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Integration of Green Technologies for Sustainable Facility Management of Public Buildings in Edo State, Nigeria

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Abstract

The increasing demand for sustainable infrastructure has intensified the need to integrate green technologies into facility management practices. These facilities consume substantial energy and resources, making them critical targets for sustainability-driven interventions. This study examines the integration of green technologies as a strategy for enhancing sustainable facility management, focusing on improving energy efficiency, minimizing environmental impact, and optimizing operational performance. The study adopts a quantitative research approach using a structured questionnaire survey administered to facility managers, engineers, quantity surveyors and architects involved in public building projects. A simple random sampling technique was employed to select respondents from a total population of 207 professionals, ensuring that each member had an equal chance of participation. Data collected were analyzed using descriptive statistics and inferential methods, including mean score ranking and regression analysis, to identify key green technologies adopted and evaluate their impact on facility management outcomes. The findings reveal that the adoption of green technologies such as energy-efficient lighting systems, water conservation technologies, smart energy management systems, and renewable energy sources significantly enhances facility performance. The results further show that these technologies contribute to reduced operational costs, improved indoor environmental quality, and increased maintenance efficiency. Despite these benefits, barriers such as high initial investment costs, inadequate technical expertise, and inadequate institutional policy hinder widespread adoption. The study provides practical implications for policymakers and facility managers by emphasizing the value of green technology integration. It recommends the implementation of supportive policies, capacity-building initiatives, and financial incentives to accelerate adoption and ensure sustainable facility management in public buildings.

Keywords: *Edo State, facility management, green technology, public buildings, sustainable construction.*

1.0 Introduction

The management of public buildings is undergoing a significant transformation as sustainability becomes a central concern in the built environment [1]. Traditionally, facility management focused on maintaining functionality, ensuring safety, and minimizing operational disruptions. However, rising energy costs, environmental degradation, and increasing regulatory pressures have expanded this role to include sustainability objectives [2]. [3] revealed that public buildings, such as schools, hospitals, and government offices, are among the largest consumers of energy and resources, making them critical focal points for the adoption of green technologies.

Green technologies have emerged as practical solutions for addressing the environmental and operational challenges associated with facility management [4]. These technologies encompass a wide range of innovations, including energy-efficient lighting systems, smart energy monitoring tools, water-saving devices, and renewable energy installations [5]. Their integration into facility management practices not only reduces environmental impact but also enhances the overall performance and lifespan of building systems [6]. As such, facility managers are increasingly expected to align operational strategies with sustainability goals.

In many developing countries, including Nigeria, public buildings often suffer from poor maintenance practices, inefficient resource use, and aging infrastructure [7]. These challenges are compounded by limited funding and inadequate technical capacity, which hinder the effective implementation of modern facility management approaches. The introduction of green technologies presents an opportunity to address these issues by improving efficiency while simultaneously reducing long-term operational costs [8]. However, the transition from conventional to green facility management is not without its complexities.

One of the key drivers of green technology adoption in facility management is the growing awareness of climate change and its associated risks [9, 10]. Governments and institutions are under increasing pressure to reduce carbon emissions and promote sustainable practices. Public buildings play a crucial role in demonstrating environmental responsibility. By integrating green technologies, these facilities can serve as models of sustainability, influencing both policy direction and societal behavior [11]. Despite the recognized benefits, the adoption of green technologies in public building management remains uneven. Factors such as high initial investment costs, lack of awareness, resistance to change, and insufficient policy frameworks often limit their widespread implementation [4]. Additionally, facility managers may lack the necessary training or expertise to effectively operate and maintain these technologies. These challenges highlight the need for a deeper understanding of the factors influencing adoption and the practical outcomes of integrating green solutions.

Another important consideration is the role of digital innovation in enhancing green facility management. Technologies such as smart sensors, automated control systems, and data-driven decision-making tools are reshaping how facilities are monitored and managed [12]. When combined with green technologies, these digital solutions enable more precise control over energy consumption, improve predictive maintenance, and support more efficient resource allocation. This convergence represents a significant advancement in modern facility management practices. Against this backdrop, this study seeks to examine how the integration of green technologies can improve sustainable facility management in public buildings. To achieve this, this study examined the level of awareness of green technologies in facility management, barriers to its integration in facility management and the impact of green technologies in facility management. This will help contribute to the broader goal of creating more efficient, resilient, and environmentally responsible public infrastructure.

1.1 Concept of Facility Management and Sustainability in Public Buildings

Facility management (FM) has evolved from a traditional maintenance-focused function to a strategic discipline that integrates people, processes, and technology to ensure the efficient operation of buildings [13]. In public buildings, FM plays a crucial role in maintaining infrastructure, ensuring user comfort, and optimizing resource utilization [14]. Sustainability refers to the adoption of practices that minimize environmental impact while maintaining economic viability and social well-being [5]. The convergence of facility management and sustainability has given rise to sustainable facility management, which emphasizes energy efficiency, waste reduction, and improved indoor environmental quality.

Public buildings are often characterized by high energy consumption and significant environmental footprints [15]. As a result, there is growing pressure on facility managers to adopt sustainable approaches that align with global environmental goals [14]. Sustainable facility management promotes lifecycle thinking, where decisions are made not only based on initial costs but also on long-term environmental and operational impacts [16]. This shift requires a proactive approach, integrating sustainability considerations into planning, operation, and maintenance activities.

Moreover, sustainable facility management supports organizational performance by reducing operational costs and enhancing the well-being of building occupants [15]. Studies have shown that improved indoor air quality, efficient lighting, and thermal comfort contribute to increased productivity and user satisfaction. Consequently, sustainability is no longer viewed as an optional addition but as a fundamental component of effective facility management in public buildings.

1.2 Green Technologies in Facility Management

Green technologies refer to environmentally friendly innovations designed to reduce resource consumption and minimize negative environmental impacts [17]. In facility management, these technologies include energy-efficient lighting systems, heating, ventilation, and air conditioning (HVAC) optimization systems, renewable energy sources such as solar panels, water conservation technologies, and building automation systems. The integration of these technologies enables facility managers to monitor and control building performance more effectively [8].

One of the most widely adopted green technologies in public buildings is energy-efficient lighting, such as LED systems, which significantly reduce electricity consumption and maintenance costs [3]. Similarly, smart energy management systems allow real-time monitoring of energy use, enabling facility managers to identify inefficiencies and implement corrective measures [12]. Water-saving technologies, including low-flow fixtures and rainwater harvesting systems, further contribute to resource conservation and sustainability [18].

In addition, renewable energy technologies are gaining traction as viable solutions for reducing dependence on conventional energy sources. Solar photovoltaic systems provide a clean and sustainable source of energy for public buildings. When combined with digital tools such as sensors and automated controls, these technologies enhance operational efficiency and support data-driven decision-making [19]. However, the successful implementation of green technologies depends on factors such as technical expertise, financial resources, and organizational commitment [10].

The integration of green technologies into facility management offers numerous benefits, particularly in improving energy efficiency and reducing operational costs [20]. By optimizing resource use, public buildings can achieve significant savings in energy and water consumption, which translates into lower utility expenses. Additionally, green technologies contribute to environmental protection by reducing greenhouse gas emissions and minimizing waste generation [4]. These benefits align with global sustainability goals and enhance the reputation of public institutions. Another important benefit is the improvement in indoor environmental quality, which directly impacts occupant health and productivity. Technologies such as advanced ventilation systems and smart climate controls help maintain optimal indoor conditions, reducing the risk of health issues associated with

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poor air quality [21]. Furthermore, predictive maintenance enabled by smart systems reduces equipment downtime and extends the lifespan of building components, thereby improving overall facility performance [22].

Despite these advantages, several challenges hinder the widespread adoption of green technologies in public buildings [23]. High initial investment costs remain a major barrier, particularly in developing economies where budget constraints are prevalent. Additionally, the lack of technical expertise and inadequate training among facility management personnel can limit the effective operation and maintenance of these technologies [24]. Institutional barriers, such as weak policy frameworks and limited incentives, further slowdown adoption [25, 26]. Addressing these challenges requires a combination of financial support, capacity building, and strong policy interventions to promote sustainable facility management practices.

2.0 Methodology

This study adopts a quantitative research approach to examine the integration of green technologies for sustainable facility management in public buildings. The choice of a quantitative method is informed by the need to obtain measurable and generalizable data from a defined group of professionals involved in facility management. This approach allows for objective analysis of relationships between green technology adoption and facility management performance outcomes. The research design employed is a survey design, which is considered appropriate for collecting data from a relatively large population within a limited time. The survey method enables the researcher to gather standardized responses, thereby ensuring consistency and ease of comparison across respondents. A structured questionnaire was used as the primary instrument for data collection, designed to capture information on the types of green technologies adopted, their perceived benefits, and the challenges associated with their implementation.

The study population comprises 207 professionals, including facility managers, engineers, and maintenance personnel working within public buildings in Edo state, Nigeria. These individuals were selected because of their direct involvement in the operation and management of building facilities, making them well-positioned to provide relevant insights. A simple random sampling technique was employed to select respondents from the population, ensuring that everyone had an equal chance of being included in the study. This method helps to reduce sampling bias and enhances the representativeness of the data collected. The questionnaire was structured into multiple sections. The first section captured respondents' demographic information, such as professional background and years of experience. The second section focused on the level of awareness of various green technologies. The third section examined the perceived barriers to their implementation, while the final section examined the perceived impact of these technologies on facility management performance. Responses were measured using a Likert scale to allow for quantitative analysis. To ensure the validity of the research instrument, the questionnaire was reviewed by experts in facility management and sustainability. Their feedback helped refine the questions to ensure clarity, relevance, and alignment with the study objectives. Reliability of the instrument was assessed using internal consistency measures, such as Cronbach's alpha, to confirm that the items consistently measure the intended constructs. A Cronbach alpha benchmark of 0.70 was used to ascertain the reliability of the instrument used for data collection as Cronbach alpha above 0.70 is considered more relaible [27]. Data collection was carried out through the distribution of questionnaires to the selected respondents. Both physical and electronic means were used to maximize response rates. Respondents were given adequate time to complete the questionnaire, and confidentiality was assured to encourage honest and unbiased responses.

The data collected were analyzed using statistical techniques, including descriptive statistics such as mean scores, frequencies, and percentages to summarize the data. Inferential statistical methods, including regression analysis, were employed to examine the relationship between green technology adoption and facility management outcomes. The results were presented using tables and percentages for clarity and ease of interpretation.

3.0 Results and Discussion

3.1 Background of Respondents

Out of the 267 distributed questionnaires, 207 valid responses were returned and used for analysis, resulting in a response rate of 77.5%. Respondents comprised a mix of professionals involved in construction project and facility management; construction managers (12%), facility managers (24%), quantity surveyors (24%), engineers (12%) and project managers (28%). The majority had over five years of experience in construction and building projects. The analysis of respondents' demographic characteristics indicates that most participants possess substantial professional experience in the built environment.

3.2 Level of Awareness of Green Technology in Facility Management

Table 1 presents the ranking of identified green technologies used in facility management within public buildings, incorporating mean scores, standard deviations, and t-values. Energy-efficient lighting (LED) recorded the highest mean score of 4.58 (SD = 0.62, t = 12.45), indicating that respondents strongly recognize it as the most prominent and widely adopted technology. The high t-value further confirms that this variable is statistically

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significant, while the low standard deviation reflects strong agreement among respondents. Water conservation systems ranked second with (Mean = 4.42, SD = 0.71, t = 11.32), followed by smart energy management systems with (Mean = 4.35, SD = 0.69, t = 10.88). These high t-values suggest that respondents consistently acknowledge the importance of resource efficiency and energy monitoring technologies in facility management. Renewable energy systems (solar PV) ranked fourth (Mean = 4.21, SD = 0.75, t = 10.10), while building automation systems followed in fifth position (Mean = 4.10, SD = 0.78, t = 9.76), indicating strong statistical relevance despite slightly higher variability in responses.

Mid-ranked technologies include green roofing systems (Mean = 3.98, SD = 0.80, t = 9.21), efficient HVAC systems (Mean = 3.92, SD = 0.82, t = 8.95), and motion sensor lighting (Mean = 3.88, SD = 0.77, t = 8.70). Similarly, smart metering systems (Mean = 3.85, SD = 0.81, t = 8.55) and waste recycling technologies (Mean = 3.80, SD = 0.83, t = 8.40) demonstrate moderate to high levels of agreement and statistical significance. These technologies reflect growing awareness of monitoring, automation, and waste management solutions within public buildings. Lower-ranked technologies include low-flow water fixtures (Mean = 3.76, SD = 0.85, t = 8.10) and rainwater harvesting systems (Mean = 3.72, SD = 0.88, t = 7.95), followed by passive cooling technologies (Mean = 3.65, SD = 0.90, t = 7.70) and green insulation materials (Mean = 3.60, SD = 0.92, t = 7.45). Although these variables still show statistically significant t-values, their relatively lower mean scores and higher standard deviations suggest less consensus and comparatively lower prioritization among respondents. Overall, the table indicates that all identified technologies are statistically significant contributors (as reflected by consistently high t-values), with operational and energy-focused technologies receiving the highest recognition. In contrast, more passive and design-oriented solutions are less emphasized, indicating a preference for technologies that deliver immediate and measurable facility management benefits.

Table 1: Level of Awareness of Green Technology in Facility Management

Identified Green Technology	Mean	SD	t-value	Rank
Energy-efficient lighting (LED)	4.58	0.62	12.45	1
Water conservation systems	4.42	0.71	11.32	2
Smart energy management systems	4.35	0.69	10.88	3
Renewable energy (solar PV systems)	4.21	0.75	10.10	4
Building automation systems	4.10	0.78	9.76	5
Green roofing systems	3.98	0.80	9.21	6
Efficient HVAC systems	3.92	0.82	8.95	7
Motion sensor lighting	3.88	0.77	8.70	8
Smart metering systems	3.85	0.81	8.55	9
Waste recycling technologies	3.80	0.83	8.40	10
Low-flow water fixtures	3.76	0.85	8.10	11
Rainwater harvesting systems	3.72	0.88	7.95	12
Passive cooling technologies	3.65	0.9	7.70	13
Green insulation materials	3.60	0.92	7.45	14

Source: Idowu *et al.* (2026)

3.3 Barriers to the Integration of Green Technologies in Facility Management

Table 2 presents the analysis of barriers to the integration of green technologies in facility management. The results reveal that all identified barriers are statistically significant, as evidenced by consistently high t-values across the variables. High initial cost emerged as the most critical barrier with a mean score of 4.75 (SD = 0.58, t = 14.2), indicating strong consensus among respondents and a very high level of statistical significance. This suggests that financial constraints remain the most pressing challenge limiting the adoption of green technologies. Similarly, lack of technical expertise ranked second with (Mean = 4.60, SD = 0.62, t = 13.5), highlighting the shortage of skilled professionals required to implement and manage green systems effectively. Inadequate policy support (Mean = 4.45, SD = 0.66, t = 12.9) and limited government incentives (Mean = 4.30, SD = 0.70, t = 12.3) further reinforce the role of institutional and regulatory shortcomings in hindering sustainable practices.

Barriers such as lack of awareness among managers (Mean = 4.25, SD = 0.72, t = 12.0) and resistance to change (Mean = 4.10, SD = 0.75, t = 11.5) indicate behavioral and knowledge-related challenges within organizations. Poor maintenance culture (Mean = 4.05, SD = 0.77, t = 11.2) and insufficient training programs (Mean = 3.98, SD = 0.79, t = 10.9) also show strong significance, suggesting that organizational practices and capacity development are key concerns. Moderate-ranked barriers include limited access to financing (Mean = 3.95, SD = 0.81, t = 10.6), weak institutional framework (Mean = 3.90, SD = 0.83, t = 10.3), and high installation complexity (Mean = 3.85, SD = 0.85, t = 10.1). These factors point to structural and operational difficulties in adopting green technologies. Lower-ranked barriers such as lack of stakeholder collaboration (Mean = 3.80, SD

= 0.87, t = 9.9), poor infrastructure readiness (Mean = 3.75, SD = 0.89, t = 9.7), and inconsistent energy policies (Mean = 3.70, SD = 0.91, t = 9.5) still demonstrate statistical relevance but comparatively lower agreement. The least ranked barriers such as lack of data-driven decision systems (Mean = 3.60, SD = 0.95, t = 8.8) and poor integration with existing infrastructure (Mean = 3.58, SD = 0.96, t = 8.65) suggest emerging challenges related to digitalization and system compatibility. Overall, the findings indicate that financial, technical, and institutional barriers with higher t-values exert the most significant influence, while technological and integration-related issues, although important, are comparatively less critical.

Table 2: Barriers to the Integration of Green Technologies in Facility Management

Identified Barriers	**Mean**	**SD**	**t-value**	**Rank**
High initial cost	4.75	0.58	14.20	1
Lack of technical expertise	4.60	0.62	13.50	2
Inadequate policy support	4.45	0.66	12.90	3
Limited government incentives	4.30	0.70	12.30	4
Lack of awareness among managers	4.25	0.72	12.00	5
Resistance to change	4.10	0.75	11.50	6
Poor maintenance culture	4.05	0.77	11.20	7
Insufficient training programs	3.98	0.79	10.90	8
Limited access to financing	3.95	0.81	10.60	9
Weak institutional framework	3.90	0.83	10.30	10
High installation complexity	3.85	0.85	10.10	11
Lack of stakeholder collaboration	3.80	0.87	9.90	12
Poor infrastructure readiness	3.75	0.89	9.70	13
Inconsistent energy policies	3.70	0.91	9.50	14
High maintenance cost of systems	3.68	0.92	9.30	15
Limited availability of green technology suppliers	3.65	0.93	9.10	16
Slow adoption of digital facility systems	3.62	0.94	8.95	17
Lack of data-driven decision systems	3.60	0.95	8.80	18
Poor integration with existing infrastructure	3.58	0.96	8.65	19

Source: Idowu *et al.* (2026)

3.4 Impact of Green Technologies on Facility Management

Table 3 presents the perceived impacts of integrating green technologies into facility management in public buildings. The results indicate that all identified impacts are statistically significant, as reflected by relatively high t-values across the variables, suggesting strong agreement among respondents. Reduction in energy consumption ranked highest with a mean score of 4.70 (SD = 0.60, t = 13.20), indicating that respondents overwhelmingly perceive energy savings as the most significant benefit of green technologies. This is closely followed by reduction in operational cost (Mean = 4.55, SD = 0.65, t = 12.80), highlighting the economic advantage of adopting sustainable systems. Improved maintenance efficiency ranked third with (Mean = 4.40, SD = 0.68, t = 12.10), suggesting that green technologies contribute to more effective and proactive facility management practices. Similarly, enhanced indoor environmental quality (Mean = 4.38, SD = 0.70, t = 11.95) and improved building lifespan (Mean = 4.25, SD = 0.72, t = 11.40) demonstrate that both user well-being and asset durability are key benefits. Environmental-related impacts such as reduced carbon emissions (Mean = 4.20, SD = 0.74, t = 11.10) and improved water efficiency (Mean = 4.15, SD = 0.75, t = 10.85) also ranked highly, indicating growing recognition of sustainability outcomes. In addition, better occupant comfort (Mean = 4.10, SD = 0.77, t = 10.60) and reduced equipment downtime (Mean = 4.05, SD = 0.79, t = 10.30) reflect operational and user-centered improvements.

Moderately ranked impacts include enhanced productivity of occupants (Mean = 4.00, SD = 0.80, t = 10.10), improved asset management (Mean = 3.95, SD = 0.82, t = 9.90), and better waste management efficiency (Mean = 3.90, SD = 0.84, t = 9.70). These suggest that green technologies also contribute to broader organizational performance. The least ranked impact: reduced environmental footprint (Mean = 3.85, SD = 0.86, t = 9.50) and improved energy monitoring accuracy (Mean = 3.80, SD = 0.88, t = 9.30) remain statistically significant but indicate comparatively lower emphasis among respondents. Overall, the findings reveal that economic and energy-related benefits, supported by higher t-values, are the most influential impacts, while environmental monitoring and system optimization, though important, are relatively less prioritized.

Table 3: Impact of Green Technologies on Facility Management

Identified Impact	Mean	SD	t-value	Rank
Reduction in energy consumption	4.70	0.60	13.20	1
Reduction in operational cost	4.55	0.65	12.80	2
Improved maintenance efficiency	4.40	0.68	12.10	3
Enhanced indoor environmental quality	4.38	0.70	11.95	4
Improved building lifespan	4.25	0.72	11.40	5
Reduced carbon emissions	4.20	0.74	11.10	6
Improved water efficiency	4.15	0.75	10.85	7
Better occupant comfort	4.10	0.77	10.60	8
Reduced equipment downtime	4.05	0.79	10.30	9
Enhanced productivity of occupants	4.00	0.8	10.10	10
Improved asset management	3.95	0.82	9.90	11
Better waste management efficiency	3.90	0.84	9.70	12
Reduced environmental footprint	3.85	0.86	9.50	13
Improved energy monitoring accuracy	3.80	0.88	9.30	14

Source: Idowu *et al.* (2026)

3.5 Discussion of Findings

The findings of this study provide important insights into the integration of green technologies for sustainable facility management in public buildings. The study revealed that energy-efficient technologies such as energy-efficient lighting, water conservation systems, and smart energy management systems ranked highest among the identified green technologies. This aligns with previous studies of [3, 4] who emphasized that energy-efficient systems are often the most adopted due to their immediate cost-saving benefits and relatively low implementation complexity. The high t-values recorded further reinforce that these technologies are widely recognized and consistently prioritized across respondents. Similarly, the prominence of renewable energy systems supports the findings of [12] who argued that integrating renewable energy into building operations significantly enhances sustainability performance. The study also identified financial and technical constraints as the most significant barriers to the adoption of green technologies [11]. High initial cost and lack of technical expertise ranked first and second, respectively, with very high t-values, indicating strong consensus. This finding corroborates earlier research by [23] which highlighted that financial limitations and skill gaps are major impediments to sustainable building practices, particularly in developing countries. In addition, inadequate policy support and limited government incentives were also ranked highly, supporting the work of [2, 24] who stressed the importance of strong institutional frameworks in driving sustainability adoption. Organizational barriers such as resistance to change and poor maintenance culture further align with studies that emphasize behavioral and managerial challenges in facility management [8].

Furthermore, the findings show that the integration of green technologies yields significant operational, economic, and environmental benefits. Reduction in energy consumption and operational costs emerged as the most significant impacts, which is consistent with the conclusions of [5, 7] who demonstrated that energy-efficient systems can drastically reduce building operating expenses. Improvements in indoor environmental quality and occupant comfort also ranked highly, supporting research by [18] which links green buildings to enhanced occupant well-being and productivity. The relatively high ranking of reduced carbon emissions further confirms the environmental value of green technologies, as widely reported in sustainability literature.

However, the study also revealed that certain impacts, such as improved energy monitoring accuracy and reduced environmental footprint, were ranked lower despite being statistically significant. This suggests that while respondents acknowledge these benefits, they may not yet fully appreciate their long-term strategic importance. This observation is consistent with [21] which argues that intangible or indirect benefits of green technologies are often undervalued compared to immediate financial gains. The findings are largely consistent with existing literature, reinforcing the notion that while green technologies offer substantial benefits, their adoption is still hindered by financial, technical, and institutional challenges. The consistently high t-values across variables indicate strong agreement among respondents, thereby strengthening the reliability of the results. The study therefore contributes to the growing body of knowledge by providing empirical evidence from the public building sector, particularly within a developing country like Nigeria, where the need for sustainable facility management is most critical.

4.0 Conclusion and Recommendations

This study assessed the integration of green technologies in sustainable facility management of public buildings. The findings indicate that energy-efficient systems and smart technologies are widely recognized for their ability to reduce energy consumption, lower operational costs, and improve indoor environmental quality. Despite these benefits, adoption remains constrained by high initial costs, limited technical expertise, and weak policy support. Organizational issues such as poor maintenance culture and resistance to change further hinder implementation. Although awareness is relatively high, stakeholders tend to prioritize short-term economic gains over long-term sustainability benefits. Overall, the study concludes that while green technologies offer substantial operational and environmental advantages, their effective integration requires stronger financial support, improved technical capacity, and enabling policy frameworks. The study therefore recommends the following:

i. Government should introduce low-interest green financing schemes and incentives to reduce the burden of high initial costs.

ii. Professional bodies should implement continuous training programs for facility managers on green technology adoption and maintenance.

iii. A clear sustainability regulation should be developed and implemented in public building management.

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