Evaluation of environmental impact and GHG emission with energy system modeling combined with LCA in building sector: a review

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Abstract. Entering the 21st century, building energy consumption ranks first in total energy consumption, environmental pollution is increasing, and the construction sector has become the main energy source. The ability to reduce greenhouse gas emissions by replacing fossil fuels such as oil, gas and coal with fuels from renewable sources is a key factor in the development of net zero energy buildings. Therefore, it is important to analyze and organize previous and current research in this area to get an overview of the importance of built environmental assessment and net zero energy buildings. This review therefore summarizes the literature of previous life cycle assessment (LCA) and energy modeling studies conducted for environmental assessment of construction and construction-related industry sectors, considering construction products and entire building systems, buildings and civil structures. Bibliographic methods and scientometric analyzes have been adopted and proposed to tentatively explore research themes in this field. This observation indicates that BIM-LCA (Building Information Management Life Cycle Assessment) optimization is currently an important and inevitable research focus in the building-related energy field. Finally, there was a qualitative discussion on the achievement of key goals. We provided an up-to-date literature review on LCA construction, used energy system models to assess environmental impacts, and discussed key challenges in LCA construction, ongoing research, and possible solutions to solve the identified problems. The results also provide a comprehensive knowledge framework linking previous and current research areas with future research trends. The results provide researchers with an interdisciplinary focus on insights and solid engineering knowledge from the latest research on BIM-LCA.

Keywords: Bibliometric analysis, Building Information Modeling, Life Cycle Assessment, Renewable energy.

1 Introduction

In 2015, UN Member States agreed on a solution for sustainable development by 2030[1]. Development has many environmental impacts, but global warming is currently the most serious and challenging change for governments, industries and people. Concerns about regional and global environmental conditions are increasing worldwide. Global warming is the result of long-term accumulation of greenhouse gases (CO2, CH4, N2O, etc.) in the upper atmosphere [2]. Buildings account for more than 40% of the world's energy consumption and one-third of the world's greenhouse gas emissions [3]. China is the second largest energy consumer and the second largest building energy consumer in the world, and ranks first in household energy consumption [4]. Building energy efficiency has long been recognized as a key component of energy security to reduce end-user energy dependence and electricity bills. Building construction and operations account for 36% of global final energy consumption [5]. Amid growing awareness of environmental concerns and pressure from multiple governments, customers and environmental activists, much research has been done to reduce the energy consumption and environmental impact of buildings. According to ISO 14040/14044[6], LCA is an eco-friendly platform with environmental and sustainability goals. The aim is to assess the environmental impact of

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properties and facilities in order to increase their sustainability. LCA has been developed gradually over the years. This concept emerged primarily in his 1970s and 1980s. In addition, life cycle studies have focused more attention on quantifying the energy and materials consumed during the life cycle and the waste released into the environment [6]. A life cycle assessment allows you to classify buildings according to their use. Basically, residential buildings can be divided into several subgroups such as single-family houses and apartment buildings, as well as several subgroups such as transport companies, public buildings, tourism, sports facilities, offices, industrial, agricultural, commercial, and communal non-residential buildings such as shops [7, 8]. There are two different understandings of building energy consumption. The first situation concerns the energy consumption of buildings during the operational phase, which is inconsistent with current international practice. Currently, most articles on building energy efficiency focus on operational energy, including the energy used for heating, ventilation, air conditioning, hot water, lighting, cooking, office space, and other electrical equipment. The second value is expressed as total energy consumption over the life cycle of the building. This includes energy consumption during operational phases such as manufacturing building materials, building construction, and building demolition. The purpose of this study is to provide an up-to-date overview of the LCA construction literature, use energy system models to assess environmental impacts, and discuss key challenges in LCA construction. Ongoing research and potential solutions are proposed to address existing problems and challenges. The method includes a literature review that provides an overview of existing life cycle assessment and energy-related building research, followed by a focus on environmental impact assessment and building life cycle assessment combined with energy system modeling.

2 Energy modeling relevant to building

Building professionals use building performance analysis tools to evaluate individual energy efficiency measurements (EEMs) and overall designs to reduce building energy consumption. Buildings consume 41% of the energy consumed in the United States, and 70% of the energy comes from electricity [9]. Energy benchmarks are recognized as an effective way to assess the energy consumption of buildings. Due to fossil fuel shortages and global warming, energy and environmental issues are getting more and more attention around the world. Energy-intensive buildings play an important role in energy conservation and environmentally sustainable development. In general, the basic idea in estimating building energy consumption is to find a viable model that determines the energy efficiency of buildings in a country based on accessible data. Modeling methods in existing studies can be divided into two parts. Top-down and top-down approach as shown in the figure1.

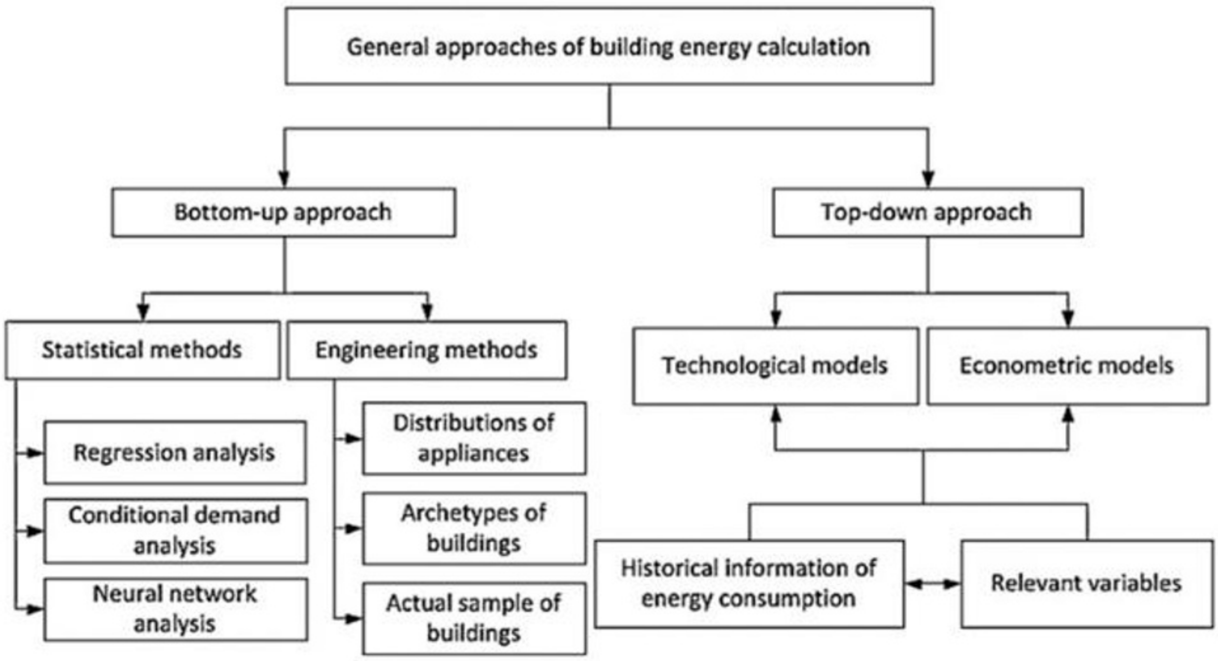

Fig. 1. General approaches to determining national building energy consumption in China.

The work of Clyde Zhengdao Li [10] and his team initially focused on a bibliographic method of selecting over 255 available papers from 2009 to 2022, with the main topic being “Building Life Cycle Energy” (LCE-B). The bibliographic method provided a holistic analytical method as a background for literature research. Secondly, symmetric analysis for classifying productive and important sources, scientists, disciplines and studies in life cycle energy research is recognized and keyword testing is recommended to predict research topics in this field. They concluded that architectural information modeling and optimization should be the focus of new research. This study contains a complete knowledge task. In addition, it uses a logical model that connects existing research areas and emerging research trends, and provides an interdisciplinary focus to help researchers better understand the latest findings on building life cycle energy [11]. The China Building Energy Model (CBEM) was developed by Siyue Guo et al. [12] he studied models the energy consumption of buildings in China and evaluates his projections of carbon emissions to 2050 under different scenarios. Buildings will use 80% more energy than they do today if the 13th Five Year Plan strategy is maintained, and almost 10% more energy if better energy efficiency strategies are incorporated. Carbon dioxide emissions are estimated to peak between 2020 and he 2035. Paolo M. Congedo and his group [13] produced a diagram showing how indoor comfort conditions differ from outdoor climatic conditions. Buildings are tested in a specific climate zone or multiple climate groups over an extended period of time. Several cities evenly distributed around the world were selected for the study, covering all climatic zones of the Koppen-Geiger classification. Using Termolog Epix 11 software, we implemented a virtual building to monitor long-term fluctuating operating temperature (FOT) and test short-, medium-, and long-term temperature changes.

2.1. LEAP: the low emissions analysis platform

LEAP is a tool for modeling energy and the environment through scenarios. LEAP is defined as a long-term alternative energy planning system [14]. Scenario meaning is obtained by a complete representation of how energy is transformed, consumed and produced in a particular region or economy, taking into account population, economic development, technology, prices, etc. LEAP's soft data structure enables analysis based on technical requirements and accurate information from scientists. The database has an easy-to-understand and well-defined structure for storing energy data. With the help of forecasting tools, energy supply and demand were projected taking into account long-term developments. On the one hand, policy analysis tools were identified to simulate and assess the economic and environmental impacts of other energy programs, investments and policies. Young-Sun [15] used the LEAP model to analyze potential energy savings and CO2 emission reductions achieved by energy efficiency policies and designs of residential buildings in South Korea. Based on the energy environment model from 2010 to 2030, current and future energy consumption and CO2 emissions in housing construction are projected. According to Sun, energy consumption in the residential construction sector is projected to increase by 33% between 2007 and 2030 in the BAU scenario. Maximum reduction in CO2 emissions in the residential sector. Veena Subramanyam et al. conducted the same research and considered Alberta as a case study. The focus of this research was on optimizing energy supply and reducing greenhouse gas (GHG) emissions in residential buildings. With the help of energy models and scenario analysis, future potential energy savings and greenhouse gas reductions in the residential sector are projected. Global warming is exacerbated by enormous energy consumption in urban areas. This situation begins with serious consideration of the relationship between energy and carbon and low-carbon urban policies. In fact, Beijing launched a low-carbon pathway for research purposes and served as a pilot city in 2010. The Panamanian government has also adopted his LEAP model for energy planning [16]. The purpose of the model in this case is to explore the current state of Panama's power generation and to learn different possible future scenarios. The model also assesses potential environmental impacts. Finally, in this work Schwartz provided several innovations in the field of modeling the energy industry.

2.2 Energy plus

Energy Plus is a building simulation application that allows construction workers and researchers to model both energy use and water supply for all devices in a building. Energy Plus is a professional database for input and output data files. There are many utilities such as IDF editors for creating input files using a simple spreadsheet as an interface. Thanks to EP-Launch, Energy Plus was able to combine input and output files and run many simulations. EP comparison: Use charts to compare simulation results. There are a lot of building energy software out there these days, but with so many features included, Energy Plus is likely to be more comprehensive and offer more options. This software is used by many building scientists for building simulations that integrate energy demand and production to reduce energy input from the grid. Using a prototype building energy model created in Energy Plus 8.0 [17] using TMY3 weather data for each location, Robert Phillips designed a window-to-wall ratio (WWR) that deviated from a baseline value of 40% and conducted a comparative study that considered three different climate zones in the United States. Pengyuan Shen conducted a similar study for the Chicago case to investigate how site geometry affects a building's winter energy use. In figure 2, the framework as shown was applied to buildings located in the residential area of Doncaster, UK. Data from 53 city-owned single-family public housing units were selected for the case study, based on available information, including addresses. The framework is applied to each house and the estimated building characteristics, including height and energy consumption, are compared with existing datasets[17].

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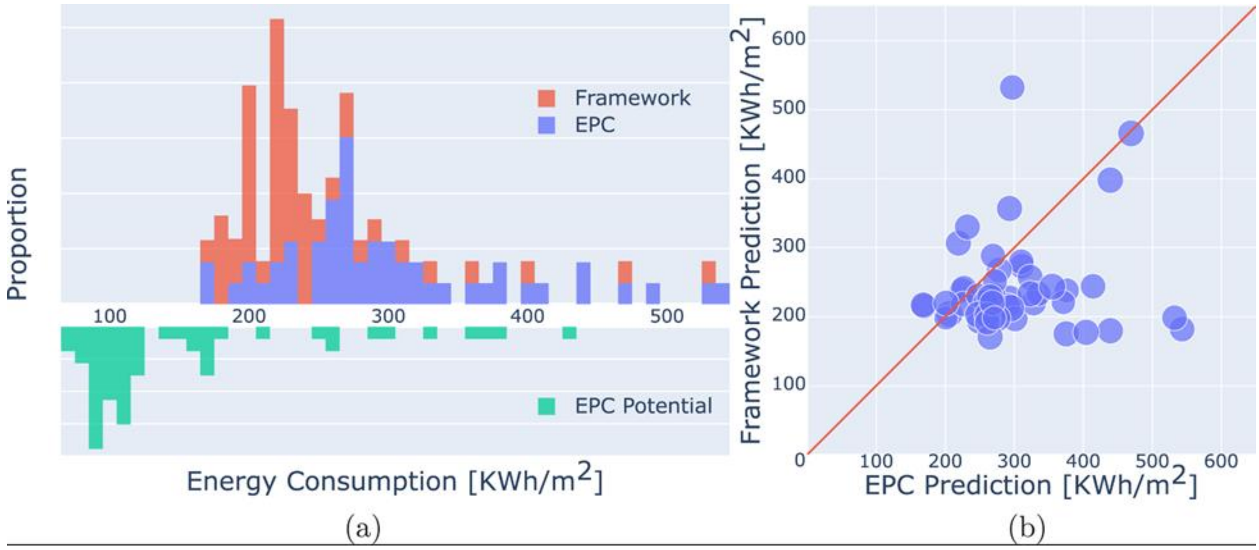

Fig. 2. Comparison of energy consumption predicted and EPC based framework. (a) Allocation of predicted energy consumption from EPCs based on SAP and proposed framework. The bottom chart shows the distribution of "potential" energy consumption based on the recommendations provided in the EPC report. (b) forecast energy consumption from each source for each case study asset.

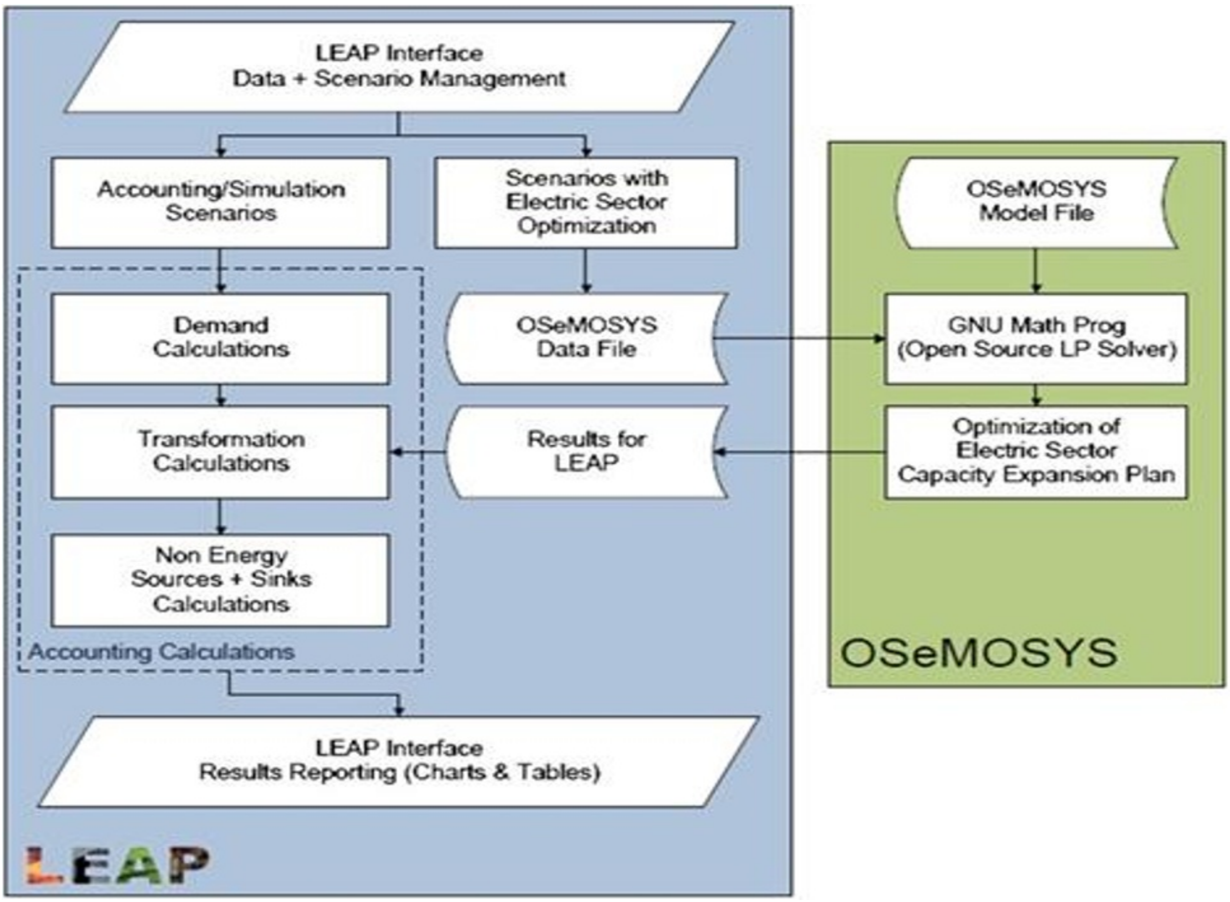

Fig. 3. Long range energy alternative planning linked with OSeMOSYS for building energy optimization.

2.3 OSeMOSYS

OSeMOSYS emphasized the characteristics of open access, the high level of abstraction, and the potential for its use and future development. One aim is to identify and calculate problems in an analytical toolbox that can also be used for energy network research and energy planning in developing countries (ERC, UK, Energy Research Centre, UK) [18]. These activities often require significant financial support, especially in the areas of personnel and training. These tools also include the acquisition of software to create analyzes and plans for sustainable energy structures. The first code was created in 2008 and made available to employees. The software has a modular structure and can be reworked by the user. It was previously established to produce local, national, transnational/continental and global energy and integrated assessment models (climate, land use, energy and water) (19). OSeMOSYS is more flexible than other software and can work with existing tools called Long Range Energy Alternative Planning System "LEAP" Current focus is on energy-related measurements and energy flow considerations in one or more disciplines. LEAP results are based on simple predictions based on scientist input and growth rates, not optimization algorithms. Adding optimization possibilities to LEAP through OSeMOSYS integration is a relatively straightforward task. As shown, OSeMOSYS combines energy sector development with LEAP software as shown in the figure 3.

Benjamin D. Leibowicz used OSeMOSYS in his research to create an optimization model with three approaches [19]. 1) Establishment of CO2-intensive fuels to achieve the lowest possible energy supply and energy mix. 2) Consider more energy efficient end devices. 3) Improving building thermal properties by balancing these properties and exploiting synergies, the most cost-effective decarburization methods were identified. The components of hourly power demand are determined by device-level experimental data and his City Sim building energy simulation software. This design was created specifically for Austin, Texas. The simulation considered climate policy, rapid population growth, and enormous energy demand in temperate regions of the United States. The best decarbonization comes first through end-user electrification and then through power source decarbonization. End-use effectiveness plays a slightly smaller role, limited to specific end-uses such as lighting, building comfort, and hot water supply. Improving the thermal efficiency of buildings will undoubtedly lead to significant cost savings for climate policy, highlighting important policy trade-offs between carbon reduction policies and building energy.

2.4 Comparative description of the models

The level of detail of the energy structure in the model varies greatly. Model refinement is done by comparing outcome models and establishing a common baseline. It's important to evaluate built-in modeling frameworks that can help from different perspectives. Additional energy modeling expands modeling possibilities and creates the basis for better policy advice. With LEAP, environmental scientists can use all the data they generate to develop better simulations. Compared to macroeconomic models, LEAP cannot estimate the impact of energy policy on employment or GDP, but it can run alongside other applications to remove software bottlenecks. Similarly, LEAP does not automatically generate optimal or market equilibrium scenarios, but can be used to classify the lowest cost scenarios. The greatest advantage of LEAP is its flexibility and ease of use, allowing decision makers to move quickly from policy idea to policy analysis without resorting to more complex models. Linking these energy models is essential to closing the gaps in the energy models. OSeMOSYS is very easy to use and does not require much knowledge and time to build and run. In addition, OSeMOSYS does not use any registered or commercial software design languages or problem-solving tools, so no financial investment is required. The benefits of OSeMOSYS extend the availability of energy modeling to networks of students, economic researchers, government agencies, and energy scientists in developing countries. EnergyPlus considers accurate building data. It also covers the physics of air, moisture, and heat transfer, with explicit mention of radiative heat transfer and convection to facilitate modeling of radiative devices. This package calculates thermal comfort index, lighting and shading, and visual comfort index. In addition, it simulates sub-hour timesteps for processing fast system dynamics and control strategies, models control sequences, and has programmable external interfaces for connecting to other analyses. EnergyPlus is validated to the ASHRAE Standard 140 methodology. EnergyPlus has traditionally focused on commercial buildings, but has recently expanded its model simulations to include residential buildings and data centers. Some of the major challenges in using these policy support models are listed in Table 1 below.

3 Life cycle assessment

3. 1 Life Cycle Assessment in Building Sector

It also takes into account the impacts that occur during the building's lifetime and provides important information support for environmental optimization to develop and design better solutions. Developed countries with a construction sector contribute about 40% of the environmental impact. A life cycle assessment has many purposes. The aim is to reduce pollution and CO2 emissions on the one hand and energy and related costs on the other. This section provided an overview of the current focus of building life cycle assessment. Priority areas were identified based on published review studies.
A summary of research objectives for the focus areas is provided in Table 2.

Table 1. Comparative study of the models

Model feature	Leap model	EnergyPlus	OSeMOSYS
Model type	Scenario-based energy environment modeling tool	Energy simulation model-based Python scripts (plugins)	Systems cost optimization model
Main topics	Comprehensive system for Maintaining energy information, allows the scientist to project energy supply and demand over a lasting planning horizon, simulates and evaluates the effects, environmental of alternative energy programs, investments activities	Provide scheduled data for use in Erl (EnergyPlus Runtime Language) programs, Comprehensive system for maintaining energy, and information,	Land use, water availability and climate change
Geographic coverage	Global with details on national level	Global with details on national level	National
Energy dimension	Allows for a quantitative analysis of the interaction between energy sectors and climate policies and the economy Take in fossil fuels and several renewables (with others bioelectricity 2nd generation biofuels) as distinct economic sectors	Allows for a quantitative analysis of the interaction between energy sectors climate policies and the economy. Take in fossil fuels and many renewables (including among others bioelectricity)	Model primarily uses the energy sector as its entry point

Life Cycle Energy Analysis (LCEA) is an approach that considers all energy inputs to a product. This includes not only the direct use of energy during production, but also the overall use of energy required to produce the components, materials and services required in the manufacturing process. A literature review shows that there are many difficulties in assessing the sustainability of buildings. Many sustainability ratings are based on life cycle energy analysis and consider the energy and carbon content embedded in the system boundary from cradle to factory gate. The heat required to scale the system from cradle to gate varies greatly from site to site and also depends on other important parameters such as transportation, energy efficiency, facility effectiveness and road conditions. A review of the literature shows that solidification energy and solidification carbon alone cannot accurately meet the criteria for assessing sustainability. There are many other assessment methods that offer solutions to the complexities of sustainability assessment. Essentially, these methods use relevant sustainability indicators created from core environmental parameters, extended boundary conditions and quality indicators. Also note that the cheaper the operating energy, the more important the energy consumption during the construction phase in the life cycle of the building. - Evaluation of life cycle CO_2 emissions. This article investigates the life cycle energy consumption and CO_2 emissions of the construction industry in Wuhan, China [31]. As a result, the construction and operation stages had the highest CO_2 emissions, followed by the indirect energy consumption and building material processing stages.

Table 2. Summary of research goals for each focus area

Building LCA Focus area	Aim	Ref.
Life cycle energy assessment	To redefine the strategies to decrease primary energy use in buildings	[20][21][22]
Life cycle carbon emissions assessments	To evaluate CO_2 in buildings to look for approaches to decrease global warming effect	[23,24]
LCA of building refurbishments	To select building retrofit actions with low life cycle environmental impacts	[25,26]
Dynamic LCA of buildings	To consider building properties that vary in time in building LCA	[27,28]
Uncertainty analysis in LCA of buildings	To evaluate uncertainties in building LCA data to improve results reliability	[29-30]
Integration of LCA in building rating systems	To encourage building sustainability assessment in practice	[31]
Integration of LCA with LCC and Social LCA	To perform Life Cycle Sustainability Assessment (LCSA)	[32,33]
BIM-based life cycle assessment of buildings	To take as less time as possible and effort in the building management data and LCA data	[34]

In this article, a decomposition analysis using log-mean divisive index (LMDI) was performed to analyze the factors contributing to carbon emissions in construction. It was found that the main cause of the increase in energy consumption and CO2 emissions was the increase in building area, followed by behavioral factors. Population growth and urbanization also contribute to his increasing CO_2 emissions. On the contrary, energy efficiency is the main obstacle to reducing CO_2 emissions. The political implications of developing low-carbon construction were highlighted. This overview organizes and summarizes the current contribution of building renovations and renovations to environmental assessment using Life Cycle Assessment (LCA) techniques. This document categorizes current contributions in this area and selects the most important methodological options. This review shows that most LCAs focus on energy retrofits, comparing environmental impacts before and after retrofits. In comparison, very few LCAs have investigated the environmental impacts of modifications to building systems such as structures and finishes. The most frequently investigated lifecycle stages relate to the manufacturing and use stages. Describe the main barriers to adoption. 15978 Interpretation of system boundaries, definition of functional units, LCI methods, operational phases and end-of-life phases. - Building dynamic life cycle assessment. Traditional Life Cycle Assessment (LCA) methods are used to perform environmental assessments (EIA) of buildings, with little attention paid to changing influencing factors and changes in usage patterns over time [32]. Since buildings have very long-life cycles, these details have a significant impact on the accuracy of the assessment results. To fill this gap and extend the LCA system, a dynamic assessment framework based on life cycle assessment was developed in this document. In this review, the new framework identified four dynamic characteristics of buildings (i.e., technological progress, changes in occupancy behavior, dynamic characteristic factors, and efficiency factors) and incorporated them into appropriate assessment procedures for conducting real-time EIA.

- Uncertainty analysis in building life cycle assessment. Life cycle analysis (LCA) is an increasingly popular technique for assessing the energy and carbon of buildings and their components over their entire life cycle. However, most existing lifecycle assessments provide highly accurate and unambiguous values that can give a false sense of security and mislead decision-making. This study demonstrates the lack of uncertainty analysis in LCA construction by discussing the root causes of the lack of this important activity. The starting point for the study is primary energy data collected from European manufacturers. The study dataset is used as input for probabilistic uncertainty modeling using Monte Carlo algorithms. In his two scenarios, his group of several random samples from 101 to 107 are tested.

Usually the data are distributed (verified empirically) and evenly distributed [33]. This result shows that assumptions about the data do not affect the results when a sufficient number of random. This conclusion holds for both the mean and standard deviation and is independent of the size of the life cycle inventory (LCI). This happens with both large and small data sets. The results of this study facilitate the analysis of uncertainties in life cycle assessments. The amount of data required to derive uncertainty information is greatly reduced, facilitating full integration of LCA uncertainty analysis into practical and academic assessments.

3.2 The strengths and limitations of life cycle assessment (LCA)

LCA provides a flexible context for a variety of analyses, ranging from construction process details to systematic policy decisions [34]. Context was created to capture the inputs and outputs of actions at all stages of the life cycle of a product or product structure, and the environmental impacts associated with those inputs and outputs. One of the benefits of LCA is the avoidance of so-called 'problem change', both in terms of environmental impact and life cycle stages [35]. A life cycle assessment is one of the most effective ways to assess the environmental impact of a product. For example, the ability to weigh and apply different analyzes to your business is supported by integration with global organizations. A life cycle assessment is one of the most reliable ways to assess the environmental impact of a product. In the construction industry, LCA offers two main benefits. Based on the results, it recommends that consumers and builders make New Year's resolutions. Drive innovation by exploring opportunities for manufacturers to improve productivity and product value throughout the design and construction process. A life cycle assessment considers the overall impact of all life cycle stages on the environment. This insightful perspective makes LCA one of the best environmental management tools available to environmental scientists. LCA can also add structure to your study. The ISO series of standards, developed in the 1990s, provide a definition of LCA and a general framework for conducting assessments in four interrelated and interdependent phases [36]. These phases are: purpose and scope interpretation, status quo analysis and impact assessment according to ISO 2006 (ISO 2006). LCA has become an important tool for gathering information for analysis, discussion, action and regulation in various fields. This helps decision makers recognize when they intentionally or unintentionally attach great importance to certain environmental aspects and little or no importance to others. However, despite all these advantages, this software has some limitations.

Many software tools are now available that make comprehensive analysis easier and more consistent. Despite the variety of tools available, it is true that LCA studies have weaknesses. Since LCA uses simple models to evaluate the world, these weaknesses are related to hypotheses, scenarios, etc. [37]. In particular, there are other research methods in which one study influences or continues another study. Scenarios and innovations vary from study to study, and so do LCA results. The different approaches, scenarios, and outcomes of LCA can be obscure, especially to non-environmental scientists. Additionally, performing life cycle analysis is expensive because it requires a large amount of data. Successful research depends heavily on comprehensive and reliable data collection, otherwise the result will be bad. Accessing data can inevitably be difficult when preparing life cycle assessments for complex building structures. This can lead to data gaps in your assessment. These are managed in different ways by different tools. Sometimes we use the best predictions to fill error bars in the data, sometimes we leave data gaps blank, and sometimes we collect more data to fill known data gaps. A sensitive area is the interpretation of "time dependence". Time dependence is directly related to the effects on the system in analyzing changes in the external environment in which the system resides. I will illustrate this with the building example. Their lifespans can reach up to 100 years, and their average annual environmental impact varies greatly. This may be relevant, among other things, to the development of renewable energy sources in the energy sector. The EN15978 approach assumes that the current conditions remain the same throughout the life cycle of the building. A good LCA study recognizes this limitation and provides a sensitivity analysis. William Michalski's team [38] prepared a study on the limitations of life cycle assessment in the building sector by conducting a survey. Figure 4 below summarizes the participant's views on limitations or barriers to his LCA implementation in architecture. Numbers in parentheses indicate the number of times the barrier was mentioned in the discussion. The limitations most frequently cited by participants were methodological gaps. Participants also discussed other obstacles such as logistical issues, gaps in LCA methodologies, educational, social and economic issues. Other notable limitations are the lack of government incentives and the difficulty of interpreting the results [39]. The discussion group identified factors contributing to LCA limitations rather than identifying a dominant factor.

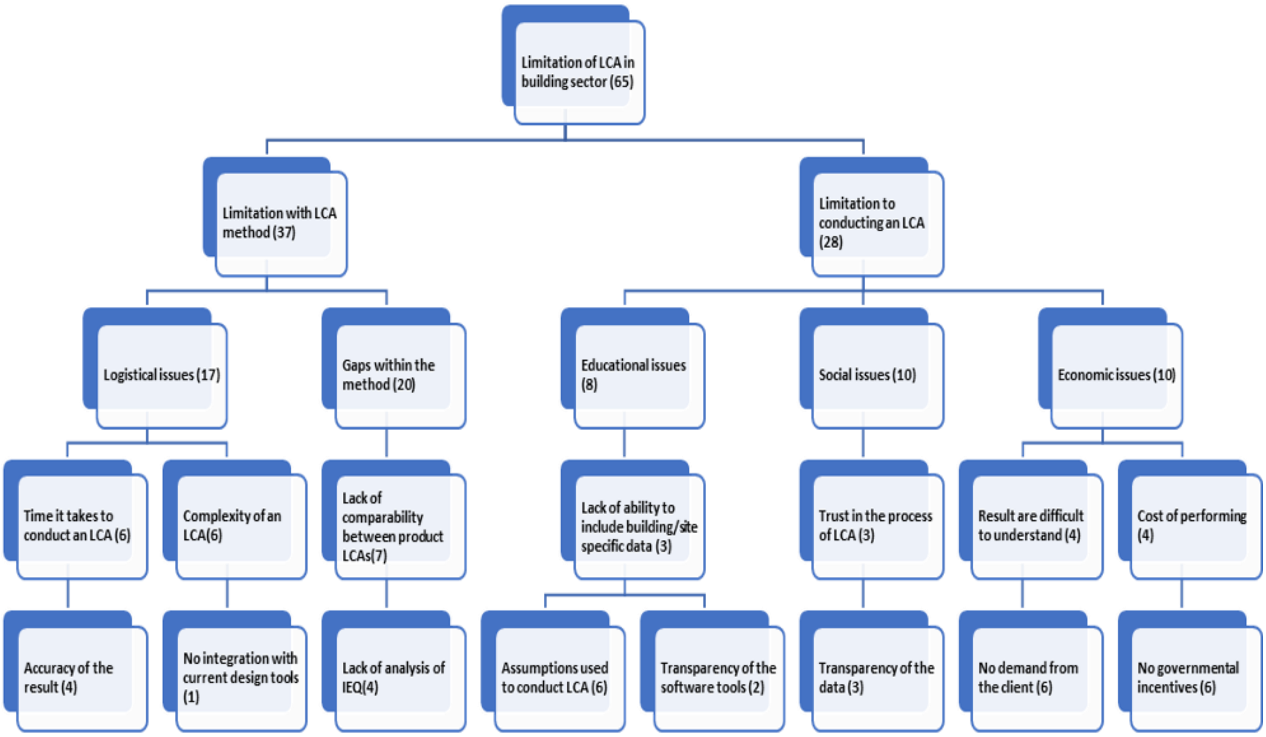

Fig. 4. Limitations to LCA in the Construction of Buildings

4. Energy modelling combine with LCA

Environmental scenario assessment is a quantitative and quantitative assessment of environmental impacts, taking into account greenhouse gas (GHG) emissions and other particulate matter that contribute to environmental impacts when modeling energy systems to evaluate it. Now let's talk about the challenges in conducting life cycle assessments. To get a wider echo you can do the following while energy systems are based on the life cycle of the system to capture the different environmental impacts of a particular mitigation strategy, particularly in the energy sector, some researchers use energy system models and life cycle analysis (LCA) approaches to be combined. This was a major advance in identifying the factors causing relevant environmental impacts. Grouping both approaches seem straightforward, but the methodological challenges and opportunities have not yet been fully explored. For example, both methods are described by different system boundaries. Furthermore, the relevance of certain assumptions to the realization of relationships has not been quantified and data uncertainties have not been tested. This can lead to uncertain results and less reliable results.

4. 1. Possibilities for coupling and description of assessment workflow

Implementation of LCA and energy modeling is supported by: Organization of inventory according to international standards (ISO 12006, national classification systems, etc.) [40] to support comparability when interpreting results. Hierarchically organize architectural components and subcomponents at specific levels of granularity that need to be considered more frequently. Link BIM components and quantities to corresponding LCA datasets and scenarios. A parametric approach to creating LCI from BIM and LCA models and adapting the model to other forms of constraints while supporting potential changes such as part material composition. Since there was no established workflow for directly linking energy models with LCA software such as SimaPro, a workflow with a table-based life cycle inventory was set up in Figure 5.

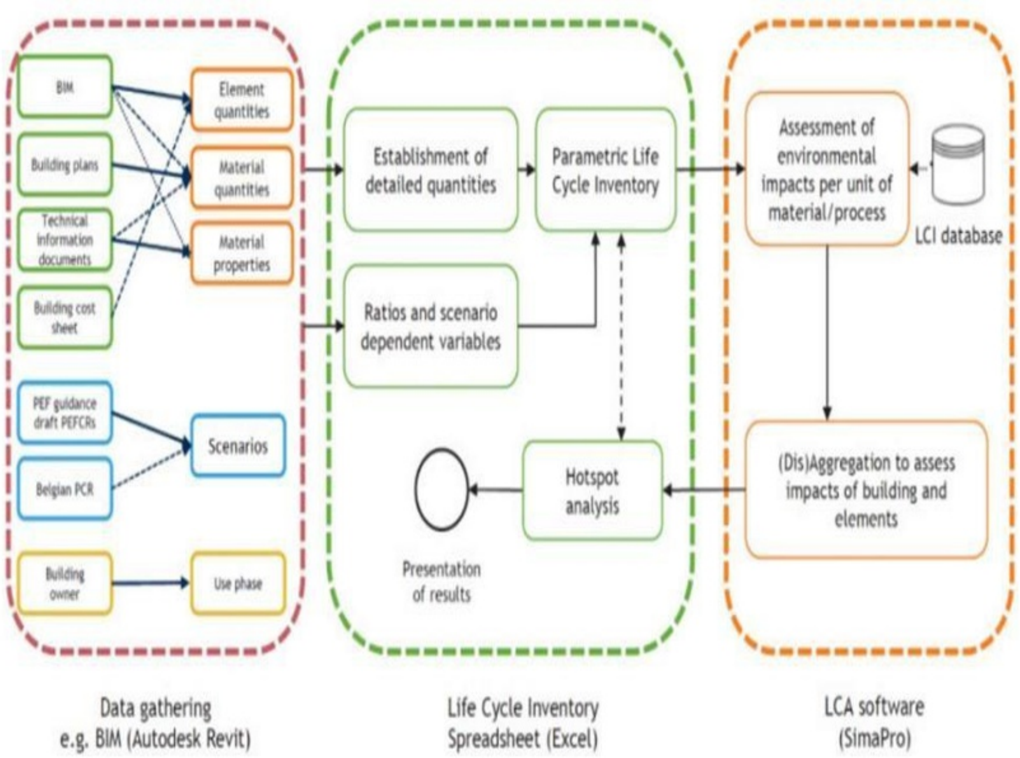

Fig. 5. Overview of Energy modeling-LCA workflow using different data sources and various tools in order to establish the LCI as well as access and analyze the building's environmental impact

4. 2. Energy modeling

To examine the contributions of different impact factors affecting the public building energy consumption and further evaluated the Energy savings in public buildings values during the 10th–12th Five-Year Plan (FYP) periods in China, an energy model of the baseline for each building under consideration was created in Design Builder software or by using a semi stationary code [41]. The obtained energy consumption results were fitted to the actual bill data following two methodologies: the established methodology of ASHRAE Guideline for dynamic models, the methodology introduced for semi-stationary models. For the first method, the parameters Mean Bias Error (MBE) and Coefficient of Variation of the Mean Square Error (CV(RMSE)) were computed to validate the energy model. The model is considered calibrated if the MBE is between 5 and the CV(RMSE) is between 15. Second methodology is based on the comparison between the annual energy consumptions of the building's generators and the simulated values: the model is adapted by modifying the input meteorological data, the internal heat gains, the system programming times and the temperature set points until the best match between the simulated and monitored values is reached. The operating energy consumption of the assumed configuration was simulated using a calibrated model and considering various retrofit options. Ecotect and Design Builder simulation results show a 15% difference in annual heating and cooling energy between the best and worst passive solar design strategies. The Design Builder results show that an overall energy savings of 21% over 10 years can be achieved cost-effectively compared to the base design.

4. 3. Building energy modeling (BIM) -LCA integration tools

After surveying US design and construction firms, Azhar and Brown [42] focus on a sustainability analysis program based on commonly used methodologies. BIM includes virtual environments from Autodesk Ecotect™, Autodesk Green Building Studio™, and Integrated Environmental Solutions®. They also reported in their evaluation that Virtual Environment™ was the most versatile and best performing program in terms of sustainability analysis skills. It is important to specify that Green Building Studio is deployed as an authority with Ecotect Analysis as the office part and Green Building Studio as the web part. In addition, Ecotect focuses on assessing building and environmental comfort conditions, including various specific types of energy analysis and global sustainability assessment tools. Inim et al. [43] developed her BIM software (SimulEICon) that makes it easier for users to select Gerber among other aspects of sustainability in the building design process. The researcher developed his EEPFD tool, which stands for Evaluative Energy Performance Feedback for Design. Conduct energy efficiency analysis in the early stages of design. Some of the most important research on tools for the full or partial integration of environmental data into his BIM references from a life cycle perspective are its availability, coverage and his LCA base in the early stages of design. Kuds Tushar et al. [44] used an integrated approach of BIM-based lifecycle assessment and energy simulation to optimize solutions for sustainability. BIM served as a platform to link the operational energy optimized by the @Risk optimizer to the resulting embedded phase. A comparative analysis of insulation performance found that using R3 instead of R6 in the Australian National Insulation Standard could reduce the total energy consumption of the ceiling in use by 95%. For walls, a 90% reduction in energy consumption can be achieved by choosing R2 instead of R4 to meet national heat standards. Studies show that insulation accounts for only 1% of a building's total mass, with corresponding carbon footprint and primary energy requirements of 4% and 7% respectively, yet LCA accounts for a significant portion of energy a reduction of about 76 % is up. In this study, an evidence-based analytical framework provides his BIM-driven optimization platform to validate and justify the impact categories of environmentally friendly and energy efficient residential design. Acedo N Haddad et al. [45] shows the application of specific environmental management tools based on Integrated Building Information Modeling (BIM) and Life Cycle Assessment (LCA) methods for selecting hot water systems in the early stages of building design. The proposed method will be implemented in the pre-operational phase to enable decision makers to assess the resulting environmental performance of hot water systems in buildings.

5. Conclusion

Decision makers are increasingly considering life cycle assessments as best practices for assessing the potential environmental impacts of products, goods and services. Most studies have been conducted in urban areas, whereas rural areas are underrepresented or rarely explored in the literature. The ISO 14000 series of standards provides a set of recognized principles for the LCA framework. Although LCA methodologies have come a long way and evolved with additional knowledge, there are still practice gaps in LCA practice that can lead to differences in LCA results. The lack of impact indicator modeling and freely accessible life cycle inventories will be addressed through continuous research and tool improvement. To support a harmonized reporting approach for all relevant aspects to ensure transparent and reproducible LCA studies on materials, elements and buildings while respecting existing LCA and BIM standardization. Since LCA should also be applied during building design, the goal is to make the application time efficient and achieve dynamically comparable results at various levels throughout the design process.

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