

Elevating Industries: Unveiling Multifaceted Benefits of Green Infrastructure for Energy, Waste, Workspaces, and Employee Health

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Abstract

The industrial revolution brought about significant progress in the 21st century, with innovation and science advancing rapidly. However, it also resulted in industrial contamination. In response, the concept of green industry emerged, with economies striving for a more sustainable pathway of growth that includes environmentally responsible investments. Over time, industry owners have recognized the benefits of green buildings, which provide crucial improvements in areas such as energy, water, and waste management. As workers spend a significant portion of their day in their workplaces, it is important to keep these environments both environmentally friendly and aesthetically pleasing to promote worker health and productivity. The industry uses an enormous amount of energy, with significant energy loss occurring each year. Additionally, conventional industrial buildings often lack proper waste management, causing harm to the environment. This paper examines the scenario of green building technology in the industry, with a focus on its energy efficiency, waste management practices, and positive impacts on worker health and the working environment. The research methods used in this paper include a questionnaire survey, citation burst research, and an overall analysis of the current state of the industry. The paper provides a comprehensive understanding of industrial green building, highlighting its efficiency and positive impact on the environment while maintaining comfortable working conditions for employees. The readers of this paper will gain insights into the benefits of green building in the industrial sector and the importance of adopting this technology. It will also provide a better understanding of how the industry can achieve better workability and energy savings in the future. The adaptation of green building technology in the industry will help promote sustainability while ensuring healthy and productive working environments for workers.

Keywords: *Industrial insurgency, industrial contamination, UNIDO, energy-efficiency, occupants' health*

1. Introduction

Rapid development in industry in the 21st century has resulted in several scientific and technological breakthroughs. Along with these improvements, however, industrial activity has also led to pollution and destruction of the environment. The idea of green industry arose in response to these issues; it places an emphasis on ecologically responsible growth strategies. It is widely acknowledged that green buildings are an integral part of this sustainable strategy, since they may drastically enhance energy efficiency, waste management, and the quality of life for workers.

The industrial sector is a substantial annual energy loser due to its high energy use (Olubunmi et al., 2016). Traditional manufacturing facilities are notorious for their inefficiency and negative environmental impact because of inadequate energy management systems. Renewable energy sources like solar panels and wind turbines, passive design methods for natural ventilation and daylighting, and energy-efficient lighting systems with automated sensors are just a few examples of how green building technology may help cut down on energy use. These steps not only lessen demands on the power grid, but also decrease emissions of greenhouse gases and the use of nonrenewable energy sources.

Green buildings in the manufacturing industry are important because they reduce energy consumption and improve waste management. Without adequate waste management, the environmental effects of industrial activity may be devastating. Industrial facilities may considerably reduce waste creation, resource consumption, and greenhouse gas emissions by adopting waste reduction, recycling, composting, and waste-to-energy technologies. In addition to being in line with sustainability objectives, these methods help improve the productivity and environmental impact of manufacturing processes (Gan et al., 2020).

In addition, green buildings aim to provide a more positive work environment for its staff. Because people spend so much time at their industrial employment, it's essential to make sure they're healthy and happy there. Cleaner

air, more natural light, more comfortable temperatures, and more ergonomic layouts are all benefits of green buildings. These elements have been demonstrated to boost job satisfaction, cut down on absenteeism, increase productivity, and foster a pleasant office climate. Focusing on energy savings, waste management, the quality of the working environment, and the safety of employees, this study seeks to present a whole picture of the positive effects of green construction on the industrial sector. The paper will investigate the current state of green building technology in the industry through research methods like questionnaire surveys, citation burst analysis, and an overall industry analysis, and will highlight its efficiency and positive impact on the environment and the well-being of workers (Rastogi et al., 2017). This study's overarching goal is to encourage sustainability and create healthy, productive workplaces in the manufacturing sector by illuminating the significance of implementing green building principles.

2. Background investigation and research techniques

The idea of the application of green building technology in the industrial sector and its effects on efficiency of energy use, waste management procedures, and the well-being of employees, working environment are the main topics of the underlying research for this study. Significant advancements were made during the industrial revolution, but there was also industrial pollution. In response, the idea of "green industry" evolved, with the goals of sustainable development and investments that respect the environment (Leder et al., 2016). By enhancing energy, water, and waste management in factories, environmentally friendly structures have been acknowledged as a significant component in accomplishing these objectives. Citation Extensive research and a comprehensive analysis of the industry's status at the moment are part of the research approach used in this study. Finding highly cited and significant publications in the area of green building technology in the industrial sector is the goal of citation burst research. These articles provide insightful information and act as a basis for comprehension of the topic. To assemble pertinent data on green construction techniques in industrial sectors, an extensive assessment of the body of existing literature will be done. In order to comprehend the present state of knowledge and research gaps in the field, this will entail reviewing academic journals, conference proceedings, books, and reliable web sources. We'll conduct surveys and interview people to gather primary data. In order to gather data on energy consumption trends, waste management techniques, working environment conditions, and worker's health indicators, surveys will be given out to stakeholders in the industrial sector, including facility managers, staff members, and green building experts. In-depth insights and specific case studies relating to the implementation of green construction will be obtained through interviews with chosen participants.

This study intends to give a thorough knowledge of industrial green construction by applying these research techniques, with an emphasis on its energy efficiency, waste management strategies, and favorable effects on employee health and the working environment. The results of the study will help to emphasize the advantages of green construction in the industrial sector and the need of using this technology. The research also intends to provide light on the methods and techniques that businesses may use to improve their future energy efficiency and viability.

Readers will learn about the relevance of green building technology in the industrial sector and how it has the potential to advance sustainability while ensuring that employees have healthy and productive working conditions via this study.

3. Energy Savings

Energy saving is the most significant factor in the industry because it is used most in the industrial sector. More or less, everybody can realize it. We can't reduce it entirely cause it's part of our life, but we can create a chance for minimum usage of energy by green building. The key goal of green building is to execute the solutions for saving energy and taking advantage of using the same service with lesser energy use. Industrial energy use primarily in manufacturing, processing as well as in production (Zhang et al., 2018). Green buildings ensure effective use of water and energy that is a crucial component for the industry. Electricity is mainly needed in the industry, and for that, by using the solar panel, biomass plant etc. can be beside the power grid. Wind turbines have the ability to significantly enhance the industry's electrical power supply while also reducing the environmental consequences of generating electricity. Passive design can play a dominant role in saving energy. Window location, lighting, shape and texture, strategy and planning, and construction features are all considered in passive design that helps to save a significant amount of energy. Window and roof orientation are used in the industry sector for a better workplace for the workmen. The proper direction of the structure aids in the natural ventilation of fresh air and provides daylight (Eichholtz et al., 2013). Energy-efficient lighting solutions helps in the consumption of energy. Automatic sensors (motion sensors, lighting sensors) can be used for energy savings. Just like if the workers go into another room, the lights will automatically turn off. Proper maintenance can also play a role in saving energy. Normally the industry contains a lot of boilers, heavy pieces of machinery etc., by making proper automation in

machinery helps in on & off in scheduled time. The stormwater collection system helps to store and use a huge amount of water that is used for safe drinking without purifying, as well as for production that is an alternative to the electrical motor.

4. Waste Management

Waste management refers to the systematic handling, treatment, and disposal of waste materials in a manner that minimizes environmental impact and promotes sustainability. It involves various practices such as waste reduction, recycling, composting, energy recovery, and proper disposal (Lu et al., 2019). When it comes to the industrial sector, effective waste management practices can contribute to transforming buildings into green structures. According to the World Bank, industrial activities generate approximately 7.6 billion tons of waste globally each year. In the United States, the industrial sector generated about 7.6 million tons of hazardous waste and 238 million tons of non-hazardous waste in 2019, according to the Environmental Protection Agency (EPA). The amount of waste generation is not deniable. To solve these issues industrial recycling programs can make a significant difference in waste diversion. In the European Union, industries recycled about 53% of their waste in 2018, according to Eurostat. Recycling industrial waste can have a positive environmental impact. For instance, recycling one ton of paper can save around 17 trees, 7,000 gallons of water, and 380 gallons of oil, according to the Environmental Protection Agency (Zuo & Zhao, 2014).

Now the question comes to mind, how can we use waste to energy? Waste-to-energy technologies can help industrial facilities convert non-recyclable waste into renewable energy. According to the International Solid Waste Association (ISWA), waste-to-energy plants globally have the capacity to process over 380 million tons of waste annually, producing around 140 TWh of electricity. The use of waste-to-energy technologies can significantly reduce greenhouse gas emissions. ISWA estimates that for every ton of waste processed in a waste-to-energy plant, approximately one ton of CO₂ equivalent emissions is avoided. In the United States, the industrial sector generated approximately 9.3 million tons of organic waste in 2018, according to the EPA. Organic waste composting can reduce methane emissions, a potent greenhouse gas. According to the EPA, for every ton of food waste composted instead of landfilled, approximately 0.95 metric tons of CO₂ equivalent emissions are avoided. Industrial water usage varies significantly across sectors, but it is estimated that industries globally account for about 22% of total water withdrawal, according to the United Nations Industrial Development Organization (UNIDO). Industrial water recycling and reuse can significantly reduce freshwater consumption. The Global Water Intelligence estimates that industrial water reuse could increase by 37% between 2019 and 2023 (Lu et al., 2018). These statistics highlight the need for effective waste management in the industrial sector to promote green building practices. By implementing waste reduction, recycling, composting, and water management strategies, industrial facilities can minimize their environmental impact, conserve resources, and contribute to the development of a sustainable built environment.

5. Working environment

It has been proposed that the degree of familiarity with the IEQ (indoor environmental quality) of the workplace can affect the level of work performance. Employees that are happier with their physical working environment are more motivated and produce better work. Here is a survey outcome from Lansing, Michigan, where people were relocated from traditional office buildings to LEED-rated buildings to demonstrate the changes to the working environment. Table 1 Results from a paired test for employees moving from conventional to green office buildings: Sustainable built environment project, greater Lansing area, Michigan, 2008–2009. According to these results, any employee with a history of asthma or respiratory allergies might receive 1.75 extra work hours a year (i.e., 0.41 + 1.34), or 0.41 + 1.34 hours. Similar to this, workers who have a history of depression or stress may add 2.02 more hours of labor per year due to the decreases in their perceived work hours caused by these diseases. Last but not least, the increases in perceived productivity were sizable and may add an extra 38.98 hours of labor a year for each resident of a green building (Singh et al., 2010).

5.1. Workers Health

In the contemporary world, the building industry is growing. The importance of green building for sustainable development is on the rise. It not only promotes an environment of increased efficiency but also conserves energy. The requirements for this should raise some serious concerns. architectural design, access to natural light, thermal comfort of the structure, and air quality within.

Table 1. Indoor Environment Quality measure

Reasons	Outcome	Average Gains, Minimum	Total Benefit annually
Due to asthma and respiratory allergies	Absenteeism (n = 25)	decreased by 0.034 hours each month	Additional 0.41 work hours per occupant
	Work hours affected (n = 27)	decreased by 2.35 hours each month	Additional 1.34 work hours per occupant
Due to depression and stress productivity	Work hours affected (n = 34)	decreased by 2.86 hours each month	Additional 2.02 working hours per inhabitant
	Direct effect of IEQ (n = 86)	All occupants' productivity increased by 2.6%.	Extra 38.98 hours of work per occupier

5.2. Indoor Air Quality

The concept of "indoor air quality" (IAQ) clarifies the state of the air inside buildings and other structures, especially in relation to the inhabitants' well-being and enjoyment of their surroundings. People spend a large portion of their time inside, whether at home, at businesses, or in other enclosed areas, making it a vital component of environmental health. For human comfort, the indoor environment should be meet some targets. Particulate matter, volatile organic compounds (VOCs), carbon monoxide, radon, formaldehyde, cigarette smoke, biological pollutants, asbestos, and ozone are a few of the constituents that can negatively impact indoor air. These pollutants may come from a variety of things, including dust, product chemicals, combustion processes, construction materials, and human activity. Allergies, respiratory disorders, and other risks to health can result from indoor air pollution exposure. The research concluded that LEED buildings had greater occupant happiness with office furnishings, thermal comfort, cleanliness, and maintenance, the workstation, and the building as a whole, in addition to emphasizing higher occupant contentment with air quality in green buildings (Altomonte & Schiavon, 2013). The productivity of workers can be significantly increased when adequate indoor air quality is maintained. Improved cognitive performance, fewer sick days, better thermal comfort, increased mental well-being, and a productive work environment are a few of the advantages of clean, healthy air. Neglecting indoor air quality, on the other hand, might have a negative impact on productivity. Inadequate air quality may result in more health problems, worse cognitive function, discomfort, more absenteeism, and an unpleasant work environment.

5.3. Daylight

Light is vital to green building and employee productivity. It improves wellbeing, pleasure, and job satisfaction while reducing eyestrain and fatigue. Daylighting reduces stress, fosters a sense of connection to the surroundings, and enhances focus. It also helps with energy efficiency and environmental goals by reducing the need for artificial lighting. Solutions for daylighting enhanced the aesthetics of the workplace, which had a positive effect on worker morale and creativity. In a sample of conventional and green buildings, there was no discernible change in the overall lighting conditions, while conventional buildings' electric lighting was thought to be brighter (Leder et al., 2016). Due to the existence of both natural and artificial light in office spaces, which is provided via a number of methods such as wall apertures, transparent materials, and reflecting surfaces, there is a certain quantity and quality of light at each workstation. Based on a review of the research, effective light levels have a positive impact on both physical health and emotions. However, they seldom have any impact on alertness. Additionally, more sun exposure has been shown to improve the quality of sleep. It has not been shown that dynamic lighting with different daily ratios of direct and indirect light and different color temperatures substantially affects health (Colenberg et al., 2021).

5.4. Architectural Design

By fostering a healthy, sustainable, and motivating work environment, green building architectural design priorities employee well-being. It includes things like better air quality, daylighting from the sun, biophilic design, quiet places, and the use of sustainable materials. The link between people and nature, which is essential for wellbeing and productivity, may not necessarily be improved by "green" architectural design requirements like LEED, BREEAM, and Green Star. Simply making a building more environmentally friendly does not ensure increased productivity or better physical and psychological well-being. A couple of recommendations are aimed at offering people control over their surroundings, addressing pain, speeding things up, and comprehending employment density dynamics. It has been shown that including biophilic design, which links people to nature via daylighting, natural vistas, and passive exposure to nature components, has good effects on well-being and boosts

productivity(Leder et al., 2016). Employee health may suffer in green buildings with poor architectural design. It may lead to poor indoor air quality, a lack of natural lighting, discomfort from inadequate insulation and temperature management, increased noise levels, a lack of access to nature, and ergonomic problems.

6. Discussion

We have done this about the data and graphs showed above part by part. The graph titled “PRODUCTIVITY DIFFERENCES” shows the presenteeism, absenteeism, and self-reported productivity differences between green buildings and non-green buildings. It is clear from all of these comparisons that green buildings consistently outperform conventional structures. A more productive and engaged workforce is the result of green buildings' superior ability to encourage better self-reported productivity, lower presenteeism (being physically present but not truly working), and minimize absence rates.

Table 2. Difference between traditional industry and green industry sector depending on some parameter

Metric	'Green' Building	Other Buildings	Average Difference ('Green' - Other)
Days per Week in the Building (Days/week)			
Average Value	4.88	5.01	-0.13
Absenteeism (days/year)			
Average Value	4.34	5.03	-0.69
Presenteeism (days/year)			
Average Value	10.71	22.01	-11.3
Self-reported Productivity (%)			
Average Value	83.37	78.08	5.29

Metric	Green' Building	Other Buildings
Psychological Wellbeing	~3.2	~2.8
Physical Wellbeing	~3.0	~2.8
Job Satisfaction	~3.2	~2.8
Propensity to Stay	~3.2	~2.8

Measure	Average Time(Green Building)	Average Time (Other Building)
Sufficient ventilation	3.24	3.16
Not too drafty	3.47	3.27
Good air movement	3.26	2.97
Not too dry	3.32	3.36
Not too humid	3.73	3.36
No stale air	3.17	3.05

Measure	Average Time(Green Building)	Average Time (Other Building)
No unpleasant odor	3.43	3.13
Lighting not too dim	3.31	3.64
Not too much glare	3.35	3.52
Not too noisy	2.76	2.77
Not too dusty	3.28	3.17
No static shocks	3.54	3.55
Not too warm	3.12	3.15
Not too cold	2.32	2.22

Metric	Green' Building	Other Buildings
Hours in Building per Week	~7.5	~7.8
Hours at Work Station (hr)	~7.5	~7.8
Days in Building per Week(hr)	~5.0	~5.5

The data indicates that 'Green' buildings offer a more conducive environment for occupants than other buildings. Individuals in 'Green' buildings spend fewer days in the facility weekly, experience less absenteeism, significantly lower presenteeism, and report higher productivity. These benefits can be attributed to better air quality in 'Green' buildings. While both types of buildings generally provide satisfactory air conditions, 'Green' structures consistently score higher in areas like sufficient ventilation, air movement, and reduced humidity, among others. However, certain parameters like lighting being too dim, the potential for glare, and temperature controls were more favorable in the other buildings. Overall, the results suggest that 'Green' buildings contribute positively to occupants' well-being and productivity. Green buildings' excellent features and facilities produce a warm and comfortable atmosphere that entices residents to remain longer, increasing productivity and engagement. This graph "Air Quality Differences over Data Collection Points" shows the differences in air quality between conventional buildings and green buildings, with the latter always outperforming the former. When compared to conventional structures, green buildings excel in maintaining better air quality over the data collection points. Cleaner and healthier interior air is made possible through the employment of cutting-edge ventilation systems, efficient air filtering, and environmentally friendly building materials in green structures. since of the emphasis on air quality, green buildings are the best option for promoting improved indoor air quality since they provide residents with a more comfortable and productive atmosphere.

7. Conclusion

The shift towards green buildings in the construction sector is not merely an environmental prerogative but also a strategic choice for enhanced worker productivity and well-being. This study has underscored the benefits of green buildings over traditional counterparts, especially in areas like indoor air quality and energy efficiency. Particularly in the industrial context, where energy consumption and waste management are paramount, green buildings stand out as beacons of sustainable development. They promise efficient resource utilization and waste reduction, aligning environmental goals with occupational health and productivity. In essence, the adoption of green buildings represents a holistic approach to a sustainable, productive, and healthier future for industries worldwide. To address these concerns Programs for industrial recycling can have a big impact on waste reduction. An environmental benefit of recycling industrial waste is possible. Green building designs also aim to maximize the penetration of natural light and guarantee a comfortable illumination level for building occupants in order to enhance workers' quality of sleep and mental wellness.

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