. CC).

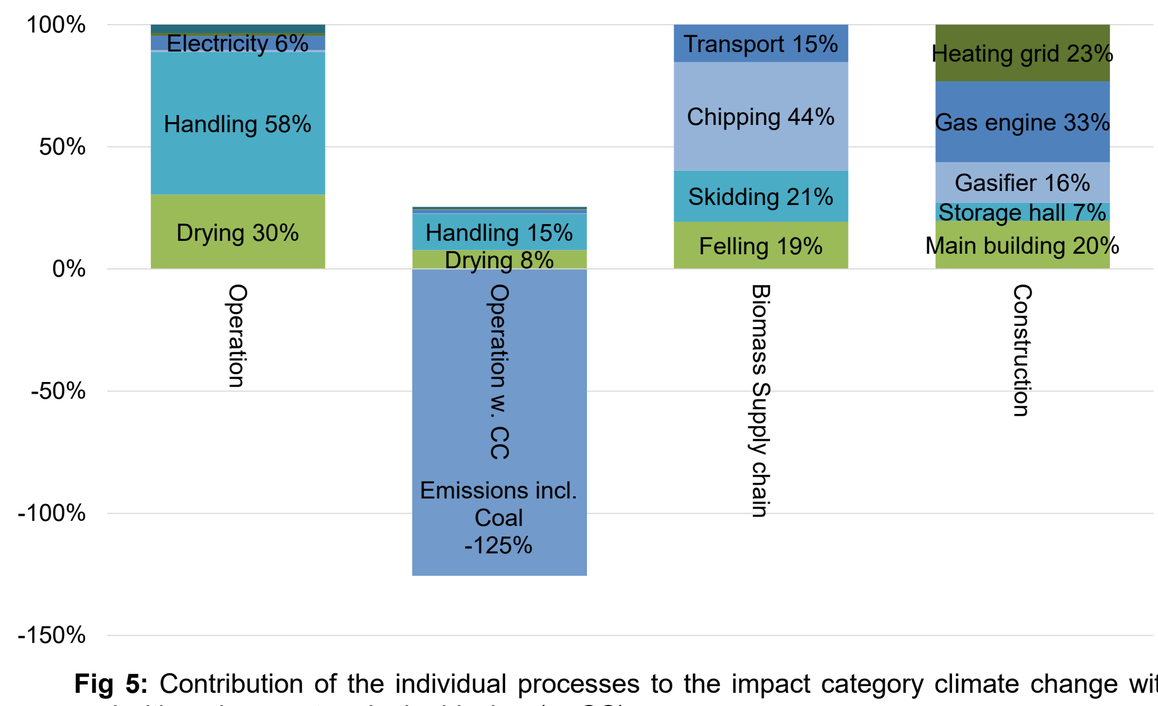

Fig 5: Contribution of the individual processes to the impact category climate change without and with carbon capture in the biochar (w. CC).

Conclusions

- The lever for reducing the total GHG emission would be a switch from diesel engines to a low-emission drive system (e.g. electric) during the biomass supply and turnover.
- Biomass gasification is a potential CO_2 sink, if the carbon bound in the biochar is considered a carbon storage. An analysis of different use cases for the biochar would be an interesting research topic for the future.

[1]E. Käppler, „Lebenszyklusanalyse der Strom- und Wärmeerzeugung einer Holzvergasungsanlage inklusive Nahwärmenetz. Am Beispiel des Schwebefestbettvergasers des Energiewerk Ilg“, Masterarbeit, FH Vorarlberg, Dornbirn, Austria, 2017.

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