Supplementary Material

A.1 Detailed assumptions and explanation of Life Cycle Inventory

Below follows a detailed explanation of the masses and processes listed in Table 1 – including sources and explained calculation:

According to Klingler et al. (2021), both a crawler excavator with demolition grapple and a wheeled excavator with sorting grapple for loading are required for the concrete demolition process (Klingler et al., 2021). The useful output in continuous operation is 20 m³/h for the crawler excavator and 35 m³/h for the wheeled excavator (Schröder and Pocha, 2015). According to Klingler et al. (2021), these values refer to weakly reinforced concrete and serve only as approximate values for this study. Since the useful output of the excavators in continuous operation is much higher than in average operation, Klingler et al. (2021) assumed that the operating time is estimated to be one-third of the operating time, which we adopt as such in this study. (Klingler et al., 2021) The fuel consumption in this case is 9.18 kg diesel/h for the crawler excavator and 5.57 kg diesel/h for the wheeled excavator (Notter and Schmied, 2015). The average diesel consumption (in kg) per m³ of concrete can now be determined: the fuel consumption was divided by the effective output and resulted in a total consumption of 1.87 kg diesel/m³ of concrete. (Klingler et al., 2021) Subsequently, this value was multiplied by the density of the double-wall (1,430 kg/0.6 m³ = 2,383.33 kg/m³) and resulted in a consumption of 7.846E04 kg diesel/kg usable material from the double-wall. This consumption was modeled in GaBi using the input process "DE: Diesel mix at filling station Sphera" and converted to 0.03382 MJ/kg.

The transport of the demolition material to the stationary processing plant was modeled using the process "GLO: Truck, Euro 4, 26-28t gross weight/ 18.4t payload capacity" and a distance of 17 km to be covered according to Müller (2018) (Müller, 2018). The truck is operated with the "DE: Diesel mix at refinery Sphera". To determine the distance to be covered, Müller (2018) first calculated the statistical mean size of the catchment area of stationary processing plants by dividing the area of Germany by the number of stationary processing plants. The resulting catchment area of 580 km was placed in a square grid over Germany. (The square root of 580 km^2 (= area of the catchment area) gives the length or width of the square catchment area (24.08 km). To now determine the distance from the center to the corner points, half of this length is multiplied by 1/[sin (45°)] and results in a distance of 17 km). To determine from this the transport distance to be covered (without overlapping or uncovered areas in the catchment areas), Müller (2018) first assumed that the recycling plant was located in the center point and the construction waste in the upper left corner point of the square catchment area. Then, the distance of the two points was calculated and resulted in a distance of 17 km to be covered for transport. (Müller, 2018)

For the processing of the concrete in a stationary processing plant, Klingler et al. (2021) drew on measured consumption data from the Swiss company KIBAG on the one hand and consumption data from an already existing LCA (Tschümperlin et al., 2016) on the other (Klingler et al., 2021; Tschümperlin et al., 2016). In KIBAG's fully diesel-powered processing plant, concrete crushers (impact crushers, cone crushers) and screening machines are used for processing the concrete demolition material, as well as excavators and wheel loaders for feeding the crusher and loading the recycled concrete fraction (Klingler et al., 2021). In the existing LCA according to Tschümperlin et al. (2016), consumption data of Eberhard Bau AG were used, in which the concrete demolition is dry processed in a multiple crushing-screening plant. The stationary processing plant of Eberhard Bau AG is operated partly with electricity and partly with diesel. Compared to the stationary processing plant of KIBAG, the concrete demolition is additionally treated by a cross-flow classifier for the separation of impurities and an overband magnet for the separation of reinforcement. (Tschümperlin et al., 2016) However, in comparison to the consumption data provided by KIBAG, Eberhard Bau AG did not indicate the electricity or diesel consumption of the individual plant components, but the electricity and diesel required for the entire preparation process of 1 kg of concrete granulate. According to Tschümperlin et al. (2016), 1.03 kg of concrete demolition material is required to produce 1 kg of concrete granulate. Klingler et al. (2021) divided the electricity and diesel consumption, which is necessary for the production of 1 kg of concrete granulate, by the required 1.03 kg of concrete demolition and thus obtained the electricity and diesel consumption for 1 kg of concrete demolition. For the life cycle inventory according to Klingler et al. (2021), average values were ultimately calculated from the data of KIBAG and Eberhard Bau AG to determine the flat-rate electricity and diesel consumption for the entire processing of 1 kg of concrete demolition. (Klingler et al., 2021)

Unlike Klingler et al. (2021), this study does not apply a flat-rate electricity and diesel consumption for the entire preparation process, since the focus is on the comparison of the emission outputs of the recycling sub-processes. Accordingly, the consumption data of the individual plant sections of KIBAG are used. However, it must be considered that the KIBAG treatment process does not include the magnetic separator required according to Kortmann (2020b) in combination with the cross-flow classifier (pre-separation) and the camera-based sorting unit (main separation). Therefore, the energy consumptions of the missing plant components are supplemented by additional data sets.

According to KIBAG, feeding the demolition material with the excavator consumes 0.11 kg diesel/t concrete demolition (Klingler et al., 2021). This consumption was modeled in GaBi using the input process "DE: Diesel mix at filling station Sphera" and converted to 0.0047 MJ/kg via the software.

The main crushing by the concrete crusher consumes 0.82 kg diesel/t of concrete demolition (Klingler et al., 2021). This consumption was modeled by the input process "DE: Diesel mix at filling station Sphera" and converted to 0.035 MJ/kg via the software.

The pre-separation with the stationary magnetic separator in combination with the cross-flow classifier is not part of the fully diesel-operated treatment plant of KIBAG, but of the stationary treatment plant of Eberhard Bau AG. Here, it is not known which plant components of Eberhard Bau AG are electricity- or diesel-powered (Klingler et al., 2021). Klingler et al. (2021) indicates an electricity consumption for the processing of 1 kg of concrete demolition waste, which cannot be generated by the diesel-powered processing plant of KIBAG, but only by the sub-processes of Eberhard Bau AG. Therefore, it is assumed that the mean value of 0.002 kWh of electricity per kg of concrete in the processing plant formed by Klingler et al. (2021) relates entirely to the magnetic separator in combination with the cross-flow classifier and thus represents the energy consumption of the pre-separation. (Klingler et al., 2021)

The consumption of 0.002 kWh/kg concrete in the preparation plant was modeled in GaBi using the input process "DE: Electricity grid mix (2020) ts" and converted to 0.0072 MJ/kg via the software (Klingler et al., 2021). It should be noted that 10 % of the carbon reinforcement is removed from the material stream in the pre-separation according to Kortmann (2020b). The extracted 10 % of the carbon reinforcement can already be recycled further (e.g.: pyrolysis and mechanical recycling) and thus neither pass through the main separation nor the subsequent screening. Since this life cycle inventory is based on the required energy per kg of re-usable material from the double-wall according to Otto and Adam (2019), this would mean that of the 0.007 kg of carbon reinforcement after this process step, only 0.0063 kg of carbon reinforcement is carried on to the subsequent process step (main separation) (Otto and Adam, 2019). In this model, however, the case is assumed that 100 % of the carbon reinforcement is retained in the concrete fraction and is therefore not removed from the material stream. This is the worst case, as all the carbon reinforcement has to pass through both the main separation and the screening, and accordingly more energy is required.

Since the main separation by Kortmann (2020a) passes through the camera-based sorting in the processing plant, this was added to the KIBAG consumption data in this life cycle inventory (Klingler et al., 2021; Kortmann, 2020a). According to Manouchehri (2006), the energy consumption is estimated to be 1.5 kWh/t of pegmatite raw material (grain size 12-30 mm) (Manouchehri, 2006). Due to the lack of data regarding the exact energy consumption of a camera-based sorting unit for CRC, 1.5 kWh/t of concrete demolition was used as an approximation for the life cycle inventory. This consumption was modeled in GaBi using the input process "DE: Electricity grid mix (2020) ts" and converted to 0.0054 MJ/kg via the software.

According to KIBAG, screening consumes 0.13 kg diesel/kg of demolished concrete (Klingler et al., 2021). The foreign mineral constituents up to 2 mm maximum grain size were neglected for the calculation of the diesel consumption resulting from the screening process. Chapter 2 also points out that a maximum of 2.3 % of the carbon roving fragments remain in the concrete recyclate after the main separation. It is assumed here in a simplified way that 100 % of the carbon roving fragments could be separated and thus no fraction remains in the concrete recyclate. Thus, 0.007 kg of material is screened, resulting in a diesel consumption of 9.1E-04 kg. This consumption was modeled in GaBi by the process "DE: Diesel mix at filling station Sphera" and converted to 3.85E-05 MJ/kg via the software.

Discharge to the bunker by wheel loader would have to be done for both the exposed carbon reinforcement and the concrete fraction. The removal consumes 0.13 kg diesel/kg concrete demolition in this process (Klingler et al., 2021). This consumption was modeled in GaBi using the input process "DE: Diesel mix at filling station Sphera" and converted to 5.7E-03 MJ/kg via the software.

The transport route from the stationary processing plant to the subsequent recycling (variant 1: mechanical recycling or variant 2: pyrolysis) of the fibers (0.007 kg) contained in the carbon reinforcement was assumed to be the average transport route of 100 km in GaBi ts. The input process "GLO: Truck, Euro 4, 12 - 14t gross weight / 9.3t payload capacity", which is operated with the "DE: Diesel mix at refinery Sphera", was used for this purpose.