Appendix:

Selection of Tools

According to Hilti Group experts' suggestion, when comparing the handheld tool (i.e. DSH 900) with rail-guided system (i.e. DST 20-CA), the latter is selected for the cutting task in this study due to its superior performance and suitability for the specific task. The decision is not based on a comparison with handheld tools or rail-guided systems. The key information related for choosing the DST 20-CA over other options are as follows:

- Machine Weight: 32 kg
- Machine Lifespan: 1000 h or 4-5 $year$ (roughly 1h service per day)
- Cooling Water Speed: 2 l/min or 120 l/h
- Versatility: Unlike the DSH 900, the DST 20-CA is capable of cutting through any rebar, including steel plates, making it suitable for a wide range of cutting tasks with varying degrees of reinforcement.
- Cutting Precision: The DST 20-CA excels in precision cutting and maintains narrow tolerances, ensuring accurate and consistent results. In contrast, the handheld DSH 900 struggles with precision due to user dependence, leading to variations in cutting speed and accuracy.
- Cutting Depth: The DST 20-CA can handle cutting depths of up to 73 cm, offering greater flexibility in tackling deeper cuts compared to the limited 15 cm cutting depth of the DSH 900.
- Environmentally Friendly: The DST 20-CA is an electric-powered system, making it environmentally friendly and suitable for indoor use without emitting fumes like the combustion engine-driven DSH 900, which is recommended for outdoor use only.
- **Cutting Speeds:** The cutting speed of the Hilti DST 20-CA depends on the depth of the cut and the type of material being cut. In reinforced concrete, the cutting speed is approximately 2 m/min at a depth of 5 cm and 0.7 m/min at a depth of 15 cm.
- **Cutting Passes:** The cutting process involves making cutting passes with a depth ($Depth\ per\ cut$) of about 12 cm. These passes are done back and forth to ensure a complete cut. Additionally, a guide cut is performed as the first pass, which runs at roughly half the normal cutting speed. This guide cut is essential to ensure a straight and accurate cutting path.
- **Speed Variation:** The cutting speed is strongly influenced by the type of base material. According to Hilti experts working with the Hilti wall saw DST 20-CA, in reinforced concrete with "normal" reinforcement of up to 1% and medium-hard aggregates, the saw can achieve a cutting speed of 6-8 m^2/hr. However, in areas with more reinforcement and harder aggregates (e.g., in cities like Paris, London, or Rotterdam), the cutting speed decreases to 3-4 m^2/hr.
- **Blade Lifetime:** The blade's lifetime refers to the total area that can be cut before the blade needs replacement. For the described environments (reinforced concrete with different levels of reinforcement and hardness), the blade lifetime is around 30 m^2 and 15 m^2 , respectively.
- **Brick and Block Cutting:** While specific cutting speeds have not been systematically measured for brick and block materials, it is reasonable to assume that the cutting speeds for these materials could be double that of reinforced concrete.
- **Process Dominance:** It is essential to consider that the cutting setup, securing of cut pieces, and handling of the cut pieces play a dominant role in the cutting process. These aspects can significantly impact the overall efficiency and time required for cutting.

In summary, the cutting path calculation involves determining the appropriate cutting speed based on the depth of the cut and the type of material (e.g., reinforced concrete, brick, or block). The cutting process is accomplished through back-and-forth cutting passes, with the first pass serving as a guide cut for precision. The type of material and its characteristics influence the cutting speed and blade lifetime. However, the overall process's efficiency is also affected by factors such as the cutting setup and proper handling of cut pieces.

Overall, the DST 20-CA stands out as the ideal choice for this cutting task due to its high power, cutting speed, versatility, precision, and suitability for both indoor and outdoor use. The decision is backed by its impressive performance in normal reinforced concrete, ability to handle different rebar types, and capacity to deliver consistent and accurate results even at greater cutting depths.

Clarification of Parameters

Given conditions are provided below and are calculated according to IPCC 2021, Ecoinvent 3.10 unless otherwise stated.

- Lean Concrete Density: 2150 kg/m^3
- Steel Density: 7850 kg/m^3.
- Lean Concrete Emissions, with cement CEM II/B: 0.0408 $kgCO_2-eq/kg$.
- Civil Concrete Emissions, 37MPa, for civil engineering, with cement, Portland: 0.0903 $kgCO_2-eq/kg$.
- Reinforcing Steel Carbon Emission: 2.3173$kgCO_2-eq/kg$.

- Green Electricity Carbon Emissions: 0.0023 $kgCO_2-eq/kWh$.
- Gray Electricity Carbon Emissions: 0.9230 $kgCO_2-eq/kWh$.
- Diesel-based Generator Carbon Emissions: 76.44 $kgCO_2-eq/hr$.
- Diamond Blade Carbon Emission GHG_{blade}: The carbon emission associated with the diamond blade used in the cutting process is determined through linear extrapolation based on a study conducted on another type of diamond blade. By applying this extrapolation, we arrive at an emission value of 19 $kgCO_2-eq/kg$ for the 800mm diameter blade utilized in our case with the Hilti wall saw DST 20-CA. This calculation takes into careful consideration the blade's unique characteristics and emission factors, enabling a more accurate assessment of its GHG emissions [1].
- Transportation Carbon Emission: EURO6 lorry of12 $ton, 9m^3$ load and space capacity are used for the calculation. The carbon emissions associated with transportation is estimated to be 0.15221 $kgCO_2\ per\ ton-kilometer\ (tkm)$, an average lorry capacity of 12 tons is taken.

Water Consumption Comparison

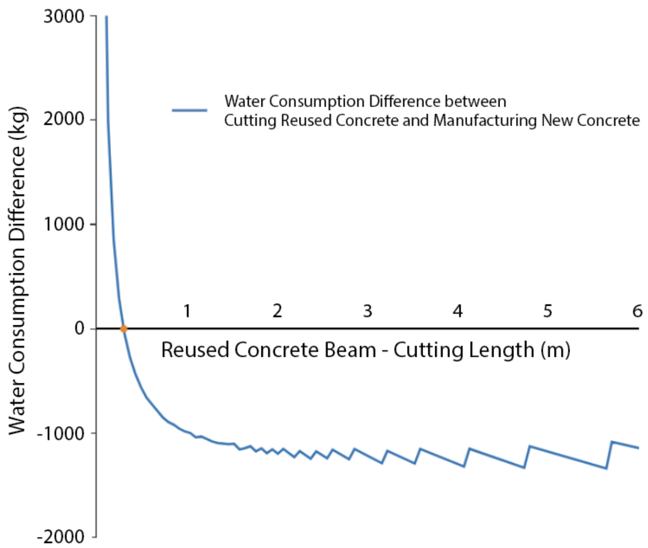

Figure 6. Comparative Water Consumption: Reuse vs. New Manufacturing of Concrete Components, Assuming Equal Transportation Distances

We also examined the difference in water consumption between the two scenarios. In the case of reusing concrete, the cutting process necessitates cooling water at a rate of 2 liters per minute to prevent equipment overheating, clear the surface, and remove cut aggregates. Wall saws are equipped with a water cooling system that sprays water onto the blade during cutting, not just to control dust but also to regulate the cutting blade's temperature [2].

For new concrete production, research by Y. Mack [3] conducted an extensive investigation into water consumption, revealing that approximately 313 kg of water is consumed to manufacture 1 cubic meter of concrete. These insights were integrated into the existing model to comprehend the influence of water consumption. As presented in Figure 6, there exists a threshold where water consumption for reuse overtakes that for new production, set at 0.3 m for a $0.4m \times 0.4m$ beam. This limit arises because smaller-sized pieces result in more cut pieces per truck load, increasing total cutting time and water consumption for reuse. However, the impact of carbon emissions outweighs the water consumption, considering that this size limit is smaller than the environmentally calculated limit. Hence, the screening threshold leans more towards the impact of carbon emissions over water consumption.

Additional Detailed Analysis on Transportation

Figure7 illustrates how the ratio of transportation distances $\Delta D_{t-reuse,t-new}$ and the cutting length of reused concrete pieces influence GHG emissions differences.

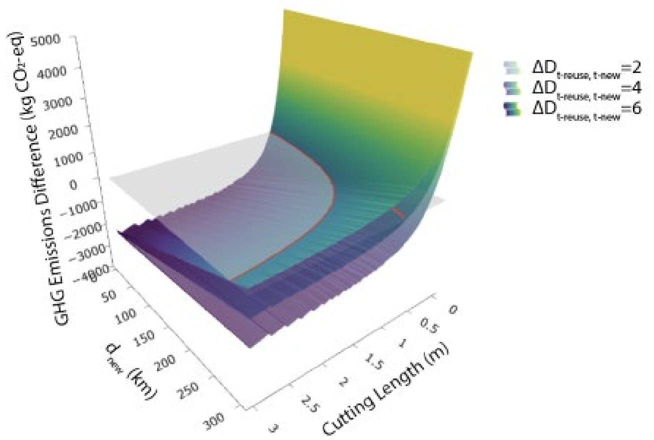

Figure 7. Multidimensional Impact Difference Analysis: Reuse vs. New Concrete with Varying Concrete Cutting Length and Transportation Distances for Different $\Delta D_{t-reuse,t-new}$ Ratios

Figure 7 shows that an increase in transportation distance and a decrease in the size of the reused beam leads to an increase in the difference in GHG emissions, even though the fluctuations are small. This highlights the direct link between transportation distance and cut size in determining the environmental impact of concrete reuse. By examining the different $\Delta D_{t-reuse,t-new}$ ratios, it is clear that the line of intersection of the impact difference surface with the z=0 plane becomes steeper and more pronounced as $\Delta D_{t-reuse,t-new}$ increases (indicating that the transportation distance for reuse is significantly greater than that for new concrete), emphasizing the increasing impact of reuse.

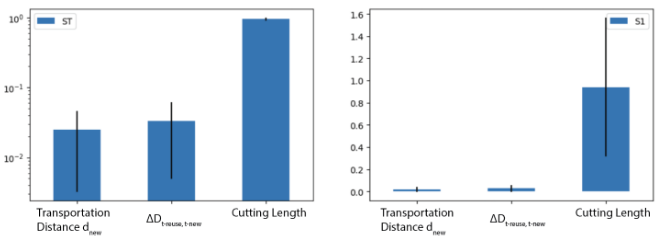

Figure 8. Sensitivity Analysis: Exploring the Influence of Transportation Distance, $\Delta D_{t-reuse,t-new}$ and Cutting Lengths on GHG Emissions Difference, Case of 0.4m x 0.4m Concrete Beam

To validate this observation, we conducted sensitivity analysis on these three parameters. As shown in Figure 8, where the first-order sensitivity index (S1) indicates how much each input parameter contributes individually to the output variability, while the total-order sensitivity index (ST) includes the interaction effects with other variables. The results reaffirm that the size of the cut piece remains the dominant factor influencing the GHG emissions of concrete reuse. This underscores the pivotal role of cutting dimensions, where even minor variations can yield significant shifts in the environmental outcome.

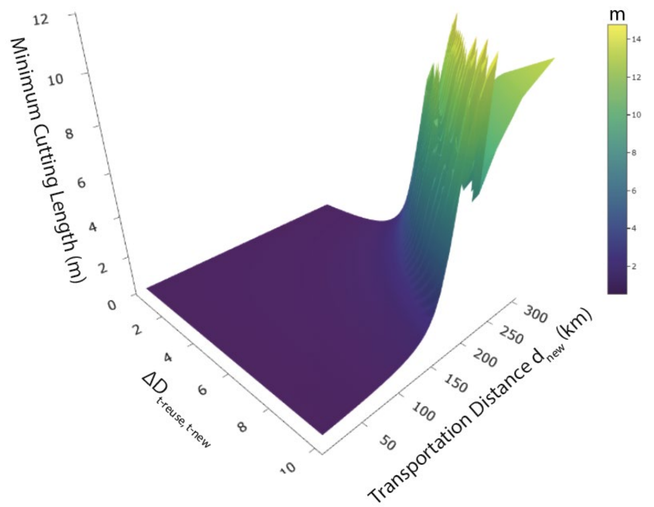

Figure 9. Exploring the Nexus of Transportation Distance and $\Delta D_{t-reuse,t-new}$ on the Minimum Concrete Cutting Length

If we take a closer look into the cutting dimensions, Figure 9 visualizes how the minimum concrete cutting length, or cutting threshold, varies with transportation distances and the ratio $\Delta D_{t-reuse,t-new}$. It reveals a concave-up trend in cutting threshold with increasing values of $\Delta D_{t-reuse,t-new}$ up to a point, beyond which the trend becomes erratic with random fluctuations, illustrating the complexity of determining a clear trend in scenarios where reused concrete is transported significantly farther than new concrete. Yet, a certain fluctuation limit suggests a level of predictability.

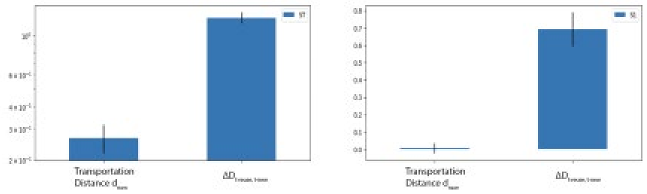

Figure 10. Sensitivity Analysis: Exploring the Influence of Transportation Distance and $\Delta D_{t-reuse,t-new}$ on Minimum Concrete Cutting Length, Case of 0.4m x 0.4m Concrete Beam

Figure 10 shows $\Delta D_{t-reuse,t-new}$ as a key influencer on the minimum cutting length, with greater variance in outcomes at different ratios. The unpredictable nature of these fluctuations underscores the study's role in aiding decision-making on a case-by-case basis. These findings emphasize the complex interplay between transportation distances, component sizes, and GHG emissions, advocating for a holistic approach to sustainability assessment in building practices.

Reference:

[1] Lv, H., et al. Full life cycle carbon footprint assessment of circular saw blades based on design feature modelling. 2022. IEEE.

[2] Megasaw, *Concrete Cutting: Why Do You Need Water Supply For Concrete Cutting?*, in *Megasaw*. 2020.

[3] Mack-Vergara, Y.L. and V.M. John, *Life cycle water inventory in concrete production—A review.* Resources, Conservation and Recycling, 2017. **122**: p. 227-250.