COMPARATIVE ANALYSIS OF WHOLE LIFE CARBON ASSESSMENTS

Key GWP parameters identified by the Concrete Sector for the appropriate accounting methodology

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Authors:

BERTAGNOLI Grazia
ERMCO

DULAJ Albanela
BIBM

ANDREOTTI Jacopo
Politecnico di Torino, Department of Architecture and Design (DAD)

DE VITO Davide
University of Bergamo, Department of Engineering and Applied Sciences (DISA)

Reviewers:

KHOSRAVI Noushin
ERMCO

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TANG Yining

INTRODUCTION

The EU's 2050 climate neutrality goal is pushing building policy toward Whole Life Carbon (WLC) assessments, which also consider emissions associated with materials, construction, maintenance, and end-of-life. However, WLC-GWP methodologies still vary significantly across Europe. This guide compares current approaches, identifies harmonisation needs, and examines how concrete is represented, especially with respect to durability, service life, carbonation, circularity, and end-of-life.

Robust assessment must consider concrete's life-cycle performance, especially durability and service life, yet these factors are inconsistently addressed across national WLC-GWP methods.

Durability reduces replacements, lowers WLC impacts, and unlocks residual value beyond the reference study period.

CONTEXT

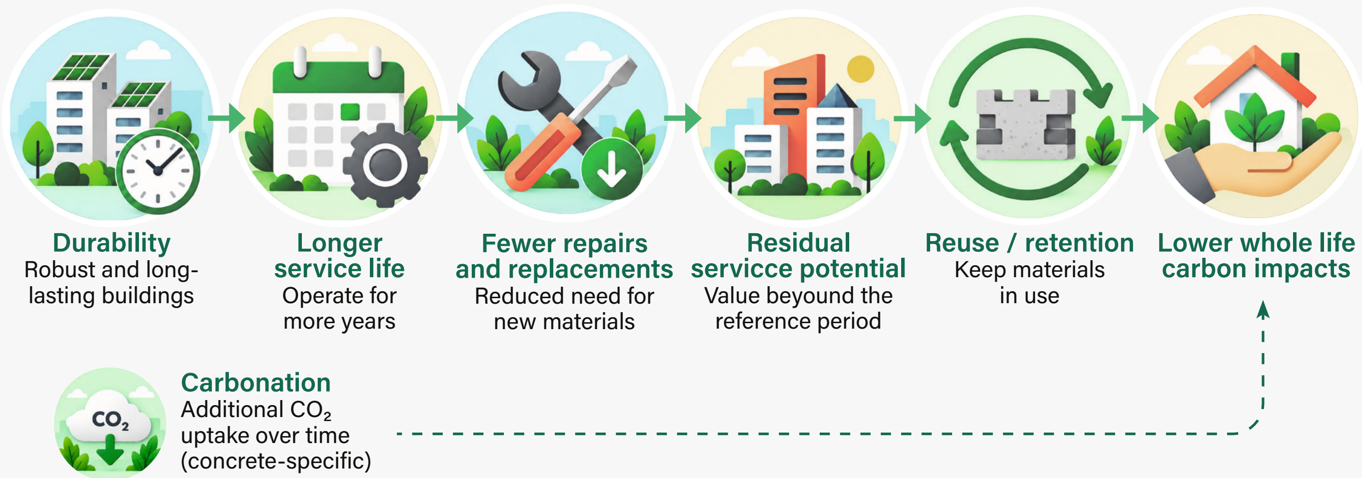
EU Net-Zero by 2050
The EU aims for climate neutrality by 2050

Shift to WLC
Focus shift from operational carbon to whole life carbon

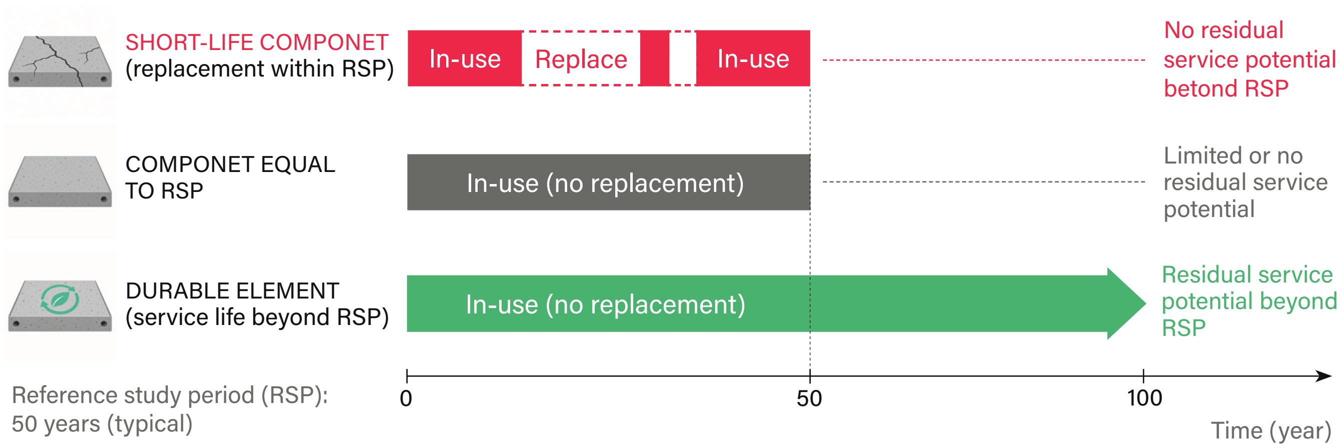
EPBD requirements
The EPBD will progressively require WLC assessment and disclosure

Objective
Ensure concrete performance is assessed in a transparent, consistent, and technically robust way.

DURABILITY AS A KEY DRIVER IN WLC-GWP



The objective is to ensure that concrete's life-cycle performance is assessed in a transparent, consistent, and technically robust way. For durable concrete, impacts are not only about upfront emissions but also about avoided replacements and residual service.



01 OVERVIEW OF THE DIFFERENT METHODOLOGIES ADOPTED ACROSS EUROPE

Selected European approaches, including France, Sweden, Finland, Spain, and Italy, highlight relevant differences in WLC-GWP accounting frameworks. The focus is on aspects that are particularly relevant to concrete: the temporal treatment of emissions, the life-cycle modules included, module D, replacement rules, service-life assumptions, carbonation, reuse, and the availability of representative environmental data.

Country/ framework	Concrete-relevant metrics	Relevance for concrete WLC-GWP	Downsides
Spain - CTE DB-HSA1 draft	Durability in Module B4 replacement formula	The draft methodology has the potential of recognising a service life > 50 years, making durability operational within the WLC calculation.	The methodology is still in draft form, and the treatment of service lives >50 years has not yet been explicitly confirmed.
Italy - Tools for decarbonisation	Carbonation accounting (Modules B1, C3-C4, D)	Provides metrics and guidelines for CO_2 uptake by carbonation.	-
France - RE2020	Simplified dynamic LCA	Gives greater weight to upfront emissions, which are significant for concrete, while later benefits such as avoided replacement, carbonation and reuse may be less visible.	Materials with high upfront emissions are more strongly affected, while materials with delayed emissions until the end-of-life may benefit from lower weighting factors.
France - RE2020	Carbon discount from module D	It can change comparative results by including Module D. For concrete products, results depend on assumptions about recycling, structural reuse and post-demolition carbonation.	RE2020 integrates Module D into the main carbon score giving biobased materials a significant advantage, while EU standards keep it separate.
Sweden - Climate Declaration	Assessment focused on A1-A5	Narrow scope that misses use-stage, replacement, end-of-life, carbonation or reuse. This can underrepresent the long-term performance of durable concrete systems.	Omits required lifecycle modules, and the planned 2030 limit values cover only A1–A5 over 50 years, ignoring use, maintenance, and end-of-life stages.
Finland - Climate Declaration	National data infrastructure and concrete-specific tools	The use of national databases, EPDs and low-carbon concrete classification can improve data consistency and allow more representative assessment of concrete mixes.	Finland's method excludes certain elements (underground structures, site facilities) and renders its carbon handprint non-binding, thereby limiting its regulatory impact.
The Netherlands	Fraction method	The draft methodology based on EN 15978, considers the entire life cycle of the building over a 50-year assessment period and it allows the long service life of concrete structures to be properly accounted for, avoiding an overestimation of their annualised environmental impact.	The limit values proposed by the government, take only 80% of the emissions in use fase (and 60% of end-of-life fase) into account. Not representing the focus of the EPBD IV (use).

Table 1: Concrete-relevant methodological issues from selected European WLC methodologies and methodological proposals.

Country	Reference surface	RSP	Production stage (A)	Construction stage (A)		Use stage (B)							End of life stage (C)				Beyond lifecycle (D)		In force	Limit values
/	/	/	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D1	D2	/	/
DK	HFA & GFA	50	■	■	■				■		■				■	■	■	■	YES	YES
EE	HFA	50	■	■	■				■		■		■	■	■	■	■	■	UD	NO
FI	HFA	50	■	■	■				■		■		■	■	■	■	■	■	YES	YES
FR	LA & UA	50	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	YES	YES
NO	GFA	50	■	■	■		■		■										YES	NO
NL	GFA	50-70	■	■	■	■	■	■	■	■			■	■	■	■	■	■	YES	YES
SE	GFA	/	■	■	■		■		■		■		■	■	■	■			YES	UD
AT	GFA, NFA, & UFA	50	■	■	■				■		■		■	■	■	■			UD	UD
HR	NFA	50	■	■	■				■		■	■		■	■	■	■	■	NO	UD
CZ	GFA & UFA	50	■	■	■				■	■	■	■		■	■	■			NO	UD
IE	GFA & UFA	50	■	■	■	■			■		■ *IR	■ *IR	■	■	■	■			UD	UD
IT	HFA & GFA	50*[1]	■	■	■	*IT	■	■	■	*IT	■	*IT	■	■	■	■		■	NO	UD
LU	GIA & UFA	50	■	■	■				■		■			■	■	■	■	■	NO	UD
ES	GFA & UFA	50	■	■	■	■	■	■	■	■	■	■	■	■	■	■			UD	UD
GB	GIA	60	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	YES	YES

GFA = Gross Floor Area
GIA = Gross Internal Area
HFA = Heated Floor Area
LA = Livable Area
NFA = Net Floor Area
UA = Usable Area

*IR B6 and B7: these modules are considered as optional, cause not related to the EC of materials and products.

*IT B1 and B7: some metrics and assumptions are described within the methodological proposal developed by Andreotti & Giordano (2024) , cited within the national standard UNI 11973:2025; B5: the IT consortium of the INDICATE LIFE project considers the module B5 as an expanded lifecycle (A1-D2) for renovation works.

UD = Under Development

Table 2: WLC-GWP methodologies and metrics across European Countries (Source: Author's interpretation based on Ramboll, 2022; BPIE, 2024; Nordic Innovation, 2024; RICS, 2024; INDICATE LIFE deliverable, 2026).

1 The implementation of Green Public Procurement (GPP) in Italy (Criteri Ambientali Minimi 2025) requires to take into account a Reference Service Life (RSL) of 100 years for public buildings, but it also highlights the importance to take under control the RSP required by the EPBD IV and other European documents. For further information visit: https://www.mase.gov.it/portale/cam-vigenti

2 BPIE (2024). How to establish Whole Life Carbon benchmarks: Insights and lessons learned from emerging approaches in Ireland, Czechia and Spain. https://www.bpie.eu/publication/how-to-establish-whole-life-carbon-benchmarks-insights-and-lessons-learned-from-emerging-approaches-in-ireland-czechia-and-spain/

3 Andreotti, J., Giordano, G. (2024). Strumenti per la decarbonizzazione. Valutazione della Whole Life Carbon (WLC) e della Circular Economy (CE) di un manufatto edilizio. Edizioni Ambiente, Milano. https://freebook.edizioniambiente.it/catalogo/579/strumenti-per-la-decarbonizzazione

02 KEY FINDINGS FROM THE EUROPEAN APPROACHES

The comparative analysis shows that, although national WLC-GWP methodologies are broadly aligned with EN 15978 and EN 15804, **significant differences remain in system boundaries, life-cycle modules, temporal assumptions, data sources and the treatment of end-of-life carbon flows**.

National approaches are progressively expanding beyond the traditional A1–A3 production stage, but at different speeds and with different scopes. Finland currently applies a relatively comprehensive life-cycle approach; Sweden remains more focused on the initial stages of the life cycle. At the same time, France's dynamic carbon accounting demonstrates how the timing and weighting of emissions can significantly influence WLC results and comparisons between materials.

Among the reviewed frameworks, the **Spanish draft methodology** (CTE DB-HSA1) appears to have the highest potential for concrete applications, as its Module B4 formula could allow the **benefits of service lives exceeding 50 years to be reflected in the WLC calculation**. Although this treatment is not yet explicitly confirmed in the draft, the methodology provides a relevant reference for integrating durability into regulatory assessments.

Italy also offers useful guidance on accounting for CO_2 uptake from concrete **carbonation** in the use (B1), end-of-life (C4), and reuse (D1) modules. Though still a proposal, it addresses an aspect often overlooked in other frameworks.

The way each methodology handles timing, module scope, and carbonation can significantly affect results. This is important for concrete because its high upfront emissions are offset by long-term benefits such as durability, reuse, and carbon uptake. A consistent methodology is therefore needed to ensure that impacts and benefits throughout the life cycle are appropriately represented without introducing preferential treatment of any material.

At the same time, national approaches broadly agree on the importance of early design decisions, durability and service-life extension in reducing whole-life impacts.

Overall, greater European harmonisation is needed to improve transparency and comparability and to ensure that WLC assessments reflect actual environmental performance rather than differences in methodological assumptions.

03 HOW TO INTEGRATE WLC METHODOLOGY WITH THE DURABILITY OF CONCRETE

Durability is an important parameter in Whole Life Carbon (WLC) assessments, as it influences the service life of building components, maintenance and repair needs, replacement cycles, and the potential for components to remain functional beyond the Reference Study Period (RSP).

If these aspects are not adequately considered, WLC-GWP assessments may place greater emphasis on upfront emissions while underrepresenting long-term performance and avoided replacements.

Durability-related effects may occur across several life-cycle modules and therefore require clear and consistent modelling assumptions.

04 RELEVANCE OF MODULES FOR CONCRETE DURABILITY

WLC-GWP methodologies should explicitly define how durability-related effects are assigned to the relevant life-cycle modules. Table 3 provides a module-by-module reading of the concrete WLC-GWP assessment, distinguishing between general concrete-related effects and durability-specific aspects.

Life-cycle stage	Durability-relatedw aspect	Relevance for concrete WLC assessment
A1-A3	/	Includes the main upfront impacts of the concrete production plant.
A4-A5	/	Relevant for ready-mix concrete logistics, on-site placement, pumping, formwork-related processes, where included, and construction losses.
B1	Use stage	May include **carbonation**, where allowed by the assessment method.
B2-B3	Maintenance and repair	Durable concrete structures may require **fewer or less frequent interventions**, depending on exposure, design and maintenance strategy.
B4	Replacement cycles	Accounts for the **replacement** of components with an SL shorter than the RSP. For long-life concrete elements, B4 is central to showing whether replacements are avoided.
C1-C4	End-of-life processes	Assumptions on demolition, crushing, sorting and waste treatment can significantly affect end-of-life impacts.
D	Benefits and burdens beyond the system boundary	May capture potential effects related to reuse, recycling, recovery or substitution. For concrete, reuse or retention of structural function should be distinguished from recycling as aggregate.

Table 3. Life-cycle modules and durability-related effects for concrete WLC-GWP assessment.

05 METHODOLOGICAL ISSUE: RSP, RSL AND RESIDUAL SERVICE POTENTIAL

WLC-GWP results depend on the relationship between RSP and component service life.

If SL < RSP, replacements are counted in B4. If SL > RSP, no replac ement is record ed, but **residual value** is often ignored.

> The 50-year RSP is widely used but can underrepresent long-life materials like concrete, whose durability and carbonation extend beyond the assessment period.

A key methodological issue in WLC-GWP assessment concerns the relationship between the **building RSP** and the **SL** of components or structural systems. The RSP defines the time horizon. At the same time, the RSL or ESL describes the period during which a component is expected to fulfil its intended function under defined design, exposure, use and maintenance conditions[4,5].

4 Steinmann, J., Röck, M., Lützkendorf, T., Allacker, K. Le Den, X. (2022). Whole life carbon models for the EU27 to bring down embodied carbon emissions from new buildings: Review of existing national legislative measures. https://c.ramboll.com/reducing-whole-life-carbon

5 Francart, N., Widström, T., Malmqvist, T. (2021). Influence of methodological choices on maintenance and replacement in building LCA. International Journal of Life Cycle Assessment 26, 2109–2126. https://doi.org/10.1007/s11367-021-01985-z

Condition	Usually represented in WLC	Methodological implication
RSL/ESL < RSP	One or more replacements are included in module B4.	Shorter-life components generate additional impacts over the assessment period.
RSL/ESL = RSP	The component is assumed to fulfil its function over the full assessment period.	No replacement is generally needed, but no residual service potential remains beyond the RSP.
RSL/ESL > RSP	No replacement is generally included in module B4.	Remaining service potential may be unreported unless specific rules address continued use, reuse or allocation beyond the RSP.

Table 4: Main methodological implications of different RSP-ESL values.

06 SERVICE-LIFE CONVENTIONS: SHORT-LIFE VERSUS LONG-LIFE ELEMENTS

EN 15978 distinguishes short-life components (replaced within RSP, adding B4 impacts) from long-life structural elements (no replacement). Short-life components (15–30 yrs) increase GWP through repeated replacements. Durable materials like concrete avoid these cycles, offering advantages over longer timeframes, supporting durability-sensitive WLC approaches.

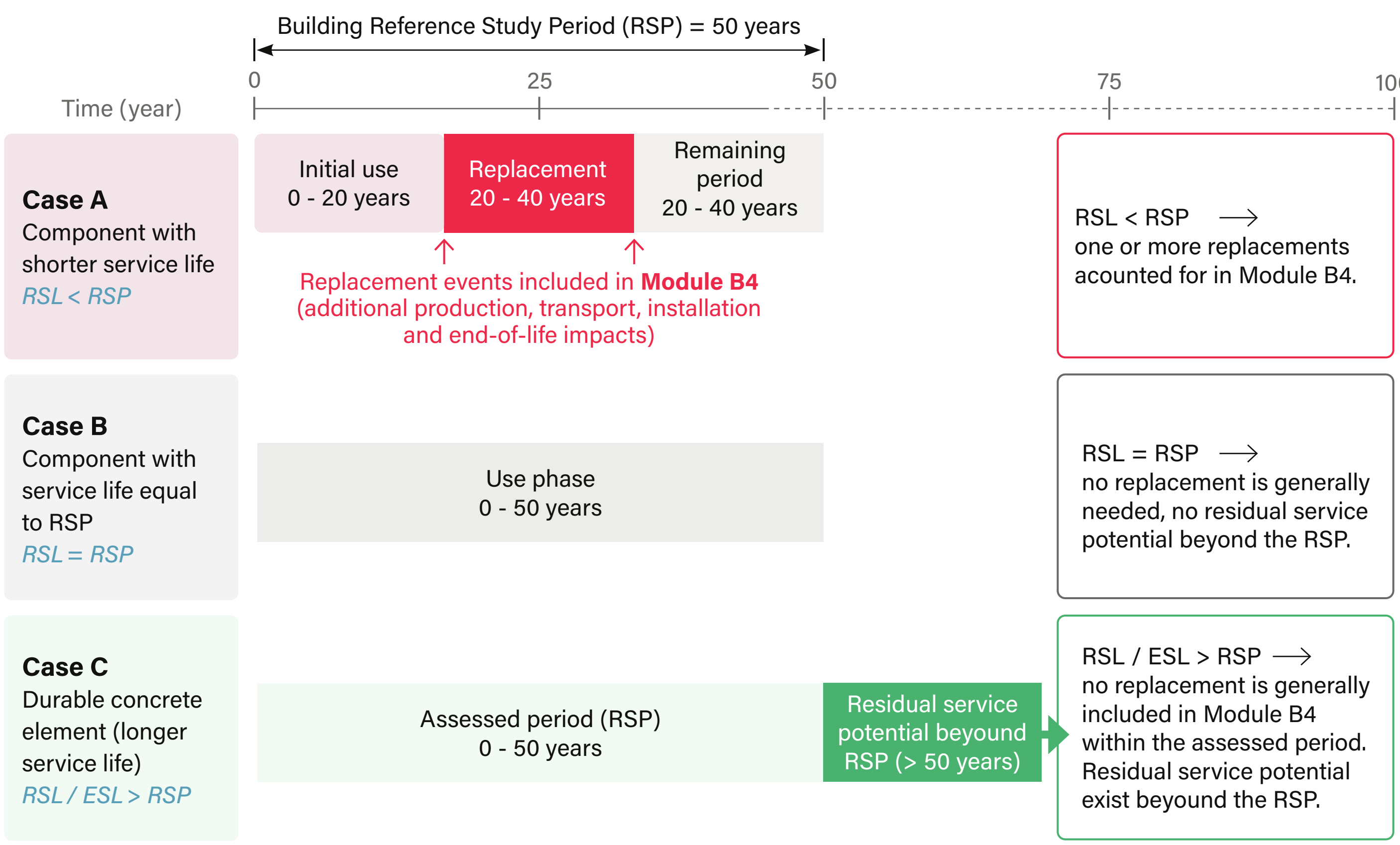


Figure 1: Relationship between RSP, service life and replacement modelling.

07 ALTERNATIVE PROPOSALS FOR DURABILITY-SENSITIVE ACCOUNTING

Standard WLC assessment methods often account for durability mainly through replacement assumptions in module B4. However, for long-lasting concrete structures, durability may also affect residual service potential, reuse opportunities and the distribution of environmental burdens across multiple life cycles. Several methodological approaches can be used to make these effects more transparent.

Approach	Relevant modules	Main principle	Practical relevance for concrete
Durability-adjusted FU[6]	System boundaries effects	Assumptions on demolition, crushing, sorting and waste treatme nt can significantly affect end-of-life impacts.	Improves functional equivalence when comparing concrete mixes, elements or systems with different durability performance.
Reuse-oriented Module D scenario / structural retention[7]	Mainly **Module D**, linked to **C1-C4**, where end-of-life scenarios are modelled	May capture potential effects related to reuse, recycling, recovery or substitution. For concrete, reuse or retention of structural function should be distinguished from recycling as aggregate.	Makes residual service potential and the reuse of concrete structures more visible, particularly where structural layouts allow future adaptation, retention, or reuse rather than demolition and recycling as aggregate.
Partial allocation models[8]	System boundaries effects	Environmental burdens are allocated across multiple life cycles according to remaining service life or use-cycle assumptions.	Useful when comparing renovation, retention, reuse and reconstruction scenarios.
50:50 and Linearly Degressive allocation[9]	System boundaries effects	Production and end-of-life burdens are shared between current and future use cycles according to fixed or sequence-based allocation rules.	Provides a structured way to distribute impacts when concrete elements or structures are reused across multiple life cycles.
Degradation-rate allocation[10]	Mainly **B2-B4**, potentially **D**	Allocation is linked to physical deterioration or loss of functional performance over time.	Connects WLC-GWP modelling to actual durability performance, using indicators such as carbonation depth, chloride ingress, corrosion risk or condition assessment.
Spanish methodology / CTE DB-HSA[11]	Mainly **B4**, with indirect effects on **A1-A3** and **C1-C4**	Introduces a potential durability-related adjustment in **B4** when service life exceeds the RSP, according to the reported draft formula.	Provides a regulatory example of how durability can be operationalised within an EN 15978-based framework. Final wording should be subject to verification of the official legal text and formula.

Table 5: Alternative approaches for durability-sensitive WLC accounting in concrete assessment.

6 Panesar, D.K., Seto, K.E., Churchill, C.J. (2017). Impact of the selection of functional unit on the life cycle assessment of green concrete. International Journal of Life Cycle Assessment 22, 1969–1986. https://doi.org/10.1007/s11367-017-1284-0.

7 Dervishaj, A., Räsänen, A., Gudmundsson, K., Lahdensivu, J. (2026). From durability to circularity: ensuring service life and enabling reuse of concrete in circular construction. Materials and Structures 59, Article 28. https://doi.org/10.1617/s11527-025-02914-4

8 Decorte, Y., Van Den Bossche, N. Steeman, M. (2023).Guidelines for defining the reference study period and system boundaries in comparative LCA of building renovation and reconstruction. International Journal of Life Cycle Assessment 28, 111–130. https://doi.org/10.1007/s11367-022-02114-0

9 Eberhardt, L.C.M., van Stijn, A., Rasmussen, F.N., Birkved, M., Birgisdottir, H. (2020). Towards circular life cycle assessment for the built environment: A comparison of allocation approaches. IOP Conference Series: Earth and Environmental Science 588, 032026. https://doi.org/10.1088/1755-1315/588/3/032026

10 Xia, B., Ding, T. & Xiao, J. (2020). Life cycle assessment of concrete structures with reuse and recycling strategies: A novel framework and case study. Waste Management 105, 268–278. https://doi.org/10.1016/j.wasman.2020.02.015

11 Ministerio de Vivienda y Agenda Urbana (MIVAU). Proyecto de real decreto por el que se modifica el Código Técnico de la Edificación, aprobado por Real Decreto 314/2006, de 17 de marzo. Borrador para audiencia e información pública, including proposed DB-HSA1 – Potencial de Calentamiento Global, November 2025.

The approaches summarised above clarify how **durability**, residual service potential and multi-cycle use may be addressed within, or alongside, existing life-cycle assessment modules.

However, they require assumptions about future use and degradation. For this reason, durability-related benefits should not be treated as automatic credits for concrete or any other durable material. Still, they should be supported by project-specific documentation, conservative assumptions, and verifiable evidence of residual performance.

> The Spanish CTE DB-HSA1 stands out as a promising reference for translating durability into explicit WLC rules, potentially accounting for service lives beyond 50 years.

CONCLUSIONS: IMPLICATIONS FOR CONCRETE WLC-GWP METHODOLOGY

The methodological options discussed above lead to four operational principles for concrete WLC assessment. These principles are intended to guide the treatment of durability-related claims and to avoid treating durability either as an automatic credit or as a purely qualitative attribute.

Principle	Operational implications for concrete WLC-GWP assessment
Durability as a performance-related parameter.	Durability should be linked to documented service life, exposure conditions, maintenance assumptions and the concrete element's ability to continue fulfilling its function over time and **beyond the RSP**.
Replacement modelling is necessary but not sufficient.	Module B4 captures avoided replacements within the RSP, but **residual service potential** should also be made transparent when concrete elements remain technically functional beyond the assessment boundary.
Reuse and **retention** before downcycling.	Reuse or retention of structural function should be assessed before assuming recycling as aggregate, provided that **technical feasibility**, **future use** and allocation rules are clearly documented.
No automatic credits.	Service-life extensions, avoided replacements, reuse potential, and degradation-based allocation should be supported by conservative, verifiable evidence, such as design specifications, exposure class, maintenance strategy, condition assessment, or recognised technical standards.

Table 6: Main methodological implications for integrating concrete durability into WLC-GWP assessment.

In conclusion, a credible European Whole Life Carbon framework should assess buildings consistently across their full life cycle and reflect their actual **long-term performance**. For concrete, this means recognising **durability**, **service life**, **avoided replacements**, **residual service potential**, **reuse** and **carbonation** where these can be demonstrated through transparent and verifiable assumptions. At the same time, such benefits should not become automatic credits or lead to preferential treatment of any material. Greater harmonisation of WLC-GWP methodologies across Europe is therefore essential to ensure fair comparisons and support design choices that genuinely minimise carbon emissions over the life of the building.

This document provides a practical summary of the more comprehensive analysis of the Global Warming Potential (GWP) calculation methodologies adopted at national level, highlighting the main approaches, differences and key findings.

You can find the full analysis on the Concrete Europe website:

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