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PROBLEMS OF CALCULATING THE CARBON FOOTPRINT IN SCOPE 3 USING BIM

PROBLEMATYKA OBLICZANIA ŚLADU WĘGLOWEGO W ZAKRESIE 3 Z WYKORZYSTANIEM BIM

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Abstract

The article presents the requirements of the EU EPBD (Energy Performance of Buildings Directive) for counting the carbon footprint (especially in Scope 3) and including it in construction projects from 2030. The obligation to count the carbon footprint will burden mainly designers, who are increasingly using BIM (Building Information Modelling) in the design process. Performing analysis and calculation of the carbon footprint in BIM models is hampered by the lack of non-graphical information on the subject in library components. The paper explains the concept of CO_2 in 3 scope, also discusses currently available tools for counting the carbon footprint, and examines how many components available on the Internet already contain non-graphical information on emissions, as well as ideas for implementing this directive. The advantages and disadvantages of these approaches were presented from the perspective of various stakeholders in the planning and investment and construction processes. The aim of the paper was to present possible solutions, ensuring compliance with the EU directive by proposing specific techniques, enabling the calculation of the Scope 3 carbon footprint, using BIM. In addition to a review of existing ideas, an authorial proposal for a national repository of carbon footprint information taking into account all stakeholders was presented.

Keywords: carbon footprint, CO_2, scope 3, EPBD, building information modeling, BIM

Streszczenie

W artykule przedstawiono wymagania unijnej dyrektywy EPBD (ang. Energy Performance of Buildings Directive) dotyczące liczenia śladu węglowego (zwłaszcza w zakresie 3) i uwzględniania go w projektach budowlanych od 2030 roku. Obowiązek liczenia śladu węglowego obciąży głównie projektantów, którzy coraz częściej wykorzystują BIM (ang. Building Information Modelling) w procesie projektowania. Przeprowadzanie analiz i obliczeń śladu węglowego w modelach BIM jest utrudnione ze względu na brak niegraficznych informacji na ten temat w komponentach bibliotecznych. W artykule wyjaśniono koncepcję liczenia CO_2 w tzw. zakresie 3, omówiono również obecnie dostępne narzędzia do liczenia śladu węglowego oraz zbadano, ile komponentów dostępnych w internecie zawiera już niegraficzne informacje na temat emisji, a także przedstawiono pomysły na wdrożenie tej dyrektywy. Zalety i wady tych podejść zostały zaprezentowane z perspektywy różnych interesariuszy procesów planistycznych i inwestycyjno-budowlanych. Celem artykułu było przedstawienie możliwych rozwiązań, zapewniających zgodność z dyrektywą UE poprzez zaproponowanie konkretnych technik umożliwiających obliczenie śladu węglowego z zakresu 3, z wykorzystaniem BIM. Oprócz przeglądu istniejących pomysłów przedstawiono autorską propozycję krajowego repozytorium informacji o śladzie węglowym z uwzględnieniem wszystkich interesariuszy.

Słowa kluczowe: CO_2, zakres 3, EPBD, modelowanie informacji o budynku, modelowanie informacji o obiekcie budowlanym, BIM

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1. INTRODUCTION

Currently, the construction sector is the largest producer of CO_2 in the world. It accounts for almost 40% of all emissions of this greenhouse gas (Fig. 1) (Huang et al., 2018). The fundamental problem is that the construction industry, together with the transportation industry, directly contributes to climate change (Gallego-Schmid et al., 2020). For this reason, there is an emerging need to regulate the carbon footprint created at each stage of a construction project (Webber et al., 2009).

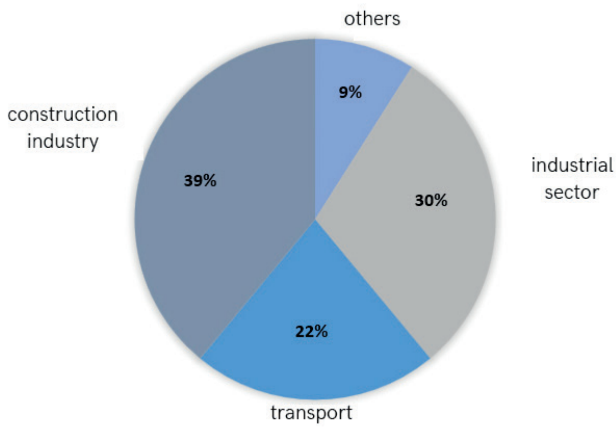

Fig. 1. Global CO_2 emissions by sector in 2018
Source: own elaboration based on (Sweco, 2023)

The European Union has set itself the goal of reducing CO_2 emissions and achieving climate neutrality by 2050 (Gilewski et al., 2023). Part of this plan set by the EPBD recast of March 14, 2023, is to give EU member states deadlines for providing details of the action plan – January 1, 2027. These concern the introduction of limits on the total cumulative global warming potential over the life cycle of all new buildings and the setting of targets for new buildings from 2030. The directive requires calculating the GWP (*Global Warming Potential*) and disclosing it on building energy performance certificates. CO_2 emissions are divided into operational (*OCF – Operational Carbon Footprint*) and embodied (*ECF – Embodied Carbon Footprint*) (Zima and Przesmycka, 2021). Currently, Polish law requires the calculation of only operational emissions, i.e. direct energy and water consumption. The directive's assumptions will also require the calculation and reporting of embedded emissions, which will translate into much more work (Wcisło-Karczewska, 2023) (Wcisło-Karczewska, 2023). Emissions CO_2 are divided, calculated and tracked by three scopes according to ISO 14067:2013. Scope 1 (Fig. 2) refers to direct emissions from sources owned or supervised by the organization. Indirect energy emissions refer to emissions in the generation of electricity, heat or steam consumed by organizations that occur in scope 2. Scope 3 emissions are those that arise from the organization's operations, but at locations under the control of other entities, e.g., the production of building materials (Kulczycka and Wernicka, 2015).

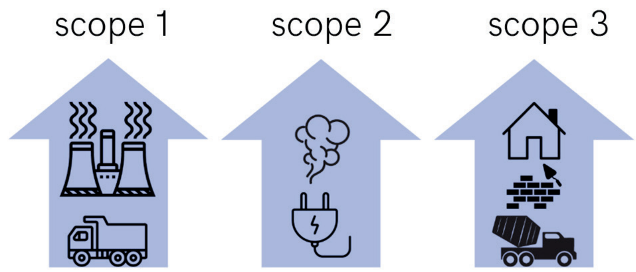

Fig. 2. Ranges of CO_2
Source: own elaboration

Scope 3 are indirect emissions that occur in an organization's value chain. This can include greenhouse gas emissions that are not controlled by organizations, but can affect them (Ruszkowski, 2022) (Ruszkowski, 2022). The problem of counting emissions in Scope 3 is complex, as they are divided into (*upstream*) higher-level and (*downstream)* lower-level emissions. Upstream emissions are those generated by organizations and institutions of which the organization counting the carbon footprint is a customer, and downstream emissions are those generated by the organization's customers. The biggest problem that occurs when counting Scope 3 emissions is that it counts the largest scope, which is also difficult to assess (Anquetin et al., 2022). It is important to determine how such emissions are counted because for many companies they account for more than 70% of the carbon footprint, e.g., a large portion of a building materials company's carbon footprint is Scope 3 emissions from mining, material handling and raw materials (Deloitte, 2023). The obligation to count the carbon footprint will fall mainly on design companies, and thus on designers, library object modelers, or analysts, who increasingly use modern digital technologies in their work.

BIM (Building Information Modeling) is defined as a collaborative process of people, systems, software, and in an even broader sense can include tangible, intangible or knowledge resources (Borkowski, 2023). From the designer's perspective, however, it is a relational database of the building object, which should be semantically rich, meaning that it contains all the necessary geometric and non-graphical information needed throughout the building life cycle (design, project implementation, management of the building object). There are also only six years to implement the objectives of the directive. Moreover, it is unrealistic to achieve it in Poland, due to the fact that the country does not have an official mandatory BIM standard (there is only an optional BIM Standard PL), nor a developed procedure for implementing it in the design process. According to experts, counting the carbon footprint is complicated, especially in the third scope, which includes the entire supply chain, yet it needs to be done (Pandey, Agrawal, Pandey, 2011). Thus, the purpose of this work was to present possible solutions to ensure compliance with the EU directive by proposing techniques to calculate the carbon footprint in scope 3. The paper conducted a deep literature review of methodologies and IT tools for tracking the carbon footprint. This poses a challenge because there is currently no established method for obtaining this information and adding it to a construction project. The biggest problem seems to be BIM library objects that do not include CO_2 information. Solutions to such a problem continue to evolve and are realizing the first steps to achieve targets for future years. This goal is very difficult or, according to some, even impossible to achieve, as it implies a very large amount of work.

2. LITERATURE REVIEW

Building products and related materials and processes require targeted requirements with more linkages between sectors and changes in production practices of commonly used materials associated with high greenhouse gas emissions (Maduta et al., 2022). At a minimum, the goal appears to be to calculate and track both embedded and operational carbon footprints. There are a number of different methods for calculating the carbon footprint of, among other things, Scope 3. They make it possible to obtain the full dimension of CO_2 for the entire life cycle of a given investment. The choice of a particular method depends on needs and data availability. A common way is to use plug-ins and services that augment any BIM-type software. One of them is Green Building Studio, which is a cloud service that allows for extensive analysis in the energy sector. It allows calculating a building's energy consumption based on building type and location (Borkowski et al., 2022). Carbo Life Calculator, on the other hand, is a tool for calculating the carbon footprint that is emitted throughout the life cycle of a building. It retrieves information on the value of materials at the scale of a model in Autodesk Revit, for example. The add-on significantly improves carbon footprint analyses and allows you to know the full scale of emissions. Carbo Life Calculator uses databases from EPD, among others, to obtain reports. Another plug-in for studying the carbon footprint is Design Builder. It is a tool for performing complex energy consumption analysis and checking the compliance of projects with energy certifications like EPCs in the UK. The software also allows you to manage lighting or other building systems like air conditioning. This makes it possible to make changes to a project to improve the conditions of the building's occupants and reduce CO_2 (Pawar and Kanade, 2018). Counting the carbon footprint is now also possible through websites or online services (Dreijerink, Paradies, 2020). These focus on electricity consumption, home heating or vehicle driving, among other things. One such program is the Carbon Footprint Calculator. It counts the approximate and total amount of CO_2 that is emitted by a household (Łasut and Kulczycka, 2014). Another group of websites are those that count direct emissions and are related to one's activities, as well as indirect emissions that are not directly influenced. A site that does such calculations includes "Carbon Footprint Ltd." It uses external databases where data on current environmental impacts are available (Łasut and Kulczycka, 2014). One Click LCA is an automated building life cycle assessment software. Among other things, it is used to quantify the operational and embedded carbon footprint of a building. It will also estimate CO_2 emissions based on the size and type of the facility in question, and compare, optimize and visualize the carbon efficiency of alternative designs (LCA, 2023).

Currently, there is no universal program for calculating the carbon footprint, nor is there a method for this program to use. This is a big problem because it makes it difficult to track the total carbon footprint for investments and makes it difficult to count the amount of CO_2 for smaller companies. Thus, the discussion on this topic is ongoing, and there are at least several proposals.

Table 1. Selected software for calculating the carbon footprint of buildings and construction projects. Source: own elaboration

Tool	Type	Destination	Properties	Cost
Green Building Studio	plug-in/web service	Energy analysis in the design phase (Borkowski et al., 2022)	Allows calculation of building energy consumption based on building type and location	Commercial (30-day free trial period)
Carbo Life Calculator	plug	Calculating the carbon footprint that is emitted throughout the life cycle of a facility	Uses databases including EPD to obtain reports; Retrieves carbon footprint information at model scale in Revit	Free
Design Builder	plug	Analyzing energy consumption and verifying projects' compliance with energy certifications like EPCs in the UK (Pawar and Kanade, 2018)	Ability to manage building systems and make changes to improve the comfort of its occupants	Commercial (30-day free trial period)
One Click	software	Counting a building's carbon footprint and its emissions (LCA, 2023)	Automated building life cycle assessment, database of information on carbon footprint of individual elements	Commercial
Carbon Footprint Calculator	website	Counting the approximate and total amount of CO_2 that is emitted by a household (Łasut and Kulczycka, 2014)	Focuses on electricity consumption and heating	Free
Carbon Footprint Ltd.	website	Counting the building's indirect and direct emissions (Łasut and Kulczycka, 2014)	Uses external databases where data on current environmental impacts are available	Free

3. COMPONENT RESOURCES WITH AN INDICATED CARBON FOOTPRINT

Working in BIM requires that the building is equipped with library components available in digital form, oriented to a certain degree of geometric information (LoD, Level of Detail), enriched with non-graphical information (LoI, Level of Information). As a rule, such objects (components) can be easily downloaded and used in currently used software. However, there is a growing demand for each object to have not only physical information, but also non-geometric data such as product information, instructions, operating costs or just the carbon footprint of the manufactured product. The website bimobject.com is one popular site that has a huge resource of building product components. For Revit software alone, it has tens of thousands of so-called families. However, there are only 1,481 components that have CO_2 included. Currently, 32 brands produce such components, and one such manufacturer is the Hansgrohe brand. It produces about 590 models that include parameters about emissions. Of all the families that offer information on CO_2, not a single one is manufactured in Poland. A significant number of components are manufactured in Germany, as many as 1152. The main reason for this result is the high level of BIM implementation in the construction sector in Germany (Schumacher et al., 2022). Thus, the awareness of building material manufacturers on this topic is growing.

Using the bimobject browser (bimobject, 2018) one product was checked: a kitchen faucet from hansgrohe (Fig. 3). It has all the necessary information along with those for producing a carbon footprint at each stage of production (Fig. 4). This can be a benchmark for other companies that intend to include CO_2 parameters for each model in the future.

Fig. 3. Kitchen faucet by hansgrohe
Source: (bimobject, 2018)

EPD Data (Simplified) A1-A3
Energy Consumption (A1-A3) 123.7 MJ
EPD Declaration Unit 1 piece of an average kitchen faucet incl. packaging
EPD Document Link
https://epd-online.com/PublishedEpd/Download/14889
EPD Expiration Date 2028-02-23
EPD Issue Date 2023-02-24
EPD Registration Number EPD-HAN-20230024-ICC1-EN
Global Warming (A1-A3) 5.977 kgCO2
Non Renewable Resources Consumption (A1-A3) 97.8 MJ
Waste Production (A1-A3) 1.15375 kg
Water Consumption (A1-A3) 0.215 m³

EPD Data (Simplified) A4-A5
Energy Consumption (A4-A5) 3.1435 MJ
Global Warming (A4-A5) 0.91033 kgCO2
Non Renewable Resources Consumption (A4-A5) 2.933 MJ
Waste Production (A4-A5) 0.43152 kg
Water Consumption (A4-A5) 0.00043 m³

EPD Data (Simplified) B1-B7
Energy Consumption (B1-B7) 5893.1 MJ
Global Warming (B1-B7) 341.0379 kgCO2
Non Renewable Resources Consumption (B1-B7) 5754 MJ
Waste Production (B1-B7) 25.60579 kg
Water Consumption (B1-B7) 0.2653 m³

EPD Data (Simplified) C1-C4
Energy Consumption (C1-C4) 1.46044 MJ
Global Warming (C1-C4) 0.82579 kgCO2
Non Renewable Resources Consumption (C1-C4) 1.1345 MJ
Waste Production (C1-C4) 1.60261 kg
Water Consumption (C1-C4) 0.00197 m³

EPD Data (Simplified) D
Energy Consumption (D) -63.2 MJ
Global Warming (D) -4.55112 kgCO2
Non Renewable Resources Consumption (D) -48.2 MJ
Waste Production (D) -0.85953 kg
Water Consumption (D) -0.167 m³

Fig. 4. List of CO_2 information found in the hansgrohe kitchen faucet family. Source: (bimobject, 2018)

Adhering to the EPBD, there is no established framework or solution for how to calculate and insert carbon footprint information in architectural and building designs. However, there are currently several proposals for systems for calculating and inserting this information. They are extremely different, each of which contains peculiar problems for particular stakeholder groups. The stakeholder groups that will be most affected by the new obligation are: (i) manufacturers, (ii) suppliers, (iii) contractors, (iv) investors, and (v) intermediaries.

4. CARBON FOOTPRINT INVOICING

One widely discussed proposal is carbon footprint invoicing. The proposal calls for each stakeholder group to independently calculate and then invoice information about the CO_2 it emitted in the course of manufacturing or performing another activity. Such information is then to be entered manually, as non-graphical information, into the BIM model that forms the basis of project development. This would most likely be the responsibility of contractors, as this is the lowest stakeholder group in the supply chain. Such a system would most likely require the hiring of additional people to enter this data, or a significant expansion of the responsibilities of BIM modelers and BIM coordinators. This is a transfer of almost all responsibility for complying with the EPBD to contractors, suppliers and manufacturers, without any help from the legislature. Moreover, the solution does not involve the introduction of a predetermined method or tool for counting the carbon footprint. Finding one then becomes the responsibility of stakeholders, which can be a problem, especially for micro and small companies. The advantage is that this information can be entered into the model using Dynamo scripts, but this requires a great deal of familiarity with programs working in BIM, which again favors large companies that use such solutions to a greater extent. In addition, all intermediaries would be required to know the process and follow it. Otherwise, there could be a disruption in the invoicing process.

5. CREATE BIM COMPONENTS SUPPLEMENTED WITH CARBON FOOTPRINT INFORMATION

The ability to create library components supplemented with the necessary carbon footprint data would allow the investment model to be enriched. The unit responsible for creating such components could use the aforementioned plug-ins or BIM-compatible tools. The process of creating them would begin at the production stage. By design, this is an innovative proposal, but unfortunately it is quite problematic in reality. In Poland, the construction industry is largely not using BIM (Apollo and Grzyl, 2023). The early stage of advancement, or lack thereof, does not only affect smaller companies. A materials manufacturer is unlikely to have access to the software and the appropriate qualifications to produce a library component enhanced with the required non-graphical carbon footprint information. Such an opportunity will be possible for larger companies with specialists in this field. Therefore, the exchange of library components between stakeholders and supplementing them with the necessary data could occur in a small number of cases. A certain solution to offset the problem would be to hire a qualified person in this area. In this case, the BIM Modeler would be responsible for enriching with information all components concerning the

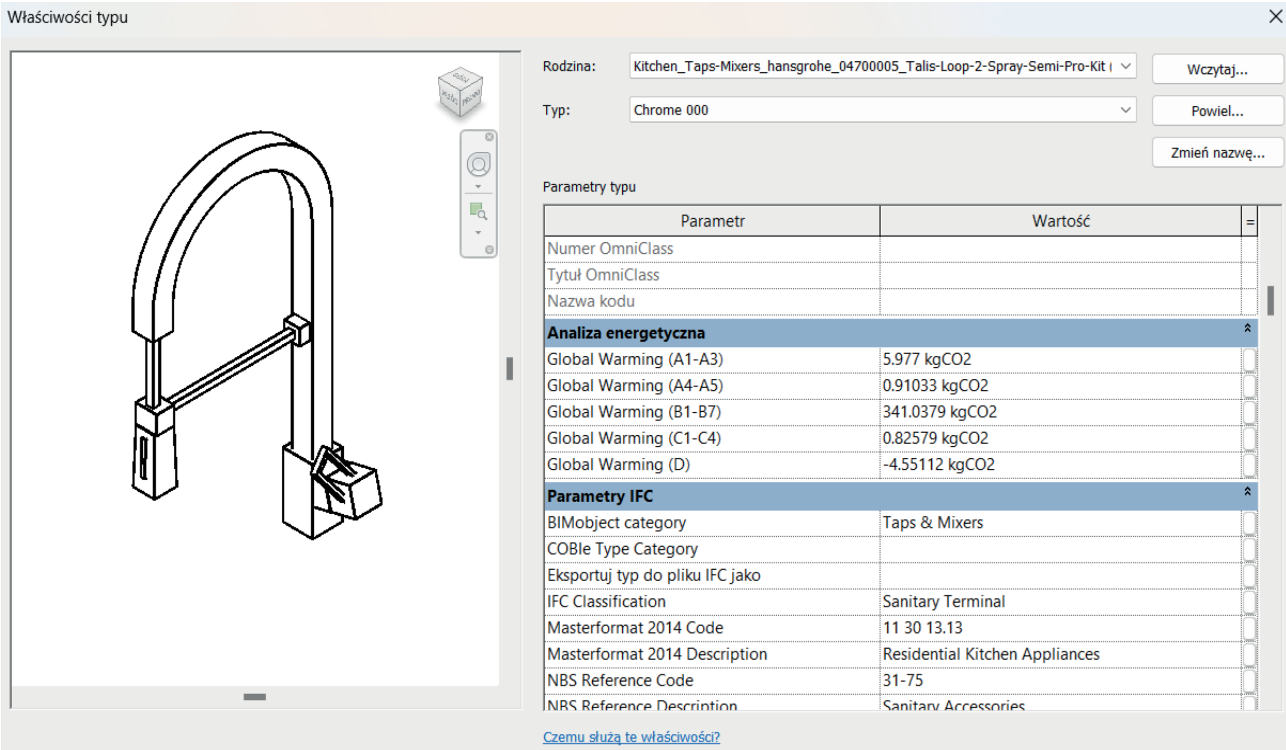

Fig. 5. Table of family parameters with included carbon footprint information
Source: own compilation based on bimobject, 2018

entire investment process. However, the person most likely to be hired on the developer's side might not have such detailed information on CO_2 in the material creation process. Theoretically, carbon footprint data can be entered by the designer using catalog information from manufacturers (Meinrenken et al., 2022). This will involve more work, but it is possible. Entering such data as entity, type or shared parameters can improve the performance of subsequent analyses (Al-Obaidy, Courard, Attia, 2022).

One example that deals with supplementing in carbon footprint information is the aforementioned kitchen faucet from hansgrohe (Fig. 5). Revit software was used to carry out the work on the family. The process began with loading the model into the project and verifying the existing parameters in it, which were provided by the manufacturer. The information was then implemented into the parameters of the family model. The result of the work was a family rich in non-graphical data on the extent of the carbon footprint, which meets the guidelines of the EU EPBD. If each library component was developed with non-graphical data, it would be a great convenience for stakeholders. Potentially, a library object modeler or designer could supplement the information manually with the properties and environmental footprint of the product from the following stages, among others: extraction and processing of raw materials, production and packaging, distribution and storage, use or disposal. Unfortunately, the level of BIM in Poland is not developed enough to make this possible and feasible (Apollo and Grzyl, 2023). The results of other research studies show that the diffusion of sustainable products can be hindered due to problems with the mechanisms for creating and exchanging BIM objects, the quality of BIM objects, the usability of BIM library platforms and participation on sharing platforms (Bahrami, Atkin, Landin, 2019).

6. PROPOSAL FOR CHANGE

A proposal to meet the objectives of the EU directive is for the legislature to create a nationwide repository of carbon footprint information. To this end, there could be a database containing information on the carbon footprint of individual facilities, along with specific codes for each product and category. The repository could use CCI (*Construction Classification International*) codes. These codes, based on the Danish CCS classification system, are a common international classification. It is hierarchical and based on the properties of the individual elements being described. The main tenets of CCI are a language understandable to humans and machines, a logical structure and standardized nomenclature, online usability and uninterrupted flow of information (Idzkowski et al., 2021). An example code for a wall of wallboard is B10.AD30.ULM(ESE.21), and the basic code for a tap is: HB01, but can be supplemented with additional information including Stage of Design, requirements for additional fixtures, costs, etc. (Liias et al., 2021). The repository could also include a tool for calculating the carbon footprint in a one-size-fits-all manner. A website would allow users to post information about their products or services, among other carbon footprints, and the system, based on the product and category, would assign it a unique CCI code used later to track changes at each stage of the investment. The repository could also allow components with CO_2 information, but this would not be mandatory. This would make it possible for larger companies with resources and BIM specialists to post their product components, while smaller companies could post non-graphical information. An additional advantage of this solution is the possibility of creating plug-ins for BIM-enabled programs, which would greatly streamline the process of adding carbon footprint information or even the components themselves to a project. The disadvantage of such a repository, however, is the large amount of work on the part of the legislator who would have to create and operate such a system, which would entail a large financial outlay. The information system of such a repository should allow plurality of BIM platforms and give the possibility to place components from different design software vendors. It may also be a problem e m to implement all stakeholders in the new process. Each of the involved stakeholder groups of the investment and construction processes (designers, general contractors, building material manufacturers, clients or administrators) would have to be given detailed instructions on how to post reliable footprint information in the repository. For the purpose of calculating the carbon footprint for an investment, new software could be developed based on data from the repository, or even an integrated tool that could be built into the IT platform. At the same time, this is a direction for further research that the authors want to undertake in the future.

7. CONCLUSION

Counting the carbon footprint, especially in Scope 3, for each investment component, as required by the EPBD, is challenging. Moreover, there is currently no legally established way to calculate CO_2 or a system for including this information in projects. The situation is further exacerbated by the fact that Poland currently has no officially established BIM standard. The systems currently proposed are unrealistic because they assume that every subcontractor and supplier would be able to calculate the carbon footprint on their own, or create a BIM component with non-graphical information. This would require training or hiring many people solely for this purpose. The repository idea, on the other hand, would make the task easier for stakeholders and make the CCI code base more widespread in Poland, but it would require significant funding and the creation and requirement of a system by the legislature. The time to introduce efficient enabling solutions is only 6 years. Therefore, it requires coordinated action by experts and the legislature to establish a standardized plan for implementing the requirements of the EPBD as smoothly as possible.

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