IOP Conference Series: Earth and Environmental Science

PAPER • OPEN ACCESS

Roles of the reference service life (RSL) of buildings and the RSL of building components in the environmental impacts of buildings

To cite this article: T Potrč Obrecht *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **323** 012146

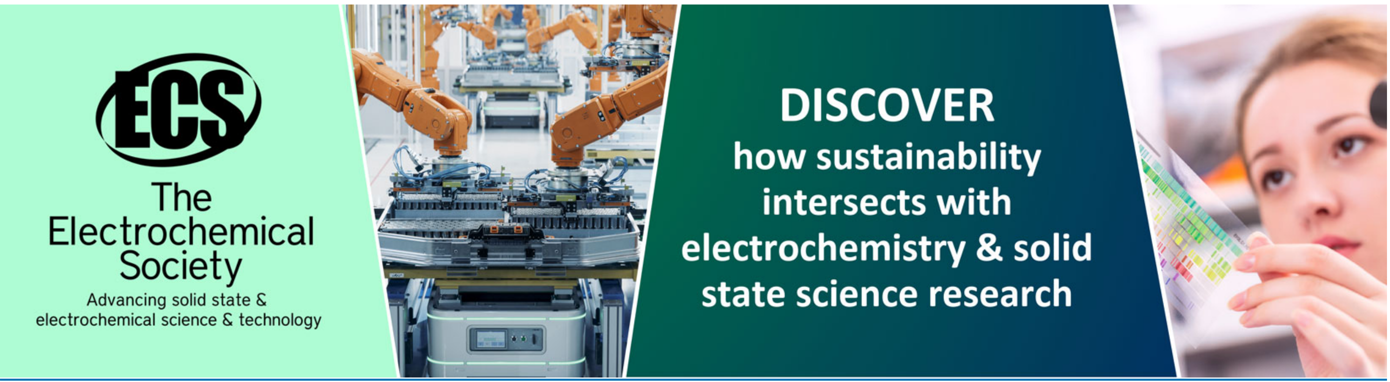
View the article online for updates and enhancements.

You may also like

- ON THE PROPER USE OF THE REDUCED SPEED OF LIGHT APPROXIMATION
Nickolay Y. Gnedin

- Radioactive seed localization is a safe and effective tool for breast cancer surgery: an evaluation of over 25,000 cases
D Miodownik, D Bierman, C Thornton et al.

- Glacial isostatic adjustment: physical models and observational constraints
W Richard Peltier, Patrick Pak-Cheuk Wu, Donald F Argus et al.



This content was downloaded from IP address 18.224.94.20 on 17/05/2024 at 02:42

IOP Conf. Series: Earth and Environmental Science **323** (2019) 012146 doi:10.1088/1755-1315/323/1/012146

Roles of the reference service life (RSL) of buildings and the RSL of building components in the environmental impacts of buildings

Potrč Obrecht T[1], Kunič R[2], Jordan S[1], Legat A[1]

[1] Slovenian National Building and Civil Engineering Institute
[2] University of Ljubljana, Faculty of Civil and Geodetic Engineering

tajda.obrecht@zag.si

Abstract. The Life Cycle Assessment of a building is a complex analysis that also involves the use of the predicted Reference Service Life (RSL) of the building components and materials, as well as the predicted RSL of the whole building. The RSL values of individual materials and building components can be obtained from different sources and are not exactly comparable. In the present study, the influence of selected RLS values on an LCA assessment was evaluated. Three different RSL databases were used as the sources of the data to estimate the environmental impacts of selected building components (internal wooden door and external finishing coat). Two scenarios were presented. In the first scenario a building component can be reused in another building, while in the second scenario the reuse of the building component is not possible. The study showed that dependent on the selected RSL database, the results can differ by up to a factor of five. Therefore, it is very important to describe clearly the maintenance scenarios for a building in order to have a reliable comparison of the results of LCA assessments.

1. Introduction

It is estimated that buildings account for 30–40% of energy use and greenhouse-gas emissions [1,2]. The EU has been focusing on reducing energy use and, consequently, the environmental impact of the use phase of buildings. As a result of these measures, the ratio between energy use and the embodied energy of a building and its components has drastically changed: the embodied energy of the building has become more significant [3]. Therefore, it is important to assess the environmental impacts during the whole life cycle of a building, including the phases of producing the materials and components, the process of constructing the building, the operation and the decomposition. A Life Cycle Assessment (LCA) is a method used to evaluate the potential environmental impacts during the whole life cycle of a product and this method is also increasingly being used to evaluate the environmental impacts of complex products, such as buildings. The methodology is outlined in the ISO 14040 series of standards [4].

LCA studies consider the service life of the building and its components; therefore, their lifetimes need to be known as a reference service life (RSL). The building's RSL is defined as the period during which a building is in use. The building itself, however, has a very long RSL, usually longer than the individual components. In addition, the RSL of the component can vary greatly from one component to another. But the most important point is that the RSL values for the same buildings or components can vary depending on the database they originate from [5].

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd

The RSL of a building component is influenced by many parameters, among them the indoor and outdoor environments, the predicted maintenance, the design of the product, etc. [6–8]. Different approaches can be used to estimate the RSL of a building's component and the building itself. In the study of Grant et al. [7] three main approaches to predict the RSL of a component were identified.

- First, the principles of structural engineering can be used to estimate the structural integrity and the fatigue of materials in accordance with the physical loading, the ongoing chemical reactions, and the degradation over time.
- Secondly, the factor method offers different factors that are used to modify the reference service life of a component (RSLC) to calculate an estimated service life of the component (ESLC). The method is declared in ISO Standard 15686-1 and includes factors for the quality of components (factor A), the design level (factor B), the work-execution level (factor C), the indoor environment (factor D), the outdoor environment (factor E), the in-use conditions (factor F), and the maintenance level (factor G):
-

$$ESLC = RSLC \times \text{Factor A} \times \text{Factor B} \times \text{Factor C} \times \text{Factor D} \times \text{Factor E} \times \text{Factor F} \times \text{Factor G}$$

- The third option is the use of empirical data. This method is seen as very accurate, but at the same time the acquisition of empirical data is very costly and time consuming.

The RSL of a component that is determined using one of the above-described methods can be acquired from different sources [9]:

- individual EPDs (cradle to gate, or cradle to grave);
- client requirements and current practices;
- product and component manufacturers' information;
- existing applicable standards such as ISO 15686-1, -2, -7 and -8;
- conventional service life in a national context or within an LCA software package for buildings.

There are also other sources that can be used to determine the RSL of building components and products:

- publicly available, national or commercial databases;
- research-group publications and initiatives;
- scientific publications.

The Eeb Guide states that in an LCA analysis the RSL of the component has an influence on several aspects of the life cycle of the building [9]. The RSL of the building influences the length of the use phase and thereby the impacts connected with the operational energy and water use as well as the maintenance. A lot of LCA studies are not paying enough attention to the maintenance scenarios of building components, although according to EN 15978, which divides the life cycle of the building into different stages (Fig. 1), various maintenance scenarios should be included in the life cycle of the building, i.e., B2 - maintenance; B3 - repair; B4 - refurbishment and B5 - replacement. According to EN 15978 the module B2- maintenance applies to planned actions and should include preventive and regular maintenance operations as well as cleaning operations. Maintenance scenarios should be provided along with a product's RSL according to EN 15804. The scenario B3 - repair encompasses all the actions, including corrective, responsive or reactive treatments of a construction product and the replacement of a broken component or part because of damage (replacement of a whole element should be assigned to B4 - replacement). B4 - replacement covers the replacement of a complete construction element [EN 15804], including the impacts on the production and installation of a new

IOP Conf. Series: Earth and Environmental Science **323** (2019) 012146 doi:10.1088/1755-1315/323/1/012146

(and identical) construction element. The B5 - refurbishment module is applied when the connected actions of modules B2, B3 and B4, for a significant part of the building or a whole section of the building, are carried out.

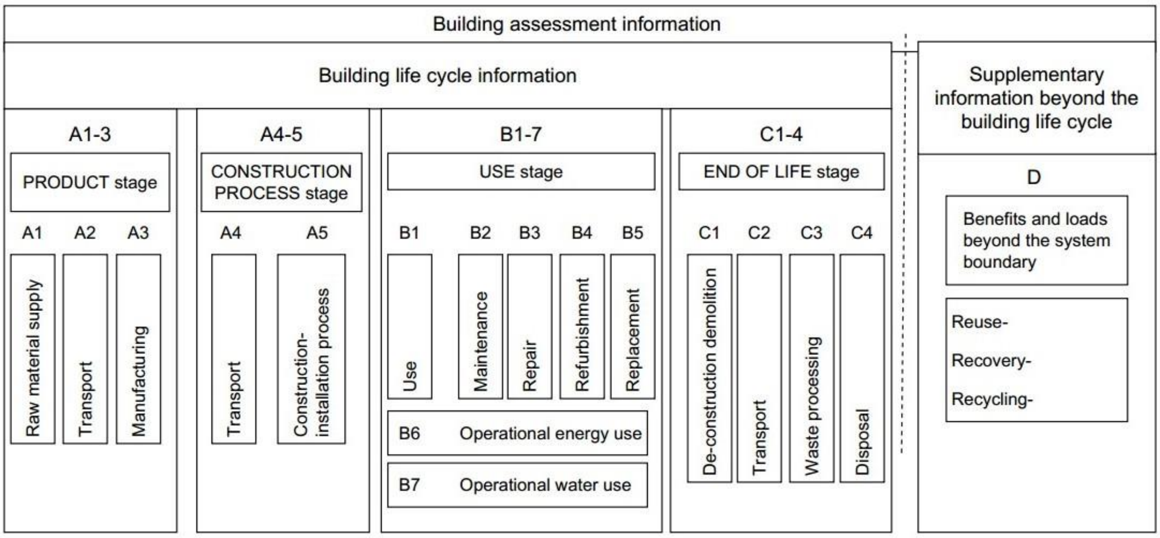


Figure 1. Building's LCA stages according to EN 15978.

A building's RSL has a significant influence on the LCA results related to the use stage of the building. Firstly, the RSL of the whole building influences the energy use of the building. In the case of a long RSL for a building, the amount of energy needed to operate the building can be much higher than in the case of a shorter RSL (modules B6 and B7). Secondly, the RSL of a building influences the results for the energy needed to maintain the building, since it affects the maintenance and the number of replacements of individual components (modules B2, B3, B4 and B5). And vice versa, the lengths of the RSLs of the components affect the number of their replacements over the entire lifetime of the building. However, it often happens that the end of the RSL of a building and the end of the RSL of the last replacement of the component under consideration do not coincide. If the RSL of the component exceeds the RSL of the building and if the component is still intact, it can be reused in another building (Figure 2). In this case the environmental impact of this last replacement can be divided between the life cycle of the first and the second buildings.

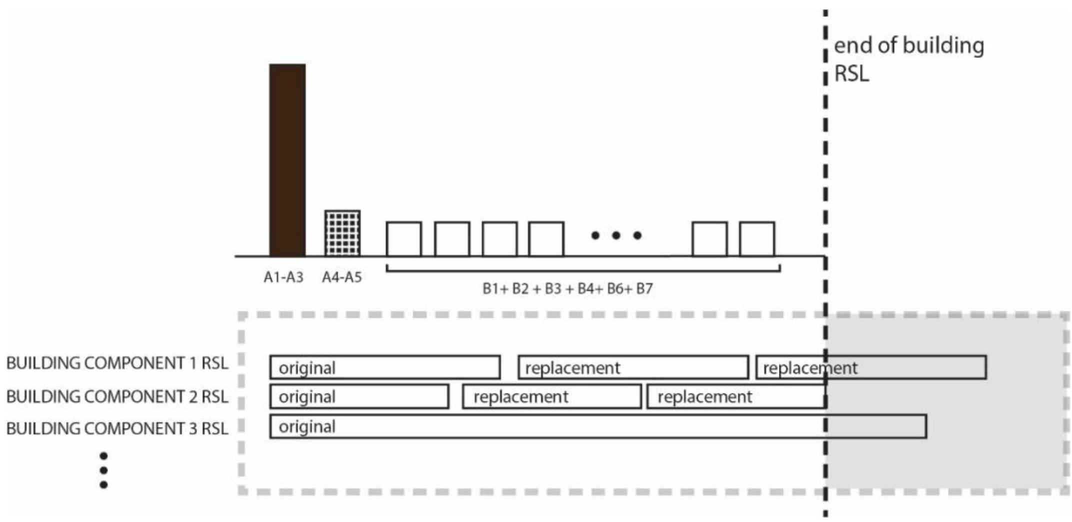


Figure 2. Residual RSLs of individual building components after the end of the building's RSL (marked grey)

Grant et al. [6,7] showed that LCA studies are not using uniform RSL values for the calculation of environmental impacts. They demonstrated that different predictions for the RSLs of building components and maintenance scenarios directly influence the environmental impacts of a building with an RSL of 50 years. In their study they compared the impact of the replacement phase for different building components in five RSL databases that are mainly present in the US market. The results can vary from 4 % to 25 % depending on the impact category. For an easier comparison of LCA studies it is very important that appropriate data about the use stage of the building's components and materials is provided, including information about their service lives and the maintenance scenarios. The RSL values of the building's components should be provided along with a maintenance scenario, as required by EN 15804. The LCA analysis should also take into account the decline in the performance of the building's products and components because this also has an influence on other aspects of the use stage (e.g., a lower performance of the heating system could result in a higher energy consumption), but this is almost never performed in practice.

The aim of the presented study is to show the role and importance of the length of the RSL of a building and its individual components in the calculation of the environmental impacts of the building. In the first part of the study the sources of the RSL values from different EU countries are described and compared. The study shows whether the RSL data is acquired from a standard or from legislation or is determined by the national method for LCA. In the second part of the study a comparison between the RSLs taken from three databases for buildings and building components is made, with the aim to clarify to what extent different RSL values in two scenarios of a possible product's reuse can influence the results of an LCA study.

2. RSLs of buildings and building components

2.1 RSL regulations in European countries

In order to carry out LCA studies, EU countries use data sources of various origins for determining the RSLs for buildings and their components. In general, the countries have developed their own databases, which are often based on the current standards, such as ISO 15686 or SIA 2032. The RSL values in Austria, for instance, are obtained from a document that is issued by the government; in Switzerland there is a standard, while the RSL in Slovenia is determined by legislation. In the case of Belgium and the Czech Republic the RSL database is included in the national LCA method.

Table 1 presents the sources of the RSLs for building materials and components in some European countries. The listed databases are mainly used for LCA calculations; although some can also be helpful for other analytical procedures (e.g., life cycle cost analysis).

Table 1. RSL regulation in European countries

Country	RSL Source for building components	Standard, legislation or part of the national assessment method	RSL of the building defined in relation to the main structural material	RSL of the building defined in relation to the building's use
Austria	Nutzungsdauerkatalog baulicher Anlagen und Anlagenteile 2012 [10]	Legislation	no	no
Belgium	Durées de vie dans MMG2017/TOTEM [11]	National assessment method	yes	no

IOP Conf. Series: Earth and Environmental Science **323** (2019) 012146 doi:10.1088/1755-1315/323/1/012146

Czech	SBToolCZE [12]	National assessment method	yes	no
Germany	Nutzungsdauern von Bauteilen für Lebenszyklusanalysen nach Bewertungssystem Nachhaltiges Bauen (BNB) [13]	National assessment method	no	no
Slovenia	Pravilnik o standardih vzdrževanja stanovanjskih stavb in stanovanj [14]	Legislation	yes	no
Spain	Documento Básico SE Seguridad structural [15]	Legislation	no	no
Switzerland	SIA 2032 [16]	Standard	no	no

Table 1 also provides information about whether there is a link between the RSL of a building according to its main construction material (fourth column) and between the RSL of a building and the use of the building (the last column). To illustrate this, the RSL value of wooden buildings in Slovenia is for 50 years, while this data for masonry buildings is for 90 years. It is clear that in the above-listed databases there is no distinction whatsoever between the RSLs of buildings according to their use (last column). Nevertheless, there are certain building-certification schemes, for instance DGNB, where the RSLs of buildings depend on the building type (e.g., office building, residential building) [10].

When calculating the environmental impacts, it is essential to differentiate between the building components that can be further reused in the same form either in the renovation of the same building or can be used in a second building and the building components that cannot be further used, although they have not reached their full RSL at the time of the building's demolition (Fig.2). For example, if a roof tile is still functional, it can easily be reused on a second building. On the other hand, it is impossible to reuse external wall finishes, even if they have not reached the full RSL at the time of the building's demolition. In the first case the environmental impacts can be divided between the two buildings, and in the second case the whole burden is assigned to only one building.

Table 2, below, shows the RSL data for building components from Slovenian's legislation, the Austrian catalogue (Nutzungsdaurekatalog) and the European Organisation for Technical Assessment (EOTA) technical guidelines.

Table 2. RSL for the building components of Slovenia, Austria and the EOTA

Building elements	**Slovenia**	**Austria**	**EOTA**
Foundations	90	60	100
External walls (above ground)	80	100	100
External door	50	30	25
Windows	50	30	25
Internal wall construction (supporting)	80	100	50
Partition wall (non-supporting)	50	30	25
Internal door	**50**	**30**	**25**
Floors (structural)	80	50	50
Ceilings	80	80	100
Roof structural construction	70	60	50

IOP Conf. Series: Earth and Environmental Science **323** (2019) 012146 doi:10.1088/1755-1315/323/1/012146

Stairs and ramps (structural)	50	70	50
Water system	40	N/D	25
Sewage system	40	N/D	50
Electrical system	40	N/D	25
Heating system (heat producer)	20	N/D	25
Heating system (heat distribution)	25	N/D	25
Ventilation system	20	N/D	25
External finishing coat	**40**	**30**	**25**
External thermal insulation (compact facade)	30	N/D	25
Roof cladding - inclined roof	30	N/D	25
Internal finishes (walls, floors)	30	30	10

2.2 Comparison of the environmental impacts of building components calculated with different RSL databases

In the continuation of this study a comparison of the environmental impacts determined based on different RSLs is presented. The environmental impacts were calculated for two building components with specific scenarios, an external finishing coat and an internal door. Each calculation was performed for three databases (Slovenia, Austria and the EOTA) in which the RSL for the building and the components under consideration differ considerably. The RSL data for both components, the finishing coat and internal door, are shown in Table 2 (marked bold). The environmental impacts were calculated with the data for the GWP impact category, taken from the Oekobaudat database [11] (Table 3).

Table 3. Oekobaudat data for the GWP impact category, used in this study

Internal wooden door (1pcs)

Indicator	Unit	Provision of raw materials A1	Transport A2	Production A3	Transport C2	Waste treatment C3	Elimination C4	Recycling potential D
GWP	kgCO(2)-Eq	-43,8	1,19	28	0,0792	101	2,6	-40,1

External finishing coat (1 kg)

Indicator	Unit	Production A1-A3	Transport A4	Installation A5	Elimination C4	Recycling potential D
GWP	kgCO(2)-Eq	1,22	0,199	0,0289	0,0112	-0,0193

For the purpose of the comparison, the study included two scenarios. The first scenario is related to the building component, the internal wooden door, which can be reused in a second building. The calculated environmental impacts of the replaced door can therefore be divided between the life cycles of both buildings. At the end of the second scenario (decomposition of the building) the building component, the external finishing coat, is destroyed. Consequently, it cannot be reused in the same form in another building, so the whole environmental burden of the finishing coat falls on the first building. The RSL of the whole building in our case study was 90 years for Slovenia, 100 years for Austria and 100 years for the EOTA database.

IOP Conf. Series: Earth and Environmental Science **323** (2019) 012146 doi:10.1088/1755-1315/323/1/012146

The internal wooden door

Within the RSL of the building the internal wooden door must be replaced several times, since the RSL of the door is much shorter than that of the building. The RSLs for the internal wooden door considered were 50 years for Slovenia, 30 years for Austria and 25 years, as proposed by the EOTA (Table 2). The needed replacements are as follows: one time according to the data for Slovenia, and three times according to the data for Austria and the EOTA.

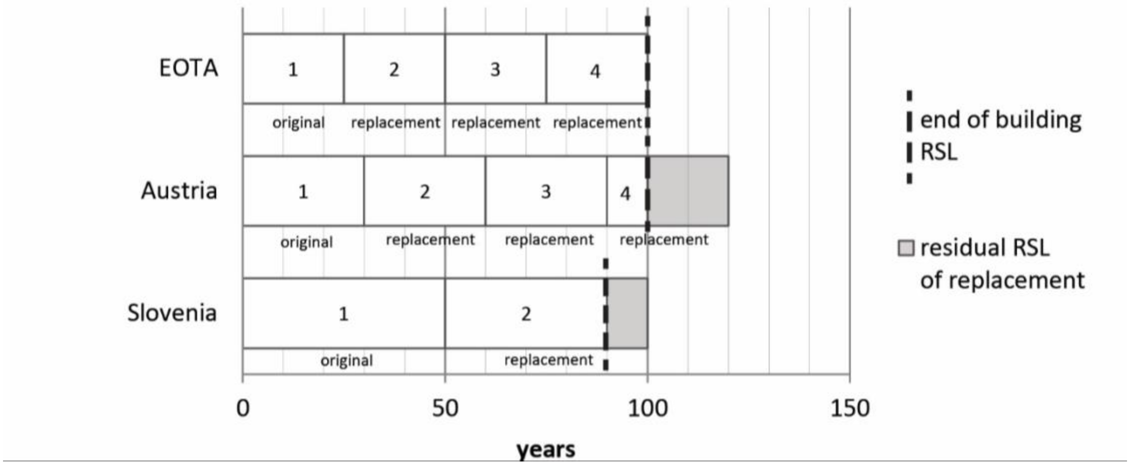


Figure 3. Internal door replacements in the RSL of the building according to the selected RSL databases

In the case of Austria and Slovenia the RSL of the last replaced internal wooden door exceeds the RSL of the building. So only the part of the production phase (A phase according to EN 15978) is assigned to the life cycle of the first building, while the rest (C3, C4 and D phases according to EN 15978) should be assigned to the LCA of the new building where the material will be subsequently used.

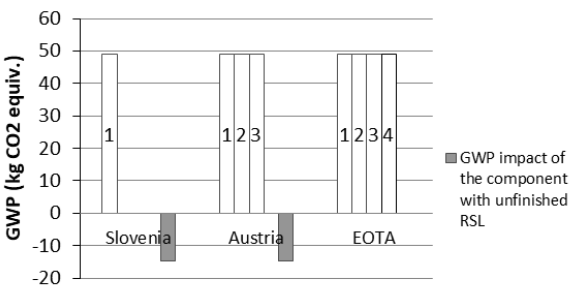


Figure 4. GWP emissions of each internal door (original + replacements) during the RSL of the building

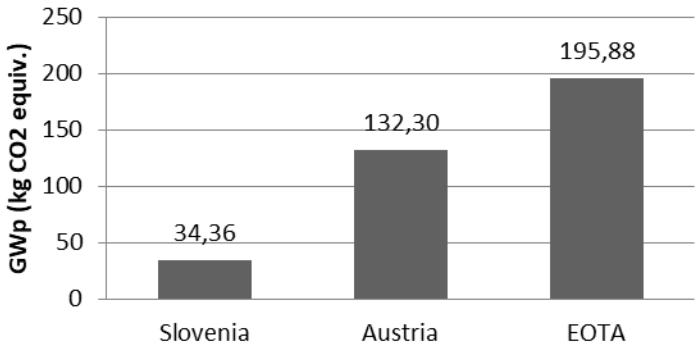


Figure 5. Total GWP emissions for an internal door (original + replacements) during the RSL of the building according the selected RSL databases

The production phase for the internal door has an impact of -14,61 kgCO2equiv., the end-of-life phase 103,6 kgCO2equiv and the D phase has an impact of -40,1 kgCO2equiv. In the case of Slovenia, the impact of the original door (the sum of all the phases) and the production phase of the replacement door are summed together. According to Austria's RSL database the impact of the original door, the impact of the first two replacements (all life cycle phases) and the production phase of the third replacement are summed. For the EOTA the total impact of the original and the total impact of all three replacements are summed.

The calculation shows that the results can differ by up to a factor of five (Fig. 4 and Fig. 5). The gap between the results is further emphasized by the fact that the internal door is made of wood, which is considered as a carbon sink. This means that the benefits of the carbon sequestration are attributed to the first building, as a positive impact on the environment (Fig. 4), while the environmental burden of wood disposal is assigned to the second building.

External finishing coat

An external finishing coat is a type of product that is virtually impossible to disassemble in such a way that it can be reused. Therefore, it is anticipated that although this product has not reached its full RSL it has to be disposed of at the end of the RSL of the building. The entire burden of the external finishing coat, even if it is still functional, needs to be ascribed to the first building.

Again, the RSL of the building in our case study was 90 years for Slovenia, 100 years for Austria and 100 year for the EOTA database. The RSL for the external finishing coat was 40 years in Slovenia, 30 years in Austria and 25 years as proposed in the EOTA (Table 2).

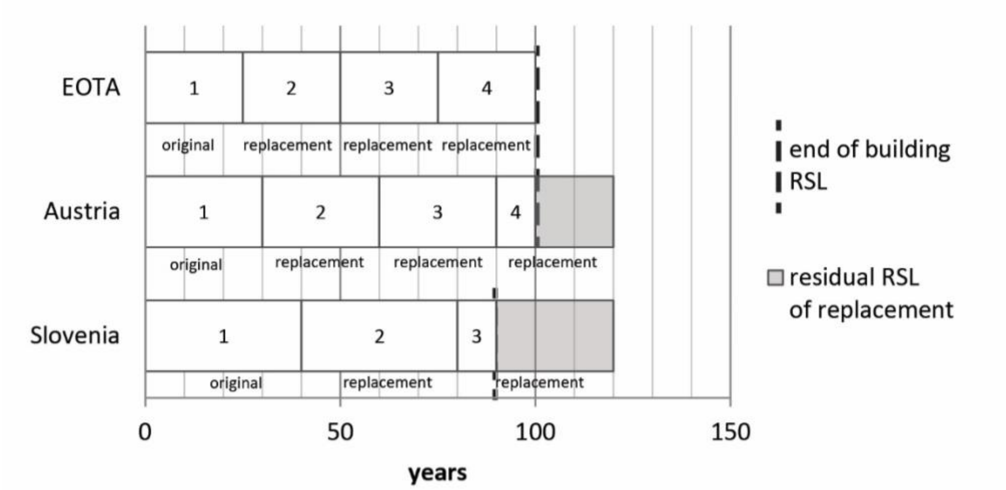


Figure 6 Finishing-coat replacements in the RSL of the building according to the selected RSL databases

Also, the external finishing coat must be replaced several times within the RSL of the building: two times according to the Slovenian data and three times according to the data from Austria and the EOTA. It is clear (Figure 6) that in the case of Austria and Slovenia the RSL of the external finishing coat exceeds the RSL of the building. Nevertheless, the whole environmental burden of the last replacement of the component must be assigned to the building.

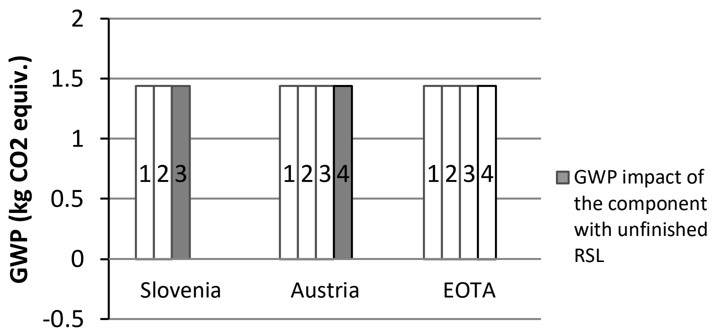


Figure 7. GWP emissions of each kg of finishing coat (original + replacements) during the RSL of the building

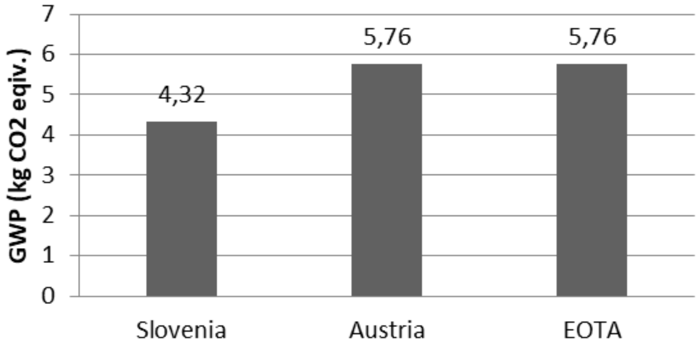


Figure 8. Total GWP emissions for 1 kg of finishing coat (original + replacements) during the RSL of the building according to the selected RSL databases

The production phase for 1 kg of finishing coat has an impact of 1.448 kgCO2equiv., the end-of-life phase 0.011 kgCO2equiv and the D phase has an impact of -0.019 kgCO2equiv. According to the Slovenian RSL database two replacements are needed (the environmental impact of all the life cycle phases is calculated). In the case of Austria and the EOTA the environmental impact of the whole life cycle of 1 kg of finishing coat is calculated four times (original + three replacements).

The GWP emissions caused by 1 kg of external finishing coat are the same when calculated with the Austrian or the EOTA RSL data, despite the fact that the RSLs of the finishing coats are 30 and 25 years. In both cases three replacements of the coating in the RSL of the building are required (Fig 7). In Slovenia the RSL of the external finishing coat is longer and only two replacements of the external finishing coat are needed; consequently, the GWP emissions of the latter are lower (Fig 7).

3. Conclusions

This study confirms that the reference service life (RSL) of a building and its components can have a significant influence on the results of the LCA analysis of a building. Therefore, for ensuring a reliable comparison between analyses it is extremely important that the RSL data in European databases are reasonably harmonized and clearly presented.

The results of the analysis showed that the calculation scenario at the end of the RSL of a building must be consistent with the actual handling of the components when the building is decomposed. In an ideal scenario, multiple RSLs of building components and the RSL of a building would end simultaneously. In reality this is very rare: the environmental impacts of the component strongly depend on the reuse scenario in terms of whether they should be attributed only to the life cycle of the first building or the next one, in which it is reused as well. This case study confirms that the scenarios for the reuse of individual components must also be methodologically consistent.

The influence of building components' RSLs was analysed with just two examples. It was shown that due to the selected European RSL databases and the predicted scenarios the results of the environmental impacts in a life cycle of a building can differ by up to a factor of five. In real buildings there are hundreds of components, so the influence of various reuse scenarios on the overall LCA analysis results can be even more significant.

RSL values of the individual materials, building components and buildings can be selected from many sources and are not completely comparable. It was found that the RSL sources in the European context are usually linked to different kinds of national legislation, but the background for their definition is not exactly known. Some countries have a uniform RSL for all the buildings, while others (including Slovenia) have RSL values that are mainly related to the type of building material (brick, concrete, wood, steel). There are some cases where the RSL values primarily depend on the use of the buildings. It is obvious that further research based on European data and subsequent comparisons of the results are needed to define reliable RSL values for specific individual materials and building components as well as for buildings.

References

[1] Ramesh T, Prakash R, Shukla KK 2010 Life cycle energy analysis of buildings: An overview *Energy Build.* **42**, 1592–1600
[2] Passer A, Ouellet-Plamondon C, Kenneally P, John V, Habert G 2016 The impact of future scenarios on building refurbishment strategies towards plus energy buildings *Energy Build.* 124 153–163
[3] Thormark C 2002 A low energy building in a life cycle—its embodied energy, energy need for operation and recycling potential *Build. Environ.* **37** 429–435
[4] Abd Rashid AF, Yusoff S 2015 A review of life cycle assessment method for building industry *Renew. Sustain. Energy Rev.* **45** 244–248
[5] Rauf A, Crawford RH 2015 Building service life and its effect on the life cycle embodied energy of buildings *Energy* **79** 140–148
[6] Grant A, Ries R, Kibert C 2014 Life Cycle Assessment and Service Life Prediction A Case

Study of Building Envelope Materials *J. of Indu. Eco*, **18**
[7] Grant A, Ries R 2013 Impact of building service life models on life cycle assessment *Build. Res. Inf.* **41** 168–186
[8] Dixit MK 2019 Life cycle recurrent embodied energy calculation of buildings : A review *J. Clean. Prod.* **209** 731–754,
[9] EeBGuide Project Available online*: https://www.eebguide.eu/.*
[10] Nutrungsdauerkatalog baulicher Anlagen und Anlagenteile 2012 Landesverband Steiermark und Karnten.
[11] Durées de vie dans MMG2017/TOTEM Available online: *https://www.totem-building.be/*
[12] SBToolCZ. Available online: https://www.sbtool.cz/cs/metodika
[13] Nutzungsdauern von Bauteilen für Lebenszyklusanalysen nach Bewertungssystem Nachhaltiges Bauen. Available online: *https://www.nachhaltigesbauen.de/fileadmin/pdf/baustoff_gebauededaten/BNB_Nutzungsdauern_von_Bauteilen__2011-11-03.pdf*
[14] Pravilnik o standardih vzdrževanja stanovanjskih stavb in stanovanj. Available online: *http://www.pisrs.si/Pis.web/pregledPredpisa?id=PRAV5263*
[15] Documento Básico SE Seguridad. Available online: *https://www.afme.es/phocadownload/Codigo_Tecnico_de_la_Edificacion/CTE-DB_SE-AE.pdf*
[16] SIA 2032 2010 *Graue energie von Gebauden* (Zurich: Swiss society of engineers and architects)
[17] DGNB Available online: *https://www.dgnb.de*.
[18] Ökobaudat Available online: *https://www.oekobaudat.de/.*
[19] EOTA Available online: *http://www.irbnet.de/daten/iconda/CIB1315.pdf*