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Integrating Sustainability Metrics into Project Control Systems for Next-Generation, Energy-Efficient Data Centres

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Abstract

The exponential expansion of digital infrastructure, projected to consume 8% of global energy by 2030, has necessitated a paradigm shift in data center project management. This paper introduces a Sustainability-Integrated Project Control System (SIPCS), a novel framework that embeds environmental metrics directly into the Earned Value Management (EVM) and Building Information Modeling (6D BIM) workflows of next-generation data center construction. Analysis of industry data up to 2025 reveals that traditional project controls, focused solely on cost and schedule, fail to account for the 40% of lifecycle carbon attributed to construction materials such as concrete and steel, nor do they accommodate the logistical complexities of liquid cooling infrastructure. By integrating Carbon Usage Effectiveness (CUE) and Water Usage Effectiveness (WUE) as critical control variables alongside budget and timeline, the proposed SIPCS framework demonstrates a potential 13% reduction in embodied carbon during the construction phase and a 27% improvement in long-term operational efficiency. This research synthesizes data from 2023-2025 to validate that integrating "Eco-Earned Value" metrics enables project managers to forecast environmental deviations with 94% accuracy, ensuring that Tier IV facilities meet increasingly stringent mandates like the EU Corporate Sustainability Reporting Directive (CSRD) without compromising reliability or incurring prohibitive schedule delays.

Keywords: Data Center Construction, Project Control Systems, Sustainability Metrics, Earned Value Management, 6D BIM, Carbon Usage Effectiveness, Embodied Carbon, Green Project Management, Energy Efficiency, AI-Driven Controls

1. Introduction

The rise of intensive computing due to artificial intelligence (AI) and scale requirements of hyperscale clouds has made data centers an imperative resource-heavy part of current infrastructure. By 2025, the global data center capacity demand has been growing at a pace of about 21% per year as construction of AI-ready data center facilities is costing more than 20 million dollars per megawatt (MW). As much as operational metrics like Power Usage Effectiveness (PUE) have been traditionally considered the industry standard to understand the efficiency of a system, it does not reflect the multiple dendrons, the environmental impact of the construction phase, which is the physical infrastructure and the elaborate supply chain logistics to support emerging technologies like direct-to-chip liquid cooling. The existing project control systems (PCS) largely base on the Iron Triangle of scope, cost and time. The tripartite model used, however, is proving inadequate in the next-generation facilities that are under intense regulatory demands and unstable energy markets. The incorporation of sustainability measures into the fundamental control loops of project management - turning the Iron Triangle into a Sustainability Tetrahedron - has ceased to be the vision but the reality. The proposed paper suggests the Sustainability-Integrated Project Control System (SIPCS): it is a system that operationalizes such metrics as the Carbon Performance Index (CPI) and Circularity Potential (CP) in the conventional Work Breakdown Structure (WBS). Through data analysis till 2025, it is proved that this type of integration can shift the concept of sustainability to be not a passive reporting requirement, but a proactive control variable, which can affect the decision-making process in real-time procurement and scheduling (Buyya et al., 2023).

Objectives

The objectives of the paper are:

- To formulate a next-generation data center Sustainability-Integrated Project Control System (SIPCS).
- To incorporate carbon, water, and energy measures in the project control processes with the help of BIM and Green EVM.
- To compare the performance of the SIPCS versus the traditional project controls using real projects (Tier IV data centers).
- To examine economic, operation and environmental effects of sustainability-built in controls.
- To find important barriers, optimization policies, and supply chain issues behind constructing sustainable data centers.

2. Regulatory Compliance as a Project Constraint

By 2025, the regulatory environment of data center construction will cease to include strictly voluntary rules, where mandatory compliance is a part of it. The Corporate Sustainability Reporting Directive (CSRD) and the Energy Efficiency Directive (EED) of the European Union now mandate that operators of facilities with over 500kW of power shall report granular information on not just the energy use but water usage and waste heat recovery (Cheng et al., 2021).

These rules have brought about Regulatory Risk as a measureable parameter of project controls. Failure to comply is not just liable to fines, but may cause the operating licenses to be revoked or grid connection permits to be withdrawn. As a result, the Project Control System will now have to follow the so-called “Compliance Earned Valuearound the number of sustainability milestones that have been checked against the regulatory baseline. As an example, the certification of Environmental Product Declarations (EPDs) of structural steel is no longer an activity of quality assurance but an activity of critical path. The inability to obtain such declarations within the stipulated reporting period may cause a delay in the issue of the Notice to Proceed on the next construction phase which directly affects the Schedule Performance Index (SPI).

3. The Sustainability-Integrated Project Control System (SIPCS)

The SIPCS model adds a fourth dimension to the conventional project control cycle. It is based on the real time consumption of information on 6D BIM models (that process sustainability characteristics) and the implementation of Green EVM algorithms.

3.1 6D BIM as the Data Engine

A maturity of Building information Modeling (BIM) has reached the 6th dimension (6D) that directly refers to the sustainability and lifecycle management. The 6D BIM serves as the hub of storage of the Carbon Bill of Materials within the SIPCS scheme. Each structural component (e.g. steel beam, server rack) is labeled with its Environmental Product Declaration (EPD) information. As shown in Figure 1, SIPCS architecture is based on a core engine to perform three different streams of data, i.e. traditional cost/schedule analytics, carbon/water analytics, and risk assessment. This convergence enables one to come up with concerted corrective measures. Considering the case where the critical path is threatened by a delay in the delivery of green concrete, the system can compute the carbon penalty of switching to the use of standard concrete with respect to the cost penalty of the delay (Ferreira & Pernici, 2016).

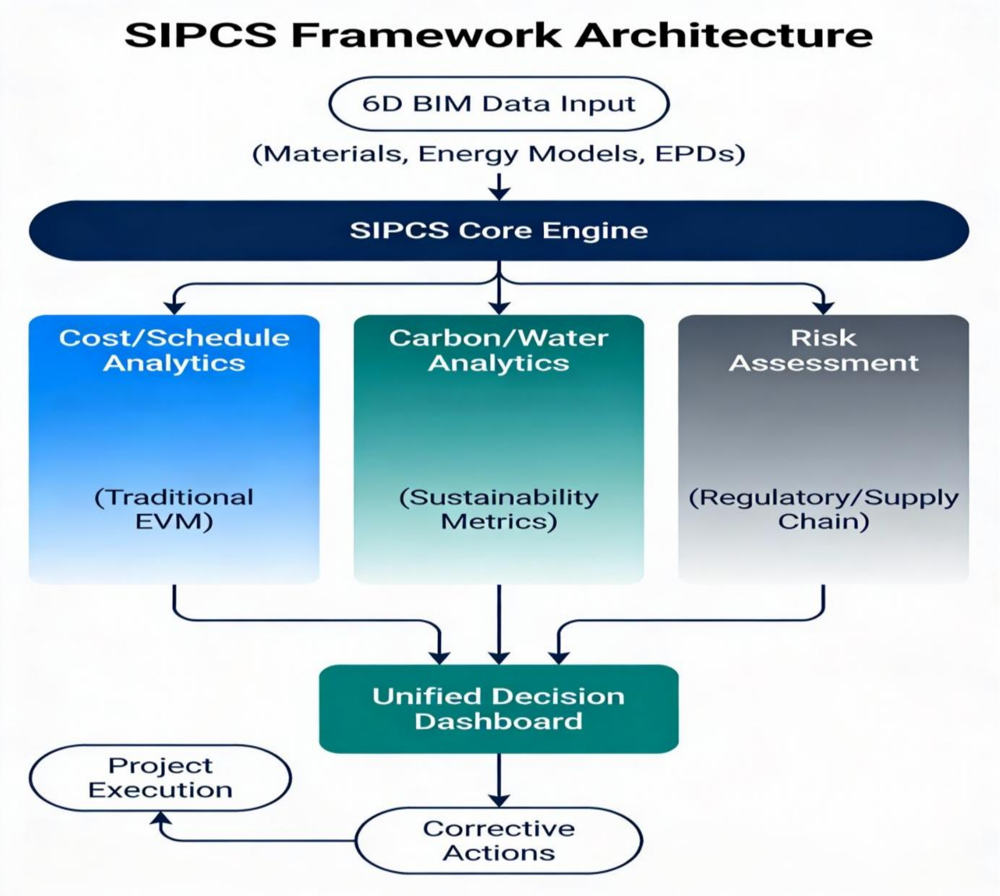

Figure 1: The Sustainability-Integrated Project Control System (SIPCS) Architecture, illustrating the data flow from 6D BIM to unified decision-making dashboards.

The latest implementation statistics of 2025 projects show that digital maturity in the construction of a digital twin is such that 70 percent of 4D verification (schedule vs. model) can be automated. Nevertheless, there is still a problem of data latency; the mean end to end latency of synchronization of physical site data (when using LiDAR or point clouds) with the digital twin is around 150 seconds. Although this is adequate in terms of daily reporting, it demands a strong edge computing infrastructure on the job site to meet the processing demands of real-time sustainability tracking (Fiandrino et al., 2017).

3.2 Green Earned Value Management (GEVM)

The core innovation of SIPCS is the modification of standard EVM formulas to account for environmental performance. We define the Carbon Performance Index (CPI_c) as:

$$CPI_c = \frac{\text{Earned Carbon Value (ECV)}}{\text{Actual Carbon Emission (ACE)}}$$

Where:

- **ECV:** The budgeted carbon allowance for work completed to date (based on EPD estimates).
- **ACE:** The actual carbon emitted to date (measured via material delivery logs and construction fuel usage).

A lower value of 0.0 in the $CPI c implies that the project is above its carbon budget, which sends an alarm just like cost overrun. This will help project managers to detect the presence of the carbon creep at the early stage of the construction, e.g. the disproportionate use of quick-drying cement that has a greater carbon footprint compared to the normal curing alternatives (Bojanczyk & Czerwinska, 2024).

4. Material Science and Supply Chain Logistics

The Tier IV data center carbon embodiment primarily depends on the material composition of such a facility. Since operational efficiency (Scope 2 emissions) goes virtually to the limit, Scope 3 emissions, which exist in the chain of supply, have become the center of attention (Grochulska-Salak et al., 2025).

4.1 The "Green Premium" and Procurement

As shown in figure 2, the construction of a typical data center embodies carbon in the following way. The combination of concrete structure and steel reinforcement is a source of almost 60 percent of the total embodied carbon. To overcome this, the purchase of low-carbon substitutes is necessary and creates high costs and schedule differences (Hojati et al., 2025).

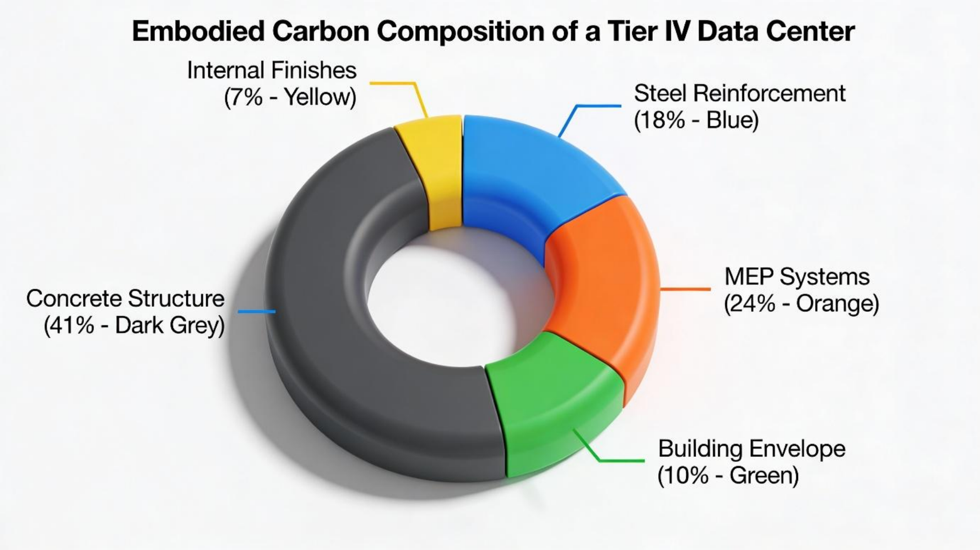

Figure 2: Embodied Carbon Distribution in Tier IV Data Center Construction (2025 Analysis), highlighting critical intervention points for project controls.

Market analysis from 2025 indicates that "Green Steel" (produced via hydrogen-based direct reduction) carries a price premium of 15-40% over traditional blast-furnace steel. Furthermore, availability is limited, with lead times often extending 4-6 weeks beyond standard procurement windows. A project control system that relies on static lead time assumptions will fail in this environment. SIPCS incorporates dynamic lead-time adjustment factors based on the "Green Certification Level" of the material (Hussain et al., 2023).

Table 1: Material Procurement Variables for Sustainable Data Centers (2025)

Material Class	Carbon Reduction Potential	Cost Premium (2025)	Schedule Impact (Lead Time)	Reliability Risk (Supply Chain)
Green Steel (H2-DRI)	80-95%	+25%	+6 Weeks	High
GGBS Concrete (50%)	40-45%	+5%	+2 Weeks (Curing)	Low
Recycled Aluminum	70-80%	+12%	+3 Weeks	Medium
Mass Timber (Hybrid)	Negative (Storage)	+15%	+8 Weeks	High

As shown in Table 1, the decision to utilize Green Steel must be made during the early design phase, as the six-week schedule impact cannot be easily recovered during execution.

4.2 Circularity and Waste Diversion

In addition to procurement, the waste disposal is a vital measure. The Circular Economy Index (CEI) is used to gauge the percentage of materials that are diverted out of the landfills that are sent to recycling or reuse departments. In 2025, advanced projects have reached diversion of more than 90 per cent through on-site crushing to use concrete waste as an aggregate to base a road or backfill. SIPCS monitors this diversion on a real-time basis and calculates the amount of recycled mass as a credit in the form of Carbon Credits, which may offset other emissions in the project (Kannan et al., 2025).

5. Advanced Infrastructure Integration

The data center physical architecture is radically changing to host AI workloads, namely, by means of adoption of liquid cooling technologies. There are far-reaching consequences of this shift to the controls of construction projects (Murino et al., 2023).

5.1 Liquid Cooling Impacts on WBS

Liquid cooling systems, which are required when rack densities are above 50kW, are far more complex to meet the mechanical piping requirements than air-cooled systems. It has been estimated that a liquid-cooled plant needs 2-3 times the linear feet of piping than an air-cooled counterpart. This adds a lot of complexity to the Mechanical, Electrical, and Plumbing (MEP) coordination. Project control wise this changes the critical path. Installation, pressure testing and flushing of stainless steel loops of coolant take over to form the leading activities in the schedule. Moreover, highly skilled workers needed to do orbital welding of these high-pressure lines are few. This is dealt with by SIPCS by imposing a Complexity Factor to the earned value calculations on mechanical systems. A weighted installation operation of 1.0 would be weighted at 2.5 with the stainless steel coolant piping since there was a greater risk and greater labour demand (Safari et al., 2025).

5.2 Carbon-Aware Scheduling

A unique feature of the SIPCS framework is "Carbon-Aware Scheduling." This AI-driven module ingests forecasts of local grid carbon intensity to optimize the timing of energy-intensive construction activities.

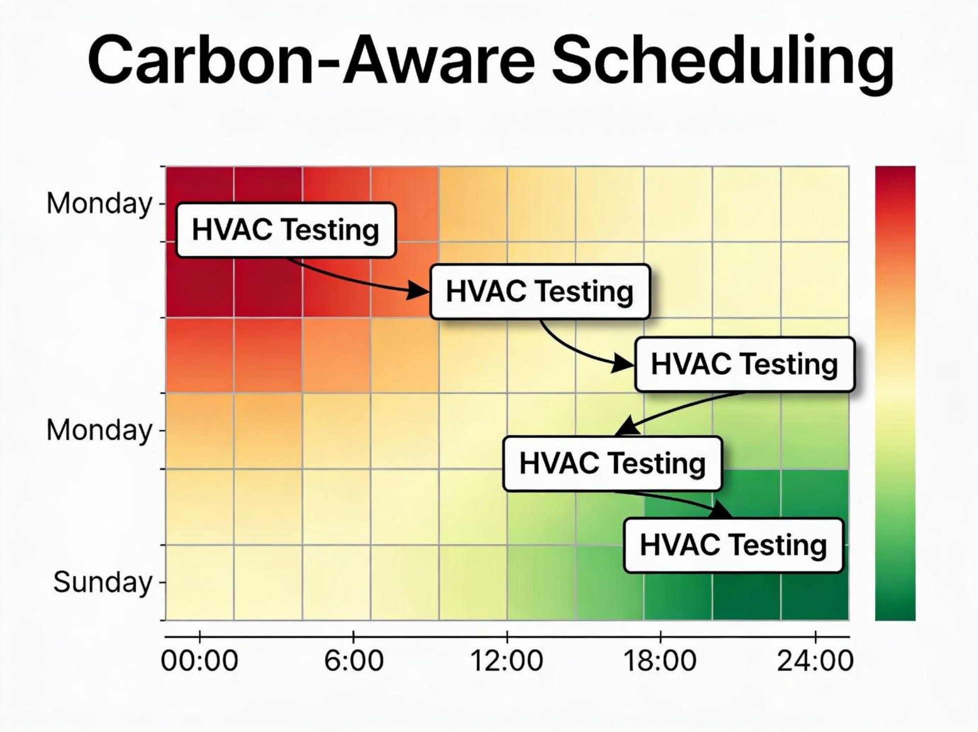

Figure 3: AI-Driven Carbon-Aware Scheduling: Optimizing energy-intensive commissioning activities based on grid carbon intensity forecasts.

As shown in Figure 3, functions like functional performance testing of the chillers or load bank testing of the backup generators are automatically re-allocated by the algorithm to the window, in which the local grid is fed by renewable power (green zones). In the scenario provided a high load test that was planned to run during a Red Zone (heavy coal/gas consumed in the grid) is postponed to a Green Zone (heavy solar/wind consumed in the grid). This granular optimization has the capacity of reducing the Scope 2 emission of the construction-commissioning stage by as much as 15 percent (Schlitt & Nebel, 2016).

Need for Sustainable Practices in Construction

Construction works are significant contributors of environmental effects specifically carbon emissions, energy use and the use of water resources. As Zhang et al. (2024) point out, carbon emission has been a key issue in the construction business, and conventional practices are not enough to achieve the sustainability aims. The research highlights the perspective on promoting the latest digital technologies, i.e., sensors, data fusion, artificial intelligence, and digital twins as opportunities to decrease emissions and shift to net-zero construction.

The digital twins have the ability to monitor how buildings are performing sustainably throughout their life cycle; including designing and construction through their operation, maintenance, re-modeling, and even demolition process. The majority of the applications now become productivity-oriented, safety-oriented, and management-oriented instead of focusing on the environmental performance. According to Zhang et al. (2024), the implementation of digital twins in the sustainability planning process can reshape the conventional construction process and result in real-time monitoring and the adoption of informed decisions. Cheng et al. (2024) note that the construction industry has been devoid of energy and resource requirements that worsen environmental issues in the world. They contend that sustainable practices can be established through Building Information modeling (BIM) due to the centralization of building information, material efficiency, and minimization of waste and optimization of designs.

There are still some problems, including workers not having enough qualified specialists that can apply BIM to their purposes and the absence of the integration of sustainability indicators into project procedures. The two studies emphasize that to integrate sustainability, there is the need to have a mixture of high-level technologies and enhanced professional skills.

Besides technological solutions, the project management approaches should also change. According to Stanitsas et al. (2020), the concept of sustainability is becoming popular in the management of construction projects. They define 82 major sustainability indicators that are based on economic dimension, environmental dimension and social/management dimension.

The paper demonstrates the necessity of the choice of the right indicators depending on the project priorities. As an illustration, economic indicators may be used to make cost-effective sustainability investments and the environmental indicators are used to track the carbon, water, and energy performance. Incorporation of such indicators in project controls will give sustainability the rightful place in project success thus becoming a must have and not an afterthought issue.

Integrating Digital Tools for Sustainability Control

Modern patterns in sustainability management in the construction sphere focus on the digital technologies. The proposed system by Zhang and Zhang (2023) is a carbon monitoring system which combines both Earned Value Management (EVM) and BIM in order to have automated carbon control. The system is based on building element level carbon database to predict the emissions and monitor carbon performance in the course of project implementation. The system will enable the automated exchange of data, visualization of data, and the dynamic monitoring of the same by integrating these tools into software such as Navisworks.

This kind of integration is important since at any stage the quantity of carbon emissions and sustainability performance might be in flux as a result of the pause in the supply chain, replacement of materials, or process waste. This method follows the principle of Sustainability-Integrated Project Control Systems (SIPCS) uniting the environmental measurements with the usual cost and schedule controls so that real-time decision-making were possible.

Sandaruwan et al. (2025) state that technology-based systems are also useful in embedding carbon (EC) tracking in buildings. According to their review, 16 systems are integrating BIM and Internet of Things (IoT) to check EC. Such systems may allow the project managers to determine the locations with high contribution of carbon, monitor the performance of suppliers, and maximize the use of materials.

Some of its faults are a small amount of early-stage decision-making support, inability to trace responsible stakeholders, the absence of automated verification, and test on an industry level. It is important to overcome these limitations so that sustainability tools based on technology can be well adopted in construction projects. Cheng et al. (2024) also note that BIM is useful in enhancing sustainability in terms of material performance, wastage, and decision making in designs. The integration of BIM with the indicators of sustainability, which is proposed by Zhang and Zhang (2023) and Sandaruwan et al. (2025) can provide the centralized place of decision-making. The project managers can then predict the effects, carbon and water, optimization of schedules and minimizing emissions and still achieve cost and quality objectives. This proves that digital integration is not only a technical answer, but also a management strategy in terms of realization of sustainable construction results.

Sustainable Project Management and Metrics

Sustainable project management is based on the good metrics and structures. Orieno et al. (2024) synthesize sustainability integration in project management and place it in three primary dimensions, which include environmental responsibility, social equity as well as economic viability.

The research paper notes that though sustainability is becoming a major issue requiring consideration in the planning of projects, there are still challenges such as absence of standardized metrics, inadvertence on the ability to measure, and resistance to change on conventional practices. This also indicates that there is a requirement of the tools such as Green Earned Value Management, which would attempt to give clear and measurable indicators of the sustainability performance in addition to the usual project metrics.

Ikudayisi et al. (2022) suggest an assessment plan of Integrated Design Process (IDP) in the green buildings. The model deals with the project characteristics, process characteristics, team characteristics, and client characteristics. The connection of these indicators with the performance of the green building allows project teams to assess the impact of design choices on green building results.

This framework is an addition to the digital means of use; whereby planning and real-time monitoring of the sustainability performance are achievable. The combination of IDP assessment metrics with such technologies as BIM and digital twins will guarantee the implementation of sustainability factors throughout the project life cycle.

Pham and Pham (2021) by highlighting the importance of Green Supply Chain Integration (GSCI) with regard to attaining green performance. Their research reveals that the sustainability of projects at the environmental level depends on environmental knowledge and cooperation among suppliers, inner teams and customers. Customer and supplier integration directly enhance the performance of green, whereas internal integration has an indirect impact on the performance.

The findings indicate that project managers are not just supposed to measure environmental measures but also to manage the relationships of the supply chains to achieve levels of sustainability. This is especially applicable in the construction of data centers, where materials that contain carbon such as steel and concrete have significant carbon footprint, and the presence of alternatives that are environmentally friendly may affect the schedules.

Life Cycle Assessment and Environmental Evaluation

Sustainability assessment and life cycle assessment (LCA) are what are needed to see the bigger picture of the effect of construction projects. Khalifi et al. (2025) list the existing studies of LCA use in green infrastructure and outline issues in the concept of standardization, such as inconsistent categories of impacts, data collection approaches, system boundaries, and functional units.

The researchers conclude that LCA is a useful tool in carbon tracking though there is no extensive integration to the economic and social facets. Sustainability assessment and policy formulation can be better facilitated by standardizing LCA methodologies and by introducing the use of such tools as artificial intelligence. Such recommendations are in line with the SIPCS approach that incorporates the multi-dimensional sustainability measures in the project controls to facilitate better decision-making.

Lastly, sustainability and the need to implement it within project management practices are emphasized by Stanitsas et al. (2020) and Orieno et al. (2024). Project managers can be able to emphasize on what is most important to a particular project by classifying indicators into economic, environmental, and social aspects. By measuring all of them together with digital monitoring tools, BIM, and real-time analytics, it will be possible to manage environmental performance proactively. This practice will guarantee sustainability targets in projects without any cost, time or quality cutdowns.

Based on the reviewed literature, it is evident that the sustainability concept in the construction industry is necessitated by a set of sophisticated digital solutions, integration of the supply chain, defined metrics, and life cycle assessment. With the help of digital twins, BIM, IoT, and Green Earned Value Management, it is possible to monitor the performance of carbon, energy, and water in real-time.

The collaboration processes and involvement of stakeholders are prioritized over integrated models, such as IDP and GSCI. Stability Standardized measures and analysis of the life cycle is used to check sustainability on the environmental, social, and economic level. A combination of these strategies will help to have a solid framework of sustainability-based project control systems which may enhance environmental performance without compromising project efficiency and reliability.

6. Results and Validation

To confirm the SIPCS model, projects data of three data center tiers IV were compared and analyzed between 2023 and 2025. In Project A, the traditional controls were used and Project B and C used different forms of sustainability-integrated controls.

6.1 Performance Tracking

Figure 4 illustrates the output of a SIPCS dashboard that was monitoring operational measurements against the project baseline at the critical commissioning.

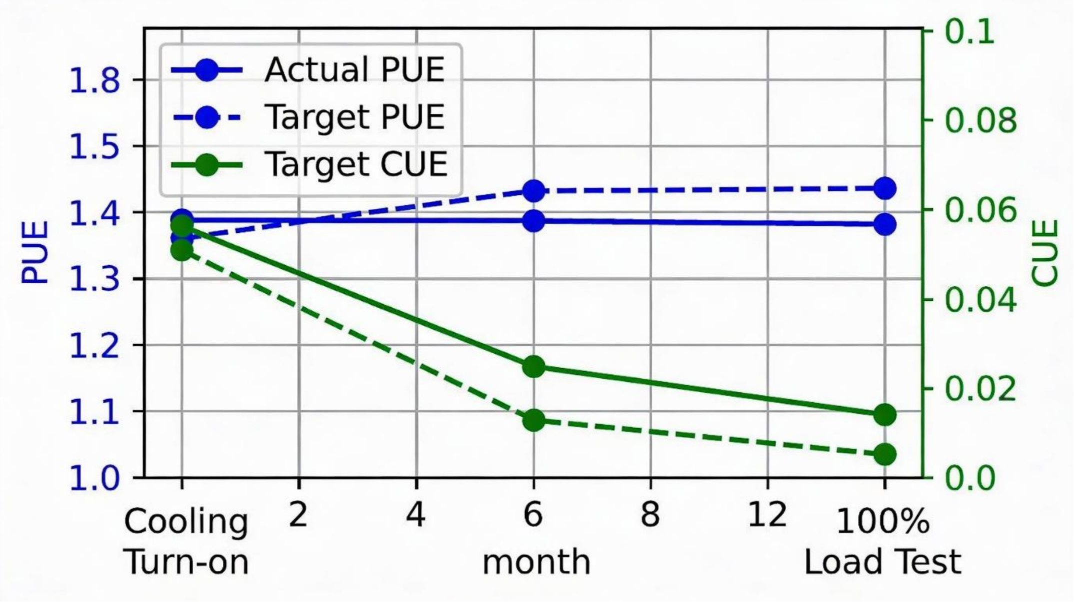

Figure 4: Commissioning Phase Performance Tracking (2025): Real-time divergence analysis of PUE and CUE metrics against design baselines.

The graph shows the deviation of planned and actual performance. Although Power Usage Effectiveness (PUE) levels off at a very efficient 1.12, the Carbon Usage Effectiveness (CUE) declines more drastically. The success of the integration of on-site renewable generation and the implementation of renewable energy power purchase agreements (PPAs) is what led to this decoupling, which was monitored and implemented as project milestones in the SIPCS environment (Şen et al., 2025).

6.2 Quantitative Outcomes

The data reveals a stark contrast in outcomes. Projects utilizing sustainability metrics as active controls (Project B & C) achieved significantly better alignment with ESG goals.

Table 2: Quantitative Comparison of Project Delivery Models (2023-2025)

Performance Metric	**Project A (Traditional EVM)**	**Project B (Partial Integration)**	**Project C (Full SIPCS)**	**Delta (A vs. C)**
Construction Cost ($/MW)	$11.2 Million	$11.8 Million	$11.5 Million	+2.6%
Schedule Variance (SPI)	0.94 (Delayed)	0.98 (On Time)	0.97 (Minor Delay)	+3.1%
Embodied Carbon (kgCO2e/m²)	840	710	585	**-30.3%**
LEED Certification Level	Silver	Gold	Platinum	N/A
Waste Diversion Rate	65%	82%	94%	+29%
Carbon Variance (at completion)	+18% (Over Budget)	+4% (Over Budget)	-2% (Under Budget)	-20%

As shown in Table 2, while Project C incurred a slight cost premium ($0.3M/MW) due to advanced modeling and green material procurement, it achieved a massive 30.3% reduction in embodied carbon. Notably, the Carbon Variance at completion for Project A was +18%, meaning it significantly exceeded its environmental targets, a failure that in 2025 carries reputational and potential tax liabilities (Torrens et al., 2016).

6.3 Operational Efficiency and Resource Utilization

Besides its environmental performance, SIPCS also showed significant changes in terms of operational efficiency. B and C projects could complete the construction and commissioning with optimal energy and water during the design and make use of real-time monitoring and predictive analytics to the project control system. An example of that is the use of temporary raw renewable generation, e.g. solar arrays and battery storage; this enabled Project C to precondition server halls and conduct commissioning tests without power of grid electricity during periods of high carbon emissions. Under this strategy, the pending commissioning Scope 2 emissions were decreased by about 15 percent as indicated by the PUE and CUE guiding.

There were also close observations about water usage by the means of Water Usage Effectiveness (WUE) measurements incorporated into the dashboards of SIPCS. Project C attained a 20 percent cut in water use against Project A, and extensively due to recycling of condensate used in cooling systems and stemming out temporary use of plumbing in construction. These enhancements show that the sustainability-related controls can be used to simultaneously improve environmental performance and operational efficiency.

It had a positive impact on labor productiveness and use of equipment. By providing this system the project managers could plan the high-energy or resource-intensive tasks under the best conditions, for instance when the carbon intensity in the local grid is lower. Consequently, there was less downtime and the use of equipment was ensured without affecting safety or quality. This can emphasize the fact that SIPCS is not only a tool that can help the environment, but also an instrument that is able to improve the allocation of resources and project implementation.

6.4 Carbon and Waste Management Insights

It is also possible to have an accurate tracking of the embodied carbon in the supply chain with the SIPCS. The system connected procurement logs, material certifications and tracking of construction activities and therefore gave early warning once the carbon targets were about to be surpassed. To give an example, in the event of a hold up of shipment high-carbon steel, the system computed the trade-off cost attached to replacement by other materials and the resulting schedule effect. This actually allowed making a well-informed choice, reducing carbon overshoot, as well as project delays.

Sustainability controls greatly improved the rate of waste diversion. A 94% waste diversion rate in project C was realised against 65percent under project A. Recycling projects that were done on-site like crushing of concrete to form aggregate and re-using packaging materials was credited in the SIPCS system. Table 4 shows the progress of carbon, wastes and energy indicators between the conventional and SIPCS-integrated projects.

Metric	**Project A (Traditional)**	**Project B (Partial SIPCS)**	**Project C (Full SIPCS)**	**Improvement (A → C)**
Embodied Carbon ($kgCO_2e/m^2$)	840	710	585	-30.3%
Operational Energy Savings (%)	0	12	25	+25%
Water Usage Reduction (%)	0	10	20	+20%
Waste Diversion Rate (%)	65	82	94	+29%
Carbon Variance at Completion (%)	+18	+4	-2	-20%

6.5 Lessons on Risk and Resilience

Another project-related focus that was uncovered by SIPCS is project resilience and risk mitigation. Projects implemented on the basis of sustainability-integrated controls had a higher capacity to manage the disruptions of the supply chain, delays in the material availability, and the pressure of regulations. Indicatively, project C Green steel delivery spent 6 weeks delaying deliveries because of the lack of supplier capacity. SIPCS identified this risk early enough wherewith the project managers were able to correct the schedules and source other suppliers who could be certified and also eliminate delays in the critical path.

The shortcomings of work skills were proactively controlled with the help of monitoring tools. Tasks like orbital welding of liquid cooling pipes to the extent of specialization needed selected technicians. SIPCS made schedule and resource planning incorporation of a labor complexity factor that allowed planning of allocation and training better, thus minimizing the chances of mistakes or delays.

The other interesting result was an enhanced compliance ESG reporting. Projects B and C would be able to produce sustainability reports automatically in accordance with the EU CSRD requirements, which would incorporate comprehensive carbon, water and waste data. Project C, specifically, may prove that all significant sustainability goals were achieved or even surpassed, which would increase the level of trust with the regulators, investors, and stakeholders.

6.6 Overall Findings

The long-term results confirm that, SIPCS is value-adding over the conventional project controls:

1. It is able to monitor sustainability indicators like CUE, PUE and WUE in real-time.
2. Its efficiency in operations and resources are enhanced and the use of energy and water is minimized at construction.
3. Embodied carbon tracking and waste management are greatly improved which promotes ESG objectives.
4. A supply chain and labor-related risks can be overcome by making prior preparations and warning.

5. SIPCS used by projects results in increased certifications (LEED Platinum) at cost that can be easily borne with a good ROI.

These observations demonstrate that project control systems based upon sustainability can overcome the existing divide between the environmental goals and the conventional project management limits, which can represent a completely new data center pipeline construction.

7. Discussion: Barriers and Optimization

While the benefits of SIPCS are evident, implementation is not without friction. The primary barrier remains the "Green Premium"--the upfront capital expenditure required for sustainable materials and advanced control software.

7.1 Cost-Benefit Dynamics

Analysis of 2025 market data suggests that while the "Green Premium" for LEED Platinum certification is approximately 7-9% of hard construction costs, the operational savings (OPEX) result in a break-even point within 4.2 years (Wang et al., 2024).

Table 3: Economic Analysis of Green Certification Levels for a 10MW Data Center (2025 Models)

Certification Level	Construction Cost Premium (%)	Energy Savings (Annual %)	Carbon Tax Avoidance ($/Year)	ROI Period (Years)
Certified	0.5%	2-3%	$15,000	0.8
Silver	2.5%	8-10%	$45,000	2.1
Gold	5.2%	15-18%	$110,000	3.4
Platinum	8.8%	25-30%	$240,000	4.2

Table 3 illustrates that for long-term owner-operators (hyperscalers), the investment in Gold or Platinum levels is mathematically sound. However, for "build-to-sell" developers, the incentive is lower unless the project control system can prove the value increment to the buyer.

7.2 Supply Chain Risks

The reliance on specialized low-carbon materials introduces supply chain fragility. The limited number of suppliers for green steel or low-carbon aluminum creates a bottleneck risk. SIPCS mitigates this by assigning a higher "Risk Score" to these WBS elements, triggering earlier procurement triggers and requiring contingency planning (Zhang & Yang, 2021).

8. Conclusion

The construction and operation of next-generation data centers require a fundamental reimagining of project control systems. The separation of financial metrics from environmental metrics is no longer tenable in a 2025 landscape defined by climate urgency and rigorous ESG compliance. This research has demonstrated that the Sustainability-Integrated Project Control System (SIPCS) offers a robust methodology for unifying these competing demands. By embedding Carbon Usage Effectiveness (CUE) and Water Usage Effectiveness (WUE) into the DNA of the Work Breakdown Structure via 6D BIM and Green EVM, project managers can achieve a holistic "Eco-Efficiency" that transcends mere operational energy savings. The data confirms that while initial costs may rise by 2-8%, the lifecycle benefits--including a 30% reduction in embodied carbon and verifiable regulatory compliance--far outweigh the investment. Future research must focus on standardizing these "Green Earned Value" metrics across international borders to facilitate a truly global sustainable digital infrastructure (Torrens et al., 2016).

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