Recarbonation of Concrete in the GCCA EPD Tool

In the context of the Environmental Product Declaration (EPD) Tool developed by the Global Cement and Concrete Association (GCCA), recarbonation plays a significant role in calculating the carbon impact of concrete and cement products over their lifecycle. Recarbonation refers to the process where concrete absorbs carbon dioxide (CO_2) from the atmosphere, partially offsetting the CO_2 emitted during cement production. This natural process can be substantial and is carefully modelled within the GCCA EPD tool.

Principle of Recarbonation

Concrete carbonation occurs as CO_2 from the atmosphere penetrates the concrete and reacts with hydration products to form carbonates. This process not only strengthens the concrete but also removes CO_2 from the environment. Concrete products absorb CO_2 during different stages of their lifecycle: during their use as structures and post-demolition when crushed or landfilled. Additionally, precast elements can carbonate during production and depending on their exposure to air.

Given the potential for concrete to reabsorb a significant portion of the CO_2 emitted during its production, recarbonation is a vital factor in assessing the true carbon footprint of cement-based products.

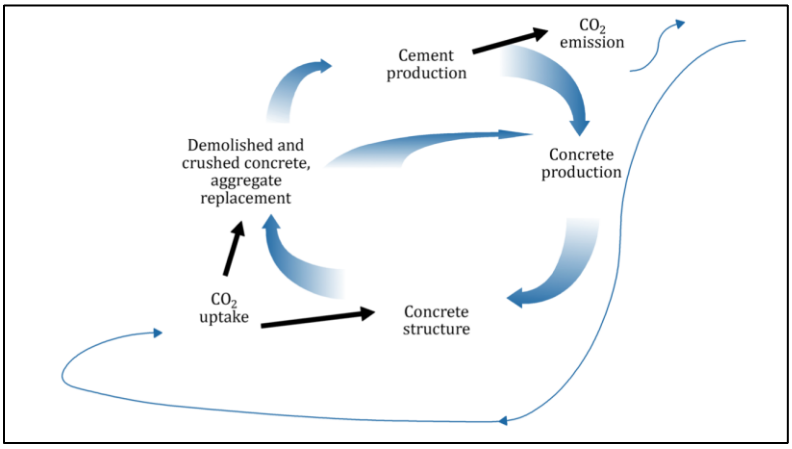

Figure 1: CO_2 cycle in cement and concrete (Source: EN 16757, Annex BB)

Modelling of Recarbonation in the GCCA EPD Tool

The modelling for recarbonation during the life cycle of the concrete products follows the guidance provided in norm *EN 16757*[1] *– Annex BB – CO_2 uptake by carbonation – Guidance on calculation, and in the British application of the norm, BRE EN 15804*[2] *– Annex C*. The model captures recarbonation across various lifecycle stages:

[1] EN 16757 - Sustainability of construction works. Environmental product declarations. Product Category Rules for concrete and concrete elements

[2] BRE EN 15804 - Global Product Category Rules (PCR) for Type III EPD of construction products to EN 15804+A2

- **Production Stage (Module A3)**: This stage is relevant for precast concrete products, where recarbonation may occur if the products are exposed to CO_2 during storage. The method accounts for factors like storage conditions, exposure time, and the surface area exposed to air.
- **Use Stage (Module B)**: During its use in structures, concrete continues to carbonate depending on exposure conditions (e.g., whether it is exposed to rain or sheltered) and the concrete's surface area. The depth of carbonation and the quantity of reactive CaO (a key compound in cement) are also considered in the model to calculate the amount of CO_2 captured during the use phase.
- **End-of-Life Stage (Module C)**: Recarbonation is considered after the demolition of concrete structures. When concrete is crushed and stored or landfilled, the particles continue to absorb CO_2. The tool models this phase by assuming the concrete is crushed into spherical particles, allowing for radial carbonation to occur. Storage duration and conditions are factored into the recarbonation potential during this phase.

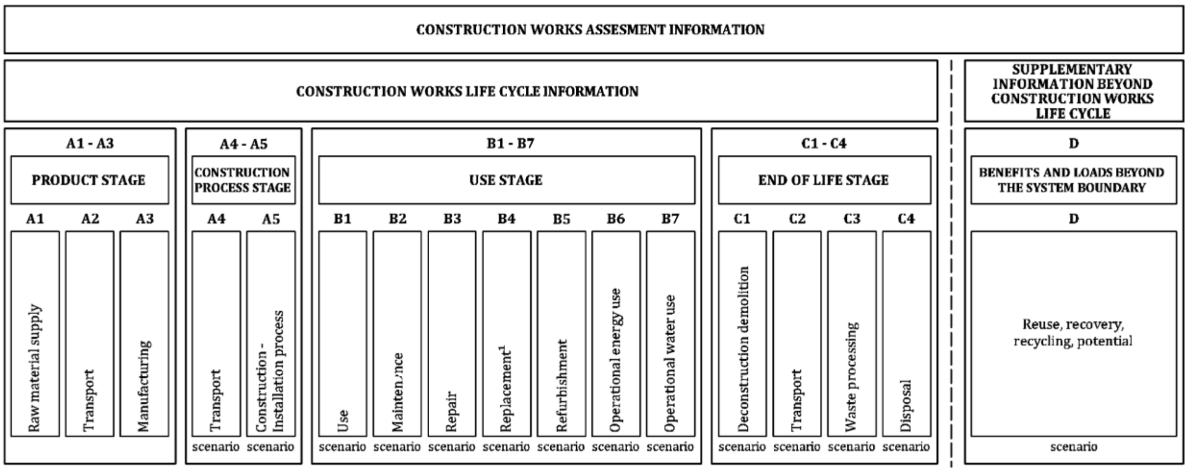

Figure 2: Lifecycle stages and modules (Source: EN 15804)

Approaches for Calculating Recarbonation in GCCA EPD Tool

The GCCA EPD tool provides three methods for calculating recarbonation depending on the availability of data:

1. **Detailed Approach**: This option requires precise data on exposure conditions, geometry, and duration. It allows users to input detailed information for each lifecycle stage. For example, during the use stage, users can specify the type of structure and its exposure conditions.
2. **Default Approach**: When detailed data is unavailable, the tool uses conservative default values to estimate recarbonation. This includes assumptions on exposure conditions (e.g., exposed to rain, indoors) and default exposed surfaces.

3. **User-defined Approach**: Users can input their specific calculations for recarbonation based on external standards or methodologies, enabling flexibility in accounting for CO_2 uptake.

Importance in Lifecycle Assessment

Incorporating recarbonation into the GCCA EPD tool is crucial because it allows for a more comprehensive assessment of a product's carbon impact. As concrete can absorb CO_2 throughout its life, the actual net emissions are lower than the gross emissions from the cement production process. By accounting for this CO_2 uptake, the GCCA EPD tool provides a more accurate and balanced environmental profile of concrete products, helping manufacturers and stakeholders make informed decisions regarding sustainability.

The tool's robust modelling of recarbonation reflects the GCCA's commitment to aligning with international standards and delivering reliable lifecycle assessments, which are essential for producing credible EPDs for the cement and concrete industry.

In summary, recarbonation is a key factor that mitigates the overall carbon footprint of concrete, and the GCCA EPD tool offers a sophisticated method for quantifying this impact throughout the lifecycle of cement-based products.

Annex A – Calculation of recarbonation in GCCA EPD Tool

The method for calculating the uptake of CO_2 during use stage (module B) is described extensively in norm EN 16757 – Annex BB. Annex BB gives the amount of CO_2 per m^2 exposed to recarbonation as follows:

$$CO_2 uptake = d * w * C_c * \frac{m_{co_2}}{m_{CaO}} * C * D_c$$

In which *CO_2 uptake* describes the amount of CO_2 captured per m^2, d is the depth of carbonation in mm, defined as:

$$d = k * K_K * \left(\frac{\sqrt{t}}{1000}\right)$$

And the other terms are defined as follows:

Term	Physical significance	Unit	Depends on
w	Part of reactive CaO	kg CaO /kg binder	Cement type
C_c	mass of binder (clinker)		Cement type
$\frac{m_{co_2}}{m}$	ratio between molar mass of CO_2 and CaO	kg/kg cement	
k	depth of carbonation	mm/year$^{0.5}$	Exposure and Concrete strength
t	time of exposure	year	
D_c	Degree of carbonation	%	Exposure
C	Cement content in concrete	kg	
K_K	Correction factor for k factor		Amount of cement constituents other than clinker (limestone, silica fumes, fly ash, blast furnace sludge) included in concrete

The approach used to model the recarbonation of the product during the End-Of-Life is described in norm BRE EN 15804 – Annex C, section 4 and 5.

After Demolition (C1), the GCCA EPD tool considers that the product is crushed into spherical particles of concrete.

Recarbonation may occur while the crushed concrete is stored before being recycled (Module C3 –waste processing), or after the product is landfilled (Module C4 - disposal). The calculation approach still applies for the recarbonation of the product, adapted to a spherical geometry - considering a radial carbonation of depth d around the sphere.

Annex B – Recarbonation calculation approaches available to GCCA EPD tool users

To calculate recarbonation throughout the lifecycle, two categories of parameters are needed: product-specific parameters (related to concrete characteristics) and module-specific parameters (related to exposure conditions, geometry, and duration). The tool uses the following product-specific inputs:

- **Reactive CaO**: Default value of 65% from EN 16757
- **Clinker mass per kg of cement**: Extracted from product composition
- **Concrete strength class**: Entered in the "Product Description" page
- **Exposed surface area**: Entered in the "Use" page
- **Cement constituents (e.g., limestone, silica fumes)**: Entered in the "Product Description" page

Module-specific parameters may be unavailable to the user therefore the tool offers three approaches:

1. **Detailed approach**: Uses exact data on exposure and exposed surface area
2. **Default approach**: Uses assumptions and default values
3. **User-specific approach**: Allows users to input their own CO_2 values based on calculations or standards.

The detailed approach for calculating recarbonation across life cycle stages is outlined as follows:

Manufacturing stage (A3) (for precast products): The user inputs the storage duration, exposure conditions, and surface area exposed to recarbonation per cubic meter of product.

Use stage (B): The user provides the lifespan of the structure and selects exposure conditions for the product.

Waste processing (C3): The user inputs the storage duration before reuse and selects exposure conditions.

Waste disposal (C4): No detailed approach is provided; the default approach is used.

For all stages, exposure conditions are requested as input. In accordance with EN 16757, the exposure conditions are: "Exposed to rain", "Sheltered", "Indoor in dry climate with cover", "Indoor in dry climate without cover", "In ground", and "Under groundwater level". If the exposure conditions are selected as "unknown", the tool considers the option that minimises recarbonation[3].

For Modules A3 and B the user must define the surface area exposed (m^2/m^3) whilst for Module C3 the tool considers spherical particles of 150 mm diameter with radial recarbonation.

The default approach for recarbonation across life cycle stages is as follows:

- **Manufacturing stage (A3)** (for precast products): No default approach is provided; only the detailed approach is available.
- **Use stage (B)**: The user selects the type of structure, which determines exposure duration and surface area per volume. If the structure type is unknown, *default* options are used (see Table).
- **Waste processing (C3)**: The user inputs the storage duration before crushed concrete is reused and selects the exposure conditions.
- **Waste disposal (C4)**: The tool assumes a 100-year carbonation period for landfilled products.

Calculation parameter	Module B	Module C3	Module c4
Duration of exposure	- Buildings (default): 50 years[4] - Infrastructure: 100 years	3 months	100 years
Exposure conditions	Most conservative option is selected[3]	Exposed to rain	In ground
Exposed surface area	- Buildings[5]: 6 m^2/m^3 - Infrastructure (default): 2 m^2/m^3	Spherical particles of 150 mm diameter with radial recarbonation	

Table 1: Module-specific parameters for recarbonation, default approach (Note: For Module A3 only the detailed approach applies)

The user-defined option allows the user to type in a value of CO_2 per functional unit for recarbonation intake. Those values may be derived from the user's own calculations or from an applicable standard or reference. This approach is available for Modules B, C3 and C4.

[3] For unknown exposure conditions the tool considers the most conservative option that minimises recarbonation. For concrete with a strength class below 15 MPa, this is "Indoors in dry climate with cover," while for other strength classes, it is "Exposed to rain."
[4] Source: EN 16757:2017
[5] Source: Gustafsson T, Gustafsson T (2018) CO2 uptake in cement - containing products Background and calculation models for IPCC