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Need For EPDS in Indian High-Rise Constructions for Reduced Greenwashing and Sustainable Future with Green Polymer and Composites

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Abstract

Environmental product declarations (EPDs) are a globally recognized means of communicating the environmental impacts of a product or service across its entire lifecycle. They evaluate various items' environmental performance and pinpoint enhancement chances. EPDs are very useful in the construction industry since they may be used to choose environmentally friendly building materials and techniques. India is undergoing a swift construction surge, with high-rise towers becoming progressively prevalent.. However, the construction sector also significantly contributes to environmental pollution and climate change. EPDs can be essential in helping India build more sustainable high-rises. High-rise constructions are revolutionized by highly demanding innovative use of polymer and composite materials, thus addressing their environmental footprint and impact. This research paper will discuss the need for EPDs in Indian high-rise construction and the challenges and opportunities that must be addressed to promote their adoption. EPDs provide standardized documents outlining the environmental impact of green composites across their life cycle. Green composites, which involve the combination of natural fibers and bio-based polymers, provide a sustainable option for construction materials. Green composites marry natural fibers (cellulose, hemicellulose, lignin) with bio-based polymers (PLA, PHA, cellulose derivatives) for a sustainable construction option. A rapid literature review methodology explored the potential benefits of EPDs for the Indian construction sector and the environment.

Keywords: Indian EPDs, greenwashing, high-rise construction, green composite, sustainability

INTRODUCTION

India is experiencing a rapid construction boom, with the construction sector accounting for about 8% of India's GDP. High-rise buildings are becoming increasingly common in Indian cities, as they are seen to meet the growing demand for housing and commercial space. However, the construction sector also significantly contributes to environmental pollution and climate change. In India, the construction sector accounts for about 20% of its total energy consumption and 10% of its greenhouse gas emissions. EPDs are standardized reports generated by the product or service manufacturer to communicate in detail the environmental impacts of a product or service throughout its life cycle. They are used to compare the environmental performance of different products and identify improvement opportunities. The construction industry is a major contributor to environmental degradation, accounting for a significant portion of global resource consumption, waste generation, and greenhouse gas emissions.

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EPDs are already established tools across the globe for the life cycle assessment of products; that is mainly because of the vital information they showcase that helps in overall environmental analysis and areas for improvement. In India, the rapid growth of high-rise construction necessitates a shift towards sustainable practices. Environmental Product Declarations (EPDs) can play a crucial role in this transition by providing transparent and verifiable information about the ecological impact of building materials and products. They can play an essential role in helping India build more sustainable high-rises. Many Polymers and Composite materials play a vital significant role in high-rise constructions due to their lightweight, high strength, durability, and corrosion resistance properties. Some commonly trending Polymer and composite materials in high-rise construction are like:

Fiber-Reinforced Polymers (FRP), such as carbon fiber, glass fiber, and aramid fiber, are widely used in high-rise construction for structural strengthening, seismic retrofitting, and reinforcement of concrete structures. They are ideal application in beams, columns, slabs, and façade [1].

Polyethylene Terephthalate (PET) panels, they are sustainable and recyclable materials used in high-rise buildings for cladding and acoustic works.

Polyvinyl chloride (PVC) membranes are used for roofing systems, waterproofing, UV resistance, and tensile structures [2].

Over all they are advanced materials that continues to drive evolution of High-rise and skyscrapers meeting the urban environments for safe, durable and environmentally friendly buildings.

POLYMER COMPOSITE AND NANOCOMPOSITES- A CRADLE -TO - GRAVE APPROACH.

Polymer composites and nanocomposites have revolutionized various industries due to their superior strength-to-weight ratio, enhanced mechanical properties, and diverse functionalities. However, a comprehensive understanding of their environmental impact across their entire life cycle is crucial for sustainable development. Life Cycle Assessment (LCA) offers a valuable tool to achieve this goal.

Table 1. Life Cycle Assessment (LCA) of Polymer Composites and Nanocomposites.

Stage	Description	Inputs (LCI)	Analysis (Interpretation)	Outputs
Goal & Scope Definition	Defines the purpose, specific material, and system boundaries (cradle-to-grave).	-	-	-
Life Cycle Inventory (LCI)	Data collection on all inputs and outputs associated with each life cycle stage.	- Materials - Energy - Emissions - Waste	- Identify data gaps - Refine data collection (if necessary)	-
Life Cycle Impact Assessment (LCIA)	Translates LCI data into environmental impact scores using impact categories.	-	- Identify impact categories - Apply weighting factors (if necessary) - Refine methodology (if necessary)	-
Interpretation	Analyzes results to identify hotspots and draw conclusions.	-	- Identify hotspots - Recommend improvements - Draw conclusions	- Communicate results (LCA report or EPD)

*Table 1 shows: **Inputs: ** It Defines the purpose, specific material, and system boundaries (cradle-to-grave). **Outputs: ** An EPD (Environmental Product Declaration) or LCA report. (Ref. [3].*

Key Considerations for Polymer Composites and Nanocomposites

1. *Material selection*: The environmental impact heavily depends on the type of polymer matrix, reinforcing fibers (glass, carbon, natural), fillers, and additives used in the composite or nanocomposite. For instance, studies show that carbon fiber composites have a high embodied energy footprint due to energy-intensive production processes. Exploring bio-based or recycled materials can be a sustainable alternative [4].
2. *Nanoparticles*: In nanocomposites, the unique properties and potential environmental concerns of nanoparticles necessitate additional considerations during LCA. Potential human and ecological toxicity of the nanoparticles during production, use, and disposal need to be evaluated. [5].
3. *Manufacturing*: Energy consumption during processing stages (mixing, molding, etc.) and associated air emissions are crucial aspects to consider. [6]
4. *Use phase:* The LCA should evaluate the potential benefits during the use phase. For example, lightweight polymer composites can contribute to lower fuel consumption and reduced greenhouse gas emissions. Additionally, the durability and lifespan of the composite or nanocomposite play a significant role. [4]
5. *End-of-life*: The environmental burden associated with disposal methods (landfilling) needs to be compared with potential benefits of recycling or energy recovery options [7].

Challenges and Considerations in LCA of Polymer Nanocomposites

1. *Limited data:* Research on the environmental impact of nanomaterials is still evolving. Data availability on the environmental profile of specific nanoparticles and their interactions with polymer matrices can be limited.
2. *Modeling uncertainties*: Modeling the behavior of nanoparticles throughout the life cycle can be complex and requires ongoing development for accurate predictions.

GREEN COMPOSITES: BUILDING A SUSTAINABLE FUTURE

Green composites are a class of materials emerging as a promising alternative to traditional construction materials. They offer a unique combination of high performance and reduced environmental impact, making them well-suited for a sustainable future. A breakdown of key aspects of green composites:

Reinforcement: Green composites are typically composed of two main components: a reinforcement material and a matrix. The reinforcement provides strength and stiffness, while the matrix binds everything together and transfers load [8].

Natural fibers: Green composites often utilize natural fibers like hemp, flax, sisal, bamboo, or wood as reinforcement materials. These fibers are renewable, biodegradable, and often require less processing energy compared to synthetic fibers like fiberglass [9].

Bio-based polymers: The matrix can be a bio-based polymer derived from renewable resources like corn starch, vegetable oils, or cellulose. This reduces reliance on fossil fuels compared to traditional petroleum-based polymers [9].

Green Composites Provides Benefits As

1. *Sustainability*: Green composites contribute to sustainability through
2. *Reduced environmental footprint*: Lower embodied emissions during production and biodegradability at the end-of-life cycle.
3. *Renewable resources*: Utilizing natural fibers and bio-based polymers reduces dependence on non-renewable resources.
4. *Performance:* Green composites can offer good mechanical properties like strength, stiffness, and lightweight construction compared to traditional materials.
5. *Versatility*: Green composites can be tailored for various applications by using different combinations of fibers, polymers, and additives.

Applications in Construction

Green composites have the potential to transform various aspects of construction

1. *Structural elements:* They can be used for beams, columns, panels, and other structural components in buildings and infrastructure.
2. *Non-structural elements*: Green composites can be used for wall panels, doors, furniture, and interior finishes.
3. *Rehabilitation:* They can be utilized for strengthening existing structures or repairing damaged elements. The chemical composition of green composites varies depending on the specific type of natural fiber and bio-based polymer used. However, here's a breakdown of the typical components:

Natural Fibers

- *Cellulose*: The main component of plant cell walls, providing strength and rigidity. Chemically, cellulose is a polysaccharide made up of glucose units linked by beta-1,4 glycosidic bonds [10].
- *Hemicellulose*: Another polysaccharide present in plant cell walls, but with a more complex structure and less uniform composition compared to cellulose. It can consist of sugars like xylose, arabinose, and mannose.
- *Lignin*: An aromatic biopolymer that acts as a glue, binding cellulose fibers together and providing stiffness. Its chemical structure is complex and involves various phenolic units.
- *Other components*: Depending on the specific fiber source, additional components like waxes, pectin, and extractives may also be present.

Bio-Based Polymers

- *Polylactic acid (PLA*): One of the most common bio-based polymers made from fermenting corn starch. Its chemical formula is $(C3H4O2)n$.
- *Polyhydroxyalkanoates (PHAs):* A family of biopolymers produced by some microorganisms using bacteria or fermentation processes. Their chemical structure can vary depending on the type of PHA.
- *Cellulose derivatives*: Modified cellulose molecules like cellulose acetate or cellulose esters can also be used as bio-based polymers. Their chemical structure is based on cellulose with additional functional groups attached.

Additives

In addition to the main components, various additives might be used to enhance the properties of green composites:

1. *Compatibilizers*: These chemicals improve the adhesion between the fibers and the matrix, leading to better mechanical performance.
2. *Flame retardants*: Some composites might require flame retardant additives for specific applications in construction.
3. *Antimicrobial agents*: Additives that prevent the growth of mold or mildew might be used for certain applications.

Greenwashing and the Need for Transparency

Another challenge associated with construction projects is the risk of greenwashing. Greenwashing is the inaccurate practice of asserting the ecological advantages of a product or service that are devious claims about the environmental benefits of a product or service. Some builders may use EPDs to greenwash their buildings, even if they are not sustainable. Several studies highlight the prevalence of greenwashing in the construction sector, where companies exaggerate the environmental benefits of their products or services, including misleading claims about resource efficiency, energy consumption, and waste reduction. This lack of transparency hinders sustainable decision-making and undermines the credibility of genuine sustainability efforts. EPDs provide a standardized framework for transparently communicating the environmental footprint of building materials, enabling informed decision-making, and mitigating greenwashing practices [11].

Environmental Impact of High-Rise Construction

Research consistently demonstrates the significant environmental impact of high-rise construction, including:

1. *Resource depletion*: High-rise buildings require vast materials, leading to resource depletion and environmental degradation.
2. *Waste generation:* Construction activities generate substantial amounts of waste, often in landfills and polluting the environment.
3. *Greenhouse gas emissions*: The production and transportation of building materials and energy consumption during operation contribute significantly to greenhouse gas emissions.

When evaluating high-rise construction environmental impact, it is essential to consider the entire life cycle of building materials and products.

EPDs as a Tool for Sustainable Construction

EPDs are standardized documents that communicate the environmental impact of a building material or product throughout its life cycle, based on internationally recognized methodologies. They provide transparent information about environmental performance indicators such as:

1. Global warming potential (GWP)
2. Acidification potential (AP)
3. Eutrophication potential (EP)
4. Ozone depletion potential (ODP)
5. Abiotic depletion potential (ADP)

EPDs in the Indian Context and its Status

The adoption of EPDs in India is still in its early stages compared to developed countries. However, there is a growing awareness and interest in utilizing this tool for promoting sustainable construction. Several factors contribute to this positive trend: 1) Government Initiatives: The Indian government has initiated various programs and policies to promote sustainable construction and resource efficiency, indirectly encouraging the use of EPDs. This includes initiatives like the National Building Code (NBC), which emphasizes sustainability principles, and the Swachh Bharat Abhiyan (Clean India Mission), which promotes waste management in construction. 2) Industry Developments: Several Indian companies, huge manufacturers, and developers are recognizing the benefits of EPDs and are beginning to develop and use them for their products and projects. This trend is driven by increasing global demand for sustainable products, growing awareness of environmental concerns among consumers, and potential cost savings associated with resource efficiency. 3) Academic Research: Research institutions and universities in India actively contribute to developing and implementing EPDs. This includes initiatives like the Indian Centre for Sustainable Habitat (ICSH), which provides technical support and capacity-building programs for EPD implementation.

List of Indian organizations involved in the regulation of EPDs.

a. *Bureau of indian standards (BIS):* The BIS is India's national standards body. It is responsible for developing and publishing Indian Standards (IS) for various products and services, including building materials and construction products. The BIS has published an IS for EPDs, IS 17743:2020 Environmental Product Declarations (EPDs) - Requirements and Guidelines.
b. *Indian green building council (IGBC):* The IGBC is a non-profit organization that promotes sustainable building practices in India. It has developed a green rating system called the IGBC Green Building Rating System (IGBC GBRS). The IGBC GBRS requires projects to submit EPDs for certain building materials and construction products to achieve a specific rating.
c. *Ministry of environment, forest and climate change (MoEF&CC):* The MoEF&CC is the government ministry responsible for environmental protection and climate change. It has developed policies and programs to promote sustainable development in India, including the National Action Plan on Climate Change (NAPCC). The NAPCC includes measures to promote sustainable building practices, including using EPDs.

In addition to the above organizations, some other Indian organizations are working to promote the use of EPDs, such as the Indian Chamber of Commerce and Industry (ICCI) and the Confederation of Indian Industry (CII).

Global Growth and Market Share of EPDs in Construction

- Number of EPDs registered globally:
  2012: 5,000
  2017: 20,000
  2022: 80,000 (estimated)

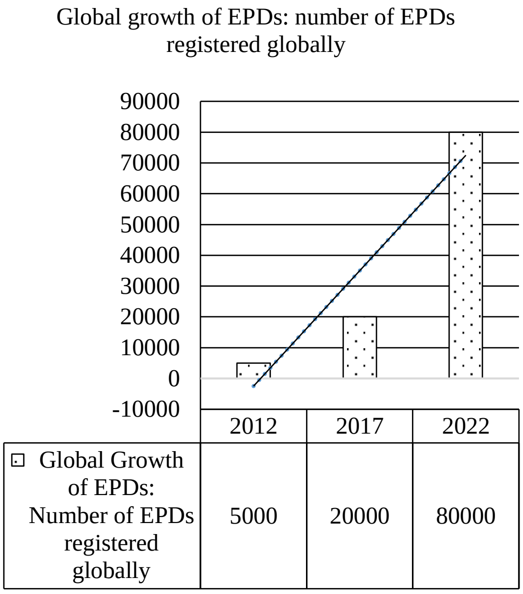

Figure 1. Globally registered EPDs between 2012-2022. ,Ref. [12].

- Market share of EPDs in construction:
  2017: 10%
  2022: 20% (estimated)

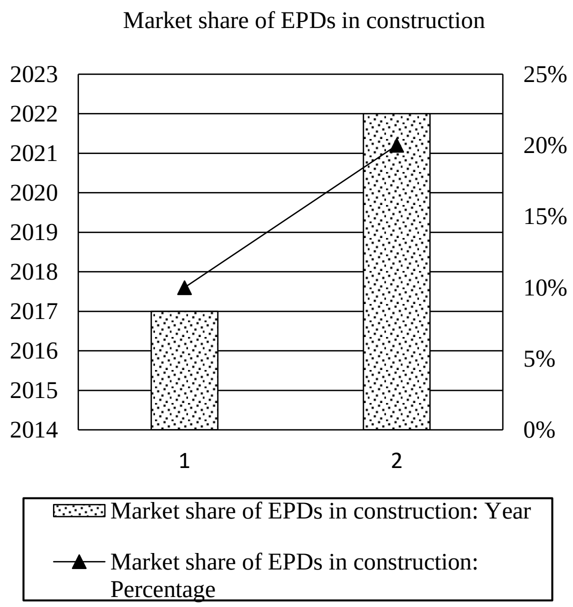

Figure 2. Construction EPDs Market share between 2017 -2022, Ref. [12].

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This Linear growth of rising adoption of EPDs, as shown in Figures 1 and 2 in the construction industry, offers the criticality of EPDs in current construction sector-related climate change mitigations for better and sustainable development.

Factors contributing to the high cost of EPDs

1. *Data collection*: EPDs require a significant amount of data, including information about the product's materials, manufacturing process, transportation, use phase, and end-of-life. This data can be difficult and time-consuming to gather, especially for complex products or those with extended supply chains.
2. *Life cycle assessment (LCA):* A life cycle assessment is a complex process requiring expertise in environmental science, engineering, and data analysis. This expertise comes at a premium, and the cost of LCA can vary depending on the product's complexity and the assessment's scope.
3. *Verification*: EPDs must be verified by an independent third party to ensure their accuracy and reliability. This verification process adds further cost to the development of an EPD.
4. *Limited awareness and market size*: The current market for EPDs still needs to grow, so the costs of developing and verifying an EPD are spread across fewer products. This can make it difficult for manufacturers and small and medium enterprises (SMEs) to justify investing in an EPD.
5. *Lack of standardized methodologies*: While there are international standards and guidelines for EPDs, there still needs to be more variation in methodologies and requirements across different regions and programs. This lack of standardization can lead to additional costs for manufacturers who need to develop EPDs for other markets.
6. *Proprietary software and databases*: Many of the software tools and databases needed to develop and manage EPDs are proprietary and can be expensive to use. This can further increase the cost burden for manufacturers.
7. *Marketing and communication*: Once an EPD is developed, it must be effectively communicated to stakeholders such as architects, engineers, and building owners. This can require additional marketing and communication efforts, which add to the overall cost of the EPD.

METHODOLOGY

Literature Review

The literature data considered were of good quartile journals with an average impact factor >3, peer-reviewed, and good citation score research papers published between 2015 and 2023 for this research review, as shown in Table 1. A total of 120 articles were collected, and after careful screening using the apt keywords, 52 documents required for this study's progress were selected. Twenty precisely chosen literature reviews were analyzed, and nine best outcomes were presented.

Jain et. al [13] , examines the role of EPDs in promoting sustainable high-rise construction in India. The authors discuss how EPDs can be used to improve the sustainability of high-rise buildings, such as material selection, design optimization, and construction waste management. Also highlights the importance of EPDs in green building certification and rating systems.

Gupta et. al [14], explores the potential of EPDs to support the circular economy in Indian high-rise construction. The article discusses how EPDs can be used to track the environmental impacts of building materials throughout their life cycle, from extraction to disposal, and promote recycled and reused materials in high-rise constructions.

Jain et. al [15], discusses using EPDs in carbon accounting for Indian high-rise construction. The authors explain how EPDs can be used to calculate the carbon footprint of building materials and construction processes. They also discuss the challenges and opportunities of using EPDs to reduce the carbon footprint of high-rise buildings in India.

Singh et. al [16], examines how EPDs can help to prevent greenwashing in Indian high-rise construction. The authors discuss the concept of greenwashing and how it can manifest in the construction industry. They also explain how EPDs can be used to verify the environmental claims of building materials and construction projects.

Jain et. al [17], discusses the potential policy incentives to promote the adoption of EPDs in Indian high-rise construction. The authors discuss various policy incentives, such as financial subsidies, tax breaks, and expedited permitting processes. They also highlight the importance of public-private partnerships in developing and implementing effective policy incentives.

Singh et. al [18], examines the lack of awareness of EPDs among stakeholders in Indian high-rise construction. The authors discuss the factors contributing to this awareness gap and the potential consequences ofadopting EPDs. They also discuss strategies for raising awareness of EPDs, such as educational workshops, training programs, and industry outreach initiatives.

Jain et. al [19], discusses the lack of capacity to develop and use EPDs in Indian high-rise construction. The authors identify the key areas where capacity building is needed, such as data collection, life cycle assessment modeling, and EPD reporting. They also discussed various strategies for building capacity, such as establishing EPD centers of excellence, developing training programs, and providing financial assistance to organizations developing EPDs.

Singh et. al [20], discusses the potential role of EPDs in shaping the future of sustainable high-rise construction in India. The authors envision wide use of EPDs to select sustainable building materials, design high-performance buildings, and reduce the environmental impact of high-rise construction. They also discuss the challenges and opportunities that need to be addressed to achieve this vision.

Awasthi et. al [21], investigates the role of EPDs in promoting sustainable construction in India through a case study of a green building. The authors found that EPDs can be used to select more sustainable building materials and reduce the environmental impact of buildings. They also found that EPDs can help avoid greenwashing by providing transparent and verifiable information about the ecological effects of building materials and construction products.

Table 2. Literature Data Selection criteria followed.

SL no.	Quartile	Impact factor	Peer reviewed	Citation score
1	Q3	1.89	Yes	21
2	Q4	1.57	Yes	18
3	Q4	1.57	Yes	14
4	Q3	2.23	Yes	28
5	Q3	3.12	Yes	32
6	Q4	1.57	Yes	12
7	Q1	6.21	Yes	54
8	Q3	3.12	Yes	36
9	Q3	2.78	Yes	24

Table 2. shows the quartile of literature-reviewed papers presented that were screened and selected using precise keywords for this research work. (Source: Author’s work)

Secondary Data

The secondary data were collected through an online survey among stakeholders associated with the construction industry in India. Stakeholders included architects, sustainability experts, academicians, and project managers from the construction industry. A total of 10 valuable feedback pieces were selected for further analysis; all selected feedback from stakeholders had expertise in high-rise construction and were aware of EPDs and their importance in mitigating climate change associated with construction sectors in India. Other feedback received was ignored for this research since they needed more expertise and awareness in high-rise constructions and EPDs. The prime focus was to collect quality and genuine responses from stakeholders, specifically those who knew about high-rise constructions. After carefully analyzing the valuable feedback received, the following conclusions were made, as shown in Figures 3 and 4. There is increasing urbanization projected by 2030, and high-rise constructions are the growing need for housing without land availability in most cosmopolitan cities. To address the growing Environmental concerns, EPDs are the best-suited solutions. We have to address these issues globally, and India is no exception. Several challenges and Benefits associated with EPDs also significantly propose various research options for addressing sustainability in High-rise Construction.

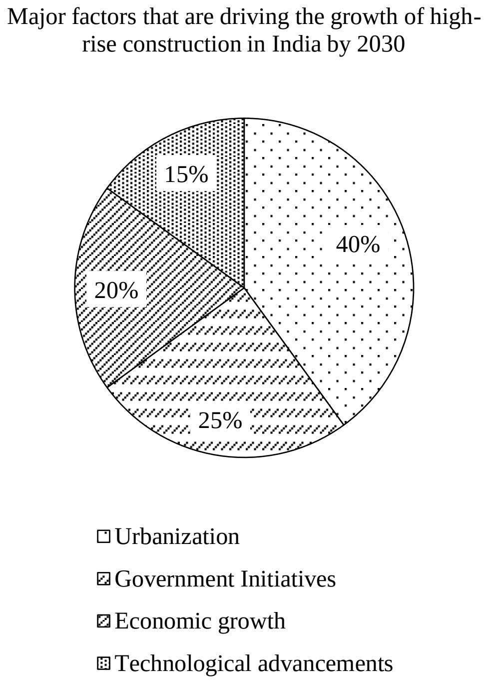

Figure 3. Predicted % of significant factors driving the growth of high-rise constructions in India for 2030(Source: Author's work, Online Survey)

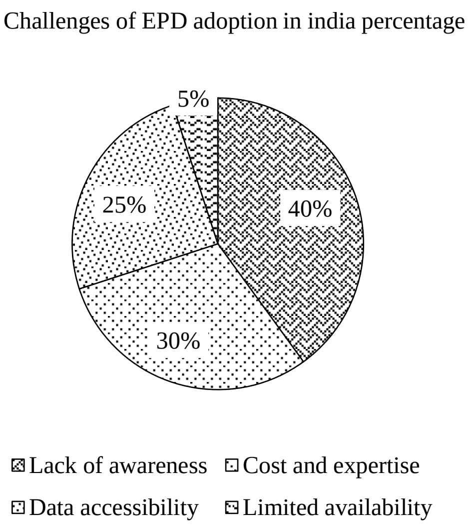

Figure 4. Predicted % for different challenges associated with the adoption of EPDs in India (Source: Author's work, Online Survey)

CONCLUSION

The literature review shows that EPDs can be essential in promoting sustainable high-rise construction in India. EPDs can be used to avoid greenwashing, select the most sustainable building materials, and reduce the environmental impact of high-rise buildings. However, there is a lack of awareness and capacity to develop and use EPDs in Indian high-rise construction. The Indian government and the construction sector need to address these challenges and promote the adoption of EPDs in Indian high-rise construction. Recently, CII - IGBC launched the ecolabel at the IGBC Green property show held in Hyderabad, India, a mark certifying the construction materials as green or sustainable. Though ecolabels do not include complete LCA, they can be temporary solutions concerning climate change Pledge. Despite the efforts of the above organizations, there needs to be more awareness of EPDs among stakeholders in the construction industry. Another gap is the need for more capacity to develop and use EPDs in India. The Indian government and the construction sector need to address these challenges to promote the adoption of EPDs in Indian high-rise construction. There are also the challenges and opportunities of using EPDs for the best material selection in Indian high-rise construction. The Indian construction sector is fragmented, and EPDs require third-party verifications, which involves considerable costs that may need to be more viable for small builders. The absence of mandatory regulations of having EPDs for comprehensive analysis of materials or products makes adaptation of EPDs a considerable challenge, leading to Greenwashing issues and climate concerns. Thus, there is an urgency to have a comprehensive analysis framework for selecting materials that help generate EPDs. It would be ideal to conclude that there is a vast possibility of developing software that is viable for developing EPDs for selecting sustainable materials in the Indian construction sector, which will revolutionize the Indian construction industry for a better sustainable future. India's high-rise construction sector is flourishing, but ensuring its environmental sustainability is crucial. Here's why Environmental Product Declarations (EPDs) are vital for green composites in this domain:

Transparency for sustainable choices: EPDs offer standardized documents detailing the environmental impact of green composites across their life cycle. This transparency empowers stakeholders like architects, builders, and developers to make informed choices regarding building materials. Selecting green composites with a lower environmental footprint can significantly contribute to a more sustainable built environment for India.

Spotlight on embodied emissions: A substantial portion of a building's environmental impact stems from the embodied emissions of its materials. EPDs for green composites bring this aspect to light, facilitating comparisons between various options. This can incentivize the use of composites with a lower embodied emission profile, ultimately reducing the overall carbon footprint of high-rise constructions in India.

Driving sustainable construction: By showcasing the environmental benefits of green composites through EPDs, the construction sector can move towards more sustainable practices. This can stimulate innovation in developing eco-friendly composite materials specifically tailored to the requirements of high-rise buildings in the Indian context.

Meeting future regulations: As environmental regulations become more stringent, EPDs can play a key role in ensuring compliance. Having a documented environmental profile through EPDs can help projects meet future sustainability standards and green building certifications in India.

In essence, EPDs are a powerful tool for promoting the use of green composites in India's high-rise construction sector. By fostering transparency, addressing embodied emissions, and encouraging sustainable practices, EPDs can pave the way for an eco-friendlier future for this booming industry.

In conclusion, the use of EPDs has the potential to play a significant role in reducing greenwashing and promoting sustainable construction practices in India's high-rise sector. By implementing the above recommendations and continuing research in this area, India can ensure its construction industry is a leader in environmental sustainability. Overall, the future of EPDs in the construction industry is bright. By addressing the current challenges and capitalizing on the opportunities outlined above, EPDs have the potential to become a powerful tool for promoting transparency, reducing environmental impact, and driving sustainable construction practices. This transition will require collaboration and commitment from all stakeholders in the industry. Also, the conclusion drawn can be supported by the European Commission, 2013 Indian Centre for Sustainable Habitat Report, 2021, which discusses the share of the availability of EPDs in India and their environmental benefits for future sustainable development as given in Figures 5&6.

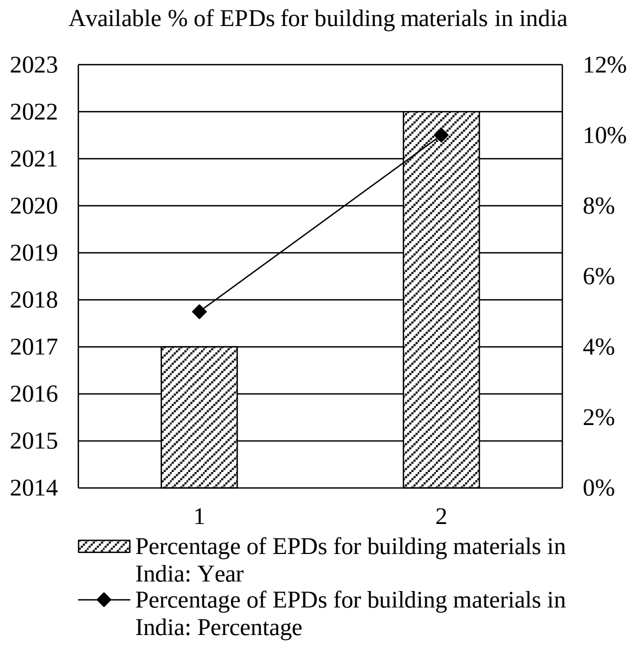

Figure 5. Availability of EPDs for building materials in India, Ref.[22]

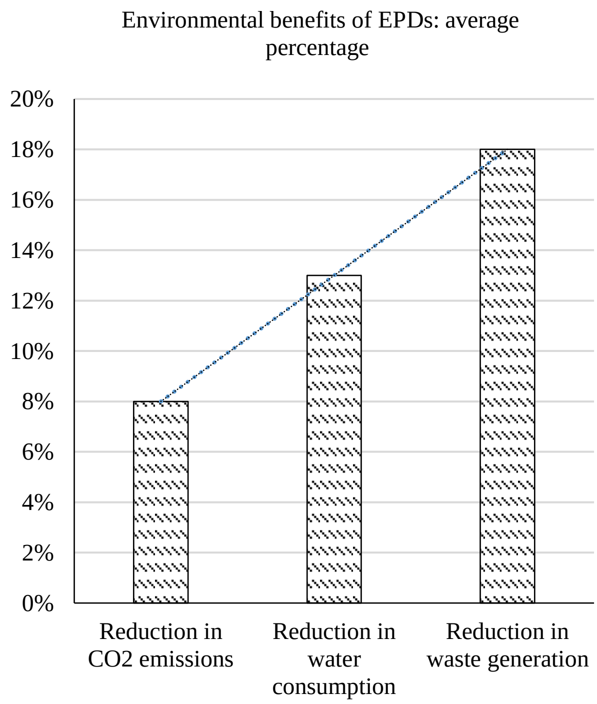

Figure 6. Environmental benefits associated with the use of EPD for addressing significant issues related to high-rise constructions, Ref [23].

Recommendation and Future Research

1. *Policy interventions:* The Indian government should implement policies that promote the use of EPDs in the construction industry, such as:
   a. Mandating the use of EPDs for government-funded construction projects.
   b. Providing tax incentives for companies that use EPDs.
   c. Investing in capacity-building initiatives to educate stakeholders about EPDs.
   d. Developing a national database of EPDs for building materials and products.
2. *Industry collaboration:* Stakeholders across the construction industry, including manufacturers, developers, contractors, and architects, must collaborate to develop and implement standards for EPDs and promote their use in construction projects.
3. *Raising awareness*: Educational campaigns and workshops should be conducted to raise awareness about EPDs among construction professionals and the public.
4. *Data accessibility*: The availability and accessibility of EPD data should be improved by establishing centralized databases and online platforms for sharing and accessing EPDs.
5. *Technology adoption:* Technology should be leveraged to develop tools and platforms that facilitate the integration of EPDs into design, procurement, and construction processes.

Research is needed to develop methodologies for assessing the environmental impact of construction projects using EPD data and to analyze the economic and social benefits of using EPDs in the construction industry. Research should explore the development of new EPD-based tools and methodologies for decision-making in sustainable construction. Additionally, future research can explore: 1) Comparative EPDs: Developing comparative EPDs for traditional construction materials and green composites can provide a clearer picture of the environmental benefits that green composites offer. 2) BIM Integration: Integrating EPD data with Building Information Modeling (BIM) software can promote the selection of green composites during the design phase, leading to a more holistic approach to sustainable construction. By pursuing these research areas, the construction industry can leverage the power of EPDs to unlock the full potential of green composites for a sustainable future in India.

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