Journal of Engineering, Management and Information Technology

Vol. 03, No. 01 (2025) 29-38, doi: doi:10.61552/JEMIT.2025.01.004 - http://jemit.aspur.rs

FROM WASTE TO WEALTH: CIRCULAR ECONOMY APPROACHES IN FACADE ENGINEERING

Arkar Htet [1]
Sui Reng Liana
Theingi Aung
Amiya Bhaumik
Om Prakash Giri

Received 08.01.2024.
Revised 10.03.2024.
Accepted 26.03.2024.

Keywords:

Circular Economy, Façade Engineering, Sustainable Construction, Material Recycling, Lifecycle Analysis.

Original research

A B S T R A C T

With resources dwindling and the environment deteriorating, the construction sector around the world is at a crossroads. Façade engineering becomes an important field for sustainable practices in this environment. In order to improve the sustainability and economic feasibility of building envelopes, this review paper delves into how Circular Economy (CE) principles might be applied to façade engineering. The focus is on material recycling, reuse, and lifespan analysis. The study finds and examines novel techniques and materials that demonstrate Circular Economy (CE) principles by critically reviewing literature and case studies on circular economy practices in building, with a special focus on façade materials. The paper demonstrates how the circular economy has the ability to make façade engineering more sustainable by examining the motivations, benefits, and obstacles linked with these activities. To achieve this transition, it is crucial to work together across disciplines, have the support of policymakers, and be open to technological innovation. The purpose of this essay is to promote a paradigm change towards more sustainable and resource-efficient design and construction processes by introducing Circular Economy (CE) principles to façade engineering. By bringing façade engineering in line with sustainable development concepts, this research hopes to alleviate construction waste, conserve resources, and lessen environmental impacts.

1. INTRODUCTION

The circular economy (CE) has become a key framework for promoting sustainability in different industries, particularly in the building industry. The construction sector, known for its high material consumption and waste production, is now being acknowledged as a crucial area for using Circular Economy principles to reduce environmental consequences. The circular economy promotes a systemic change in material usage patterns by focusing on maximising the value retained in products, materials, and resources for as long as possible through the principles of reduce, reuse, and recycle (Salleh et al., 2022). This method differs significantly from the linear model of 'take, make, dispose,' which has been the primary model in industrial operations for many years, resulting in substantial environmental harm and depletion of resources (Torgautov et al., 2021).

[1] Corresponding author: Arkar Htet
Email: arkarhtet@lincoln.edu.my, arkarhm@gmail.com,

CE principles have great potential when applied in the field of façade engineering. Facades are essential for the energy efficiency, visual appeal, and sustainability of buildings since they connect the constructed environment with its surroundings (Prieto Hoces, 2018). Yet, the lifecycle of facade materials, from extraction and processing to disposal, frequently reflects the inefficiencies and wastefulness of the linear economy. The significance of circular economy ideas for façade engineering is the capacity to convert this sector into a model of sustainability and creativity. By incorporating Circular Economy principles, façade engineering can play a key role in decreasing construction waste, improving material efficiency, and encouraging the reuse and recycling of materials, thereby making a substantial contribution to the sustainability of the built environment (Mercader-Moyano et al., 2021).

1.1 Objective

The fundamental aims of this review are threefold. To begin, we will look at how circular economy principles might be used to façade engineering, namely in the design, building, and end-of-life phases of façade systems. This investigation will look into sustainable material choices, design for disassembly, and options for material reuse and recycling. Second, identify the hurdles and limitations that now prevent the widespread application of CE principles in façade engineering, including as technical, economic, and regulatory obstacles. Finally, we will discuss the opportunities and benefits that a circular economy strategy may provide to the industry, such as reduced environmental impact, increased economic efficiency, and the promotion of innovation and sustainability in building design.

To achieve these goals, this review intends to provide a complete assessment of existing circular economy practices in façade engineering, as well as insights into future research, policy, and practice trends. By doing so, it hopes to contribute to the larger conversation about sustainability in the building sector and advocate the adoption of circular economy ideas as standard practice in façade engineering.

2. CIRCULAR ECONOMY: PRINCIPLES AND PRACTICES

2.1 Definition and Core Principles

A paradigm shifts from the old linear economic model, which follows a 'take-make-dispose' trajectory, to a regenerative strategy that emphasises sustainability and the effective use of resources is represented by the circular economy (CE). This shift is a paradigm shift. According to Aleksić et al., (2023), the essence of circular economy (CE) is the elimination of waste and pollution via design, the maintenance of products and materials in use, and the regeneration of natural systems. These key concepts are encompassed in the three core principles of reducing, reusing, and recycling. According to Kioupis et al., (2020), the purpose of these principles is to develop closed-loop systems that reduce waste by making continuous use of resources.

Reduce: This principle strives to reduce the number of resources that are used and the amount of waste that is produced during the production process. Optimising design for minimal material consumption and selecting materials with lower environmental footprints are two examples of what this term means in the context of building (Finger et al., 2021).

Reuse: Instead of throwing away products or resources, reuse involves making use of them in their original state. Reuse is an alternative to throwing things away. When it comes to the design of buildings, this may involve the utilisation of building components or materials in new constructions (Broniewicz et al., 2023).

Recycling: Recycling refers to the process of reclaiming material for the purpose of using it for a different purpose or purpose entirely. In the realm of construction, it refers to the process of reusing building materials, such as transforming debris from demolition into aggregate for use in the production of fresh concrete (Rangel et al., 2019).

2.2 Application in Construction

Due to the fact that the construction industry is responsible for a sizeable portion of the world's resource consumption and waste production, the implementation of CE principles in this sector has become increasingly vital. According to the CE framework, sustainable construction entails the adoption of methods that cover the entirety of the lifecycle of buildings, beginning with the design and construction of the building and continuing through its operation and decommissioning (Charef et al., 2021).

A major component of the circular economy (CE) strategy is design for flexibility and disassembly, which enables buildings and their components to be changed to multiple uses or readily disassembled for reuse and recycling at the end of their life Bocken et al. (2016) present an additional strategy that involves the utilisation of sustainable materials.

This strategy entails the selection of materials that have diminished environmental impacts throughout their entire lifecycle, or that are capable of being recycled or biodegraded once they have served their purpose.

The notion of Building Information Modelling (BIM) also makes it easier to implement CE practices. This is because it enables the virtual modelling of buildings, which in turn optimises the utilisation of materials and makes it easier to manage buildings over their entire lifecycle (Cao et al., 2022). Furthermore, the industry has been investigating the possibility of utilising prefabricated components, which can be produced with a small amount of waste (Xue et al., 2017). These components can then be reused or remanufactured in the future.

In the construction industry, examples of circular economy have been seen in practice through the

utilisation of recycled materials in new structures, the design of buildings that are intended for deconstruction, and the implementation of modular construction techniques that allow for the reuse of components. According to Lehmann (2011), these techniques not only help to save resources and cut down on waste, but they also frequently result in economic benefits, such as the reduction of material waste and the development of new markets for environmentally friendly goods.
It is necessary to overcome substantial obstacles in order to make the transition to a circular economy in the construction industry. These obstacles include the linear economic incentives that are now widespread, the requirement for industry-wide standardisation, and the difficulties that are connected with changing existing habits. It is necessary for stakeholders across the value chain, from policymakers to practitioners, to work together in order to develop regulatory frameworks that are supportive of CE practices, to create market incentives for CE practices, and to cultivate a culture of innovation and sustainability within the industry (Abadi & Sammuneh, 2022).

3. CIRCULAR ECONOMY IN FAÇADE ENGINEERING

3.1 Material Selection and Design

A strategic approach to the selection of materials and the design of facades is the foundation upon which the incorporation of circular economy (CE) principles into facade engineering is built. The implementation of this strategy calls for a multi-faceted comprehension of the methods by which resources are obtained, processed, and utilized in order to guarantee a low impact on the environment and the greatest possible possibility for reuse and recycling. In order to choose sustainable materials, it is necessary to conduct a comprehensive analysis of their life cycle impacts, giving preference to those materials that have a lower embodied energy and a smaller carbon footprint. In order to minimize emissions caused by transportation, it is vital to take into account the origin of materials, with a preference for local sourcing. Additionally, it is necessary to evaluate the possibility of the materials' recovery at the end of their useful lives (Azcarate-Aguerre et al., 2022).
The modularity of a design is an extremely important factor. Modular facades make it possible to repair or upgrade specific components without having an effect on the complete system. This design concept makes it easier to do maintenance and recover materials, as well as extending the service life of facade elements (Torres et al., 2021). Flexibility in design also adds to circularity since flexible facades can be reconfigured for new applications or aesthetic preferences over time, hence decreasing the need for restorations that require a significant amount of resources (Htet et al., 2023).
A further enhancement of circularity can be achieved by the standardization of facade components. This ensures that components can be simply replaced, repaired, or improved, which in turn makes it easier to disassemble products and reuse resources. Additionally, this makes it possible to achieve economies of scale in the production of components, which has the potential to lower production costs and the environmental problems that are connected with them (Attia et al., 2018).
For optimal façade design in a Circular Economy context, it is crucial to include sophisticated sustainable materials like bio-based composites or recycled materials. These materials provide substantial reductions in environmental impact and are becoming more accessible and economically feasible (Icibaci, 2019).
In addition, the utilisation of life-cycle assessment (LCA) methods throughout the design phase can serve as a means of directing the selection of materials and design decisions by measuring the environmental impacts that occur from the cradle to the grave (Eberhardt et al., 2020).
Ultimately, incorporating concepts of sustainable design into facade engineering requires a holistic strategy that considers material selection, design, and the harmonization of environmental considerations with functionality and visual appeal. A paradigm shift is needed to change how materials are valued and handled over their entire existence. This change will encourage innovative design methods that focus on sustainability and resource efficiency.

3.2 Reuse and Recycling of Façade Materials

Reusing and recycling concepts play a key role in implementing the circular economy in façade engineering, reducing the environmental impact of construction techniques. Reuse, in this context, is using façade materials again without altering their form, which helps prolong the lifespan of resources and avoids the energy-intensive production of new materials. An instance of this is seen in the utilization of recycled wood, providing both visual appeal and ecological advantages. Responsibly obtained wood can serve as a low-carbon alternative to new materials and help in developing carbon-negative construction solutions (Akhimien et al., 2021).
Facade materials are recycled in a transformative manner, being repurposed into a new product. Metals and glass from façade systems can be recycled numerous times without a substantial loss in their qualities. Innovative recycling technologies have improved the purity and quality of recycled materials, enabling their use in higher-value new façade products (Asdrubali et al., 2015).
In the field of glass recycling, developments in sorting and processing technologies have led to a considerable rise in the recycling rates as well as the quality of recycled glass that may be utilized in facade engineering. According to Tamanna and Tuladhar (2020), this involves the utilization of optical sorting technologies

that are able to separate glass based on its color and chemical composition. This helps to guarantee that the recycled product is of a high enough quality to satisfy severe quality requirements.

The recycling process for metal has seen improvements in both its energy efficiency and its environmental performance as a result of the advent of furnaces and purifying processes that are more efficient that are more efficient. These developments not only lessen the carbon footprint that is linked with the materials used for metal facades, but they also help to save raw materials and lessen the industry's reliance on mining (Santero & Hendry, 2016).

On the other hand, it is very necessary to take into account the entirety of the lifecycle of facade materials in order to guarantee that the procedures of recycling and reuse do not become a source of environmental burden within itself. According to Gheewala (2023), lifecycle assessment (LCA) studies have been extremely helpful in determining the most environmentally friendly methods for the reuse and recycling of facade materials. These studies take into account a variety of elements, including transportation, processing energy, and the potential emissions that may end up being produced by recycling operations.

In conclusion, the reusing and recycling of facade materials are not only essential for lowering the demand for virgin resources, but they are also essential for limiting the impact that the construction sector has on the environment. The incorporation of these principles into facade engineering has the potential to make a substantial contribution to the development of a built environment that is more environmentally friendly.

3.3 Lifecycle Analysis (LCA)

In the field of facade engineering, lifecycle analysis (LCA) is an indispensable instrument that provides a systematic framework for quantifying environmental consequences across the entirety of a product's lifecycle, beginning with the acquisition of raw materials (often known as the "cradle") and ending with the "grave" of the product's existence. This all-encompassing method makes it possible to identify and evaluate the environmental impacts that a facade may have during the phases of material extraction, production, shipping, installation, usage, and maintenance, as well as the phases of eventual disposal or recycling (ISO 14040, 2006).

It is possible for engineers to compare the environmental implications of different materials and design decisions with the assistance of life cycle assessment (LCA) when applied to facade materials. For instance, the environmental cost of utilizing virgin aluminum as opposed to recycled aluminum for curtain wall systems can be fully recognized through life cycle assessment (LCA), which can measure consequences such as emissions of greenhouse gases, energy consumption, and trash generation (Ding, 2020).

The transportation phase of the life cycle assessment (LCA) takes into account not only the distance that materials travel but also the mode of transportation, which can have a variety of different environmental footprints. For instance, depending on the distance traveled and the effectiveness of the mode of transportation, transporting products by water may have a smaller carbon footprint than transporting them by road (Meex et al., 2018).

The life cycle assessment (LCA) investigates not only the phases of installation and maintenance, but also the energy that was consumed during the construction phase and the effects that maintenance operations had on the structure over its lifetime. For instance, a facade system that needs to be painted or sealed on a regular basis has a different environmental profile than one that does not require any care (Keles & Yazicioglu, 2021).

LCA is used to analyze the potential benefits and downsides of various disposal strategies, such as recycling versus landfilling, when the product has reached the end of its useful life. This specific feature is of utmost significance for facade systems, which, by the time a building reaches the end of its lifespan, can be rather large in terms of both volume and varied material composition. According to Singh et al. (2021), this study evaluates the viability of recycling processes as well as the environmental cost-benefit analysis of these processes. It takes into account the amount of energy that is required for the reprocessing of materials and the quality of the recycled materials.

In general, life cycle assessment (LCA) gives facade engineers a data-driven basis when it comes to making decisions that are ecologically responsible, which helps facilitate the transition towards more sustainable facade systems. In addition to contributing to the development of facades that are not only visually beautiful but also environmentally responsible, it highlights the significance of taking into account the long-term environmental implications that are associated with the design and selection of materials for facades.

4. CASE STUDIES AND PRACTICES

4.1 Innovative Examples

The ideas of the circular economy (CE) are gradually being included into facade engineering, and various projects all across the world are serving as benchmarks for this process. The use of recycled glass in facade panels is a good example of this type of application. The BVLGARI Store in Shanghai is a noteworthy initiative in this field. The front of the store is comprised of panels that are manufactured from reused glass bottles. This not only helps to minimize waste but also provides distinctive aesthetic features (Living Spaces, 2023). An additional example of innovative design is the use of green walls as living facades. These walls are not only environmentally friendly but also contribute to the preservation of urban biodiversity and the regulation of energy temperatures. Jean et al. (2014) describes the One Central Park skyscraper in Sydney as a pioneer in this field. The structure features the world's highest vertical garden, which contributes to the building's thermal performance and urban ecology.

Figure 1: The BVLGARI Store in Shanghai
*(**Source:** Living Spaces, 2023, https://livinspaces.net)*

4.2 Comparative Assessment

Comparative analysis of these case studies indicates a wide range of outcomes, difficulties, and advantages with regard to the situation. The utilization of recycled glass panels at the BVLGARI Store in Shanghai is evidence of a successful reduction in the accumulation of material waste and the consumption of energy during the production process. Nevertheless, there were obstacles to overcome, such as assuring the structural integrity of the facade panels and locating reliable suppliers of recycled glass (Living Spaces, 2023). On the other hand, the living facade of One Central Park makes a substantial contribution to the building's energy efficiency as well as the well-being of the people who live there. Nevertheless, it confronts difficulties in terms of maintenance and the requirement for a specialized irrigation system (Jean et al., 2014).

Both of these situations highlight the significance of innovation in terms of materials and design in order to accomplish carbon emission goals. These findings also bring to light the necessity of a supportive infrastructure, which includes recycling facilities and maintenance standards, in order to meet the requirements of these unique facade systems during their entire duration. The benefits, on the other hand, are readily apparent in the reduction of the impact on the environment, the improvement of building performance, and the promotion of urban sustainability (Kibert, 2016).

Figure 2: The One Central Park skyscraper in Sydney
*(**Source:** Archi daily, 2014, https://www.archdaily.com/551329/one-central-park-jean-nouvel-patrick-blanc)*

5. CHALLENGES AND OPPORTUNITIES

5.1 Barriers to Implementation

The incorporation of circular economy (CE) ideas into facade engineering is confronted with a number of obstacles that have the potential to prohibit its broad adoption. It is common for economic feasibility to be the primary issue, given that initial investments for environmentally friendly materials and design processes may be costlier in comparison to more conventional alternatives. While the return on investment has the potential to be substantial, it may be long-term, which presents a problem for stakeholders who are hoping for rapid results (Rizos et al., 2016).

Regulatory difficulties are another big obstacle that must be overcome. According to Kirchherr et al. (2017), the predominant purpose of the existing legal frameworks is to give support for linear economic models. It is possible that these frameworks do not offer sufficient incentives or mandates for CE practices. Consequently, organizations and professionals who are interested in using circular techniques in facade engineering may find themselves in a position where they lack clarification and support.

The readiness of the industry is still another significant impediment. Historically, the construction industry has been known for its conservatism; therefore, the implementation of new techniques necessitates the modification of long-standing mentalities and procedures. The adoption of novel approaches that have not yet been demonstrated to be effective on a big scale or that do not have widespread industry backing is frequently greeted with opposition (Nandha Gopan & Balaji, 2023).

5.2 Enabling Factors

There are a number of enabling variables that might make the implementation of CE standards in facade engineering easier, notwithstanding the challenges that are there. Innovation in technology is essential, as developments in materials science and design software are making environmentally responsible practices more accessible and efficient. As an illustration, the creation of novel materials that are either highly recyclable or biodegradable might result in the provision of more possibilities for the construction of facades (Braungart & McDonough, 2013).

For the purpose of fostering a climate in which CE ideals can flourish, policy support is absolutely necessary. Incentives for environmentally responsible practices in the form of tax breaks or subsidies, as well as legislation that require recycling and reuse, are examples of what can fall under this category. According to Geissdoerfer et al. (2017), policies that incentivize or mandate the utilization of life-cycle assessment in the design of buildings have the potential to also propel the implementation of CE.

Facilitating collaboration among stakeholders has the potential to greatly speed up the transition to a circular economy for facade engineering. Collaboration may take the form of partnerships between the private sector and academic institutions in order to progress research. Additionally, it may involve involvement with legislators in order to develop legislative frameworks that are conducive to work. In addition, public-private collaborations have the potential to encourage innovation and provide evidence that CE practices are viable (Webster, 2017).

6. FUTURE DIRECTIONS IN CIRCULAR ECONOMY AND FAÇADE ENGINEERING

6.1 Technological Innovations

Considering the setting of a circular economy, the future of facade engineering is inextricably linked to the advancement of technology advancements. Emerging technology, such as sophisticated modular construction methods, make it possible to create, disassemble, and reuse facades in a more efficient manner. The development of intelligent materials that are capable of self-healing or adapting to changes in the surrounding environment is also on the horizon. These materials have the potential to extend the lifecycle of facades and reduce the amount of maintenance and repairs that need a significant amount of resources. Furthermore, developments in digital technologies such as Building Information Modeling (BIM) are expected to improve the precision of design and the utilization of materials, which will in turn provide improved waste management and recycling procedures (Eastman et al., 2011).

6.2 Policy and Regulatory Frameworks

Within the realm of the construction sector, the future of circular economy activities is significantly influenced by the policies and laws that are in place. According to Iyer-Raniga and Huovila (2022), the implementation of more stringent construction rules and standards that necessitate the incorporation of circular principles that are incorporated into new designs has the potential to result in a more sustainable sector. There is the potential for stakeholders to be incentivized to adhere to circular economy practices through the implementation of a certification system for circular facade designs. Additionally, the application of government incentives for research and development in environmentally friendly materials and construction methods has the potential to stimulate innovation within the sector.

6.3 Industry Implications

The transition to a circular economy in façade engineering has significant ramifications for the sector as a whole. It requires professionals to integrate sustainability and resource efficiency into all stages of their work, prompting a reassessment of present procedures. Educational curricula for architects and engineers should be revised to provide thorough instruction on circular economy principles and practices. Research should focus on investigating the enduring effects of circular building exteriors, evaluating the overall costs and advantages over time to guide upcoming architectural ideas (McDonough, W., & Braungart, M., 2002).

7. CONCLUSIONS

This review thoroughly examined how circular economy (CE) principles are integrated into façade engineering, uncovering important findings. The significance of choosing sustainable materials and design has been emphasized, demonstrated through unique case studies that have implemented circular economy ideas. The analysis emphasized the need of reusing and recycling façade materials and the essential function of lifecycle analysis in assessing environmental effect. The assessment has found significant obstacles such as economic, regulatory, and industry preparedness issues, despite the proven advantages. However, the discussion has also addressed the possibilities of new technologies and emphasized the important role of policy and regulation in promoting circular economy practices, indicating a strong future for the business.

8. RECOMMENDATIONS FOR PRACTICE AND POLICY

To integrate CE principles into façade engineering effectively, a multi-faceted approach is recommended:

8.1 Recommendation for practice

Integration into Design: It is important to encourage the incorporation of CE principles throughout the early stages of design. This will ensure that the choices of materials and the architecture of facades are intrinsically sustainable.

Training and Education: It is important to make investments in the education and ongoing training of engineers and architects so that they are equipped with the information and tools necessary to include community engagement into their profession.

8.2 Recommendation for policy

Incentive Structures: Projects that demonstrate a commitment to the principles of CE should be eligible for incentive structures such as tax incentives and subsidies.

Regulatory Standards: In the field of facade engineering, it is necessary to develop and implement regulatory standards that mandate the utilization of environmentally friendly materials and designs.

8.3 Call to Action

Innovation, collaboration, and a persistent commitment to the circular economy are the three pillars that will pave the road for a sustainable future in the field of construction facade engineering. In order to develop the concepts of CE, it is absolutely necessary for stakeholders from all different walks of life, including politicians, practitioners, academics, and industry leaders, to collaborate and work together simultaneously. It is necessary to do ongoing research into new materials and processes, to continuously innovate in order to overcome existing obstacles, and to collaborate throughout the industry in order to exchange information and best practices. These efforts, when combined, have the potential to stimulate a shift toward an industry that is more environmentally friendly, resource-efficient, and commercially viable in the field of facade engineering.

Acknowledgement: The findings presented are supported by thorough examinations and fundamental studies from the academic and professional communities, for which the academic community is acknowledged. A special appreciation goes out to the committed participants in the peer-review process whose critical assessments have substantially improved the work's substance. Acknowledgment is also given to the larger network of supporters, such as mentors and co-workers, who offered steadfast support and priceless discussions that helped to define the course of this study. Their combined knowledge and support were invaluable in bringing this project to completion.

References:

Abadi, M., Moore, D., & Sammuneh, M. A. (2022). A framework of indicators to measure project circularity in construction circular economy. *Proceedings of the Institution of Civil Engineers - Management, Procurement and Law, 175(2),* 54-66. DOI:10.1680/jmapl.21.00020.

Akhimien, N., Latif, E., & Hou, S. (2021). Application of circular economy principles in buildings: a systematic review. *Journal of Building Engineering, 38*, 102041. DOI:10.1016/j.jobe.2020.102041 .

Aleksić, A., Jovanović-Vujatović, M., & Veselinović, N. (2023). Sustainability and product life cycle in circular economy. *Economics of Sustainable Development, 7(1)*, 29-38. DOI:10.5937/esd2301029a.

Asdrubali, F., D'Alessandro, F., & Schiavoni, S. (2015). A review of unconventional sustainable building insulation materials. *Sustainable Materials and Technologies, 4*, 1-17. DOI:10.1016/j.susmat.2015.05.002.

Attia, S., Bilir, S., Safy, T., Struck, C. C., Loonen, R. R., & Goia, F. (2018). Current trends and future challenges in the performance assessment of adaptive façade systems. *Energy and Buildings, 179*, 165-182. DOI:10.1016/j.enbuild.2018.09.017.

Azcarate-Aguerre, J. F., Klein, T., Konstantinou, T., & Veerman, M. (2022). Facades-as-a-service: the role of technology in the circular servitisation of the building envelope. *Applied Sciences, 12(3)*, 1267. DOI:10.3390/app12031267.

Bocken, N., Pauw, I. d., Bakker, C., & Grinten, B. v. d. (2016). Product design and business model strategies for a circular economy. *Journal of Industrial and Production Engineering, 33(5),* 308-320. DOI:10.1080/21681015.2016.1172124.

Braungart & McDonough. (2013). *The Upcycle: Beyond Sustainability- Designing for Abundance.* North Point Press.

Broniewicz, E., Broniewicz, M., Skubiak, B., Bryliński, A., & Grabowska, P. (2023). Adaptive reuse of buildings. *Ekonomia I Środowisko - Economics and Environment, 83(4),* 338-357. DOI:10.34659/eis.2022.83.4.575.

Cao, Y., Kamaruzzaman, S. N., & Aziz, N. M. (2022). Building information modeling (bim) capabilities in the operation and maintenance phase of green buildings: a systematic review. *Buildings, 12(6),* 830. https://doi.org/10.3390/buildings12060830.

Charef, R., Morel, J., & Rakhshan, K. (2021). Barriers to implementing the circular economy in the construction industry: a critical review. *Sustainability, 13(23)*, 12989. DOI:10.3390/su132312989.
Ding, G. (2020). Lifecycle assessment of building materials – a cradle-to-gate approach. *Encyclopedia of Renewable and Sustainable Materials*, 476-488. DOI:10.1016/b978-0-12-803581-8.10542-9.
Eastman, C., Teicholz, P., Sacks, R. & Liston, K. (2011). *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers, and Contractors.* Hoboken: John Wiley & Sons.
Eberhardt, L. C. M., Stijn, A. v., Rasmussen, F. N., Birkved, M., & Birgisdóttir, H. (2020). Development of a life cycle assessment allocation approach for circular economy in the built environment. *Sustainability, 12(22)*, 9579. DOI:10.3390/su12229579.
Finger, D. C., Sævarsdóttir, G., Svavarsson, H. G., Björnsdóttir, B., Arason, S., & Böhme, L. (2021). Improved value generation from residual resources in iceland: the first step towards a circular economy. *Circular Economy and Sustainability, 1(2)*, 525-543. DOI:10.1007/s43615-021-00010-7.
Geissdoerfer, M., Savaget, P., Bocken, N., & Hultink, E. J. (2017). The circular economy – a new sustainability paradigm? *Journal of Cleaner Production, 143*, 757-768. DOI:10.1016/j.jclepro.2016.12.048.
Gheewala, S. H. (2023). Material recycling in a circular economy—a systems view. *WIREs Energy and Environment, 13(1)*, 503. DOI:10.1002/wene.503.
Htet, A., Liana, S.R., Aung, T., & Bhaumik, A. (2023). Economic and Environmental Impact Analysis of Green Building Materials in Facade Engineering. *International Journal of Membrane Science and Technology, 10(2)*, 2805-2814. DOI: 10.15379/ijmst.v10i2.2973.
Icibaci, L. (2019). Re-use of Building Products in the Netherlands. *Architecture and the Built Environment, 9(2)*, 1-422. DOI:10.7480/abe.2019.2.3248.
ISO 14040. (2006). *Environmental management Life cycle assessment Principles and framework.* International Standard Organization.
Iyer-Raniga, U. & Huovila, P. . (2022). Mapping sustainability indicators for circular built environment in the global south. *IOP Conference Series: Earth and Environmental Science, 1101(6)*, 062033. DOI:10.1088/1755-1315/1101/6/062033 .
Jean, N., Principal, Ateliers, J.N., Bertram, B., & Partner. (2014). Case Study: One Central Park, Sydney. *Council on Tall Buildings and Urban Habitat, 4*, 11-18.
Keles, C. & Yazicioglu, F. (2021). Analyzing the environmental sustainability of primary schools' facades within the scope of life cycle assessment in turkey and recommendations for improvement. *Smart and Sustainable Built Environment, 12(2)*, 298-324. DOI:10.1108/sasbe-04-2021-0072.
Kibert, C. J. (2016). *Sustainable construction: green building design and delivery.* John Wiley & Sons.
Kioupis, D., Skaropoulou, A., Tsivilis, S., & Kakali, G. (2020). Valorization of brick and glass cdws for the development of geopolymers containing more than 80% of wastes. *Minerals, 10(8)*, 672. DOI:10.3390/min10080672.
Kirchherr, J., Reike, D., & Hekkert, M. P. (2017). Conceptualizing the circular economy: an analysis of 114 definitions. *Resources, Conservation & Recycling, 127*, 221-232. DOI:10.2139/ssrn.3037579.
Lehmann, S. (2011). Optimizing urban material flows and waste streams in urban development through principles of zero waste and sustainable consumption. *Sustainability, 3(1)*, 155-183. DOI:10.3390/su3010155.
Living Spaces. (2023, October 13). *Living Spaces*. From www.livinspaces.net: https://livinspaces.net/ls-tv/inspired-by-circular-design-mvrdv-deliver-a-stunning-facade-made-from-recycled-glass-bottles-for-the-bulgari-shanghai-store/
McDonough, W., & Braungart, M. (2002). *Cradle to Cradle: Remarking The Way We Make Things.* North Point Press.
Meex, E., Hollberg, A., Knapen, E., Hildebrand, L., & Verbeeck, G. (2018). Requirements for applying lca-based environmental impact assessment tools in the early stages of building design. *Building and Environment, 133*, 228-236. DOI:10.1016/j.buildenv.2018.02.016.
Mercader-Moyano, P., Anaya-Durán, P., & Romero-Cortés, A. (2021). Eco-efficient ventilated facades based on circular economy for residential buildings as an improvement of energy conditions. *Energies, 14(21)*, 7266. DOI:10.3390/en14217266.
Nandha Gopan, S. & Balaji, M. (2023). Indian automotive supply chains: barriers to circular economy for sustainable development. *Management Decision, 61(11)*, 3589-3609. DOI:10.1108/md-03-2023-0435.
Prieto Hoces, A. (2018). Coolfacade. *Architecture and the Built Environment*, 2775. DOI:10.59490/abe.2018.29.2775.
Rangel, C. S., Filho, R. D. T., Amario, M., Pepe, M., Polisseni, G. d. C., & Andrade, G. P. d. (2019). Generalized quality control parameter for heterogenous recycled concrete aggregates: a pilot scale case study. *Journal of Cleaner Production, 208*, 589-601. DOI:10.1016/j.jclepro.2018.10.110.
Rizos, V., Behrens, A., Gaast, W. v. d., Hofman, E., Ιωάννου, A., Kafyeke, T., & Topi, C. (2016). Implementation of circular economy business models by small and medium-sized enterprises (SMEs): barriers and enablers. . *Sustainability, 8(11)*, 1212. DOI:10.3390/su8111212.
Salleh, H., Ying, C. K., Hanid, M., Abdul-Samad, Z., Sabli, N. A. M., & Khuzzan, S. M. S. (2022). Development of guidance for the adoption of circular economy in construction and demolition waste management. *Planning Malaysia, 20*, 1216. DOI:10.21837/pm.v20i24.1216.

Santero, N. J. & Hendry, J. (2016). Harmonization of LCA methodologies for the metal and mining industry. *The International Journal of Life Cycle Assessment, 21(11)*, 1543-1553. DOI:10.1007/s11367-015-1022-4.

Singh, J., Molinari, G., Bui, J. D., Soltani, B., Rajarathnam, G. P., & Abbas, A. (2021). Life cycle assessment of disposed and recycled end-of-life photovoltaic panels in Australia. *Sustainability, 13(19)*, 11025. DOI:10.3390/su131911025.

Tamanna, N. & Tuladhar, R. (2020). Sustainable use of recycled glass powder as cement replacement in concrete. *The Open Waste Management Journal, 13(1)*, 1-13. DOI:10.2174/1874347102013010001.

Torgautov, B., Zhanabayev, A., Tleuken, A., Türkyılmaz, A., Mustafa, M., & Karaca, F. (2021). Circular economy: challenges and opportunities in the construction sector of Kazakhstan. *Buildings, 11(11)*, 501. DOI:10.3390/buildings11110501.

Torres, J., Garay-Martinez, R., Oregi, X., Torrens-Galdiz, J. I., Uriarte-Arrien, A., Pracucci, A., & Angel, M. (2021). Plug and play modular façade construction system for renovation for residential buildings. *Buildings, 11(9)*, 419. DOI:10.3390/buildings11090419.

Webster, K. (2017). *The Circular Economy: A Wealth of Flows.* Ellen MacArthur Foundation Publishing.

Xue, H., Zhang, S., Su, Y., & Wu, Z. (2017). Factors affecting the capital cost of prefabrication—a case study of China. *Sustainability, 9(9)*, 1512. DOI:10.3390/su9091512.

Arkar Htet
Faculty of Business and Accounting,
Myanmar
arkarhtet@lincoln.edu.my,
arkarhm@gmail.com
ORCID 0000-0003-1301-3604

Sui Reng Liana
Faculty of Business and Accounting,
Myanmar
Williamrsim2017@gmail.com
ORCID 0000-0001-6053-6120

Theingi Aung
Faculty of Business and Accounting,
Myanmar
htetmyatarkarcoltd@gmail.com
ORCID 0009-0003-5063-575X

Amiya Bhaumik
Faculty of Business and Accounting,
Malaysia
amiya@lincoln.edu.my,
ORCID 0000-0002-9188-2269

Om Prakash Giri
Faculty of Science and Technology,
Nepal
Omgi5@pu.edu.np
ORCID 0000-0003-4799-3129