ACADEMIA International Journal for Social Sciences
Volume 5, Issue 3(c), 2026 ISSN-L (Online): 3006-6638

The Cost of Compliance: Aligning NEPA Environmental Impact Statements with Strategic Risk Allocation and Value Engineering in High-Density Data Centre Rollouts

Rao Shahrukh Suleman
shahrukhrao@gmail.com
Institution of Civil Engineers (ICE) UK, Pakistan Engineering Council (PEC)

Corresponding Author: Rao Shahrukh Suleman shahrukhrao@gmail.com

Received: 15-01-2026 **Revised:** 04-02-2026 **Accepted:** 15-02-2026 **Published:** 08-03-2026

ABSTRACT

The rapid expansion of high-density data centers, driven by artificial intelligence demands, frequently triggers the National Environmental Policy Act (NEPA). Historically, the resulting Environmental Impact Statements (EIS) imposed severe regulatory bottlenecks, leading to protracted project delays, increased litigation risks, and massive capital expenditure bleed. However, recent statutory reforms mandating strict two-year EIS completion deadlines have shifted the primary developer risk from prolonged delays to premature project rejection. To address this evolving challenge, this study employs a qualitative theoretical modeling approach to bridge the interdisciplinary gap between environmental jurisprudence and construction management. This study proposes the 'Compliance-Value-Risk' (CVR) integration model, a predictive project delivery framework distinct from retrospective cost value reconciliation accounting. This framework leverages value engineering as a proactive technical strategy to embed sustainable technologies, such as advanced cooling architectures and renewable microgrids, into the early design phase. This satisfies strict EIS evidentiary thresholds and actively secures regulatory approvals. Simultaneously, the model applies strategic risk allocation through agile Engineering, Procurement, and Construction (EPC) contracts. By utilizing phased conditions precedent and revised force majeure clauses, this approach shields developers from the financial fallout of residual regulatory friction. Ultimately, this study demonstrates that by shifting environmental compliance from an isolated legal hurdle to a core project management function, project directors can effectively mitigate the financial and temporal costs of NEPA regulations in modern digital infrastructure rollouts.

Keywords: *National Environmental Policy Act (NEPA); High-Density Data Centres; Value Engineering (VE); Strategic Risk Allocation (SRA); Engineering Procurement Construction (EPC)*

INTRODUCTION

The rapid development of artificial intelligence (AI) and hyperscale computing has triggered significant changes in global infrastructure, fundamentally transforming the scale, scope, and physical needs of contemporary data centres. To sustain advanced graphics processing unit (GPU) architectures, rack power densities are increasing at an unprecedented rate. Consequently, the physical and environmental footprints of these facilities have increased significantly. According to a recent charter of the congressional hearing, the total electricity used by data centres in the United States in 2024 amounted to 183 terawatt-hours (TWh), almost five percent of the total electricity used in the country, with estimates showing an astounding 133 percent of that amount by 2030 (U.S. House of Representatives Committee on Science, Space, and Technology, 2026) With such power guzzlers of electricity and water to cool down their systems, they begin to overlap with federal interests, in terms of either federal lands, federal money, or even the need to get federal permits, thus initiating the enhanced environmental scrutiny.

With developers falling all over each other to roll out these high-density facilities, they are bound to come into conflict with the procedural requirements of the federal environmental statute, the National Environmental Policy Act (NEPA). Adopted to ensure that federal agencies pay close attention to the environmental impacts of their activities, NEPA necessitates the development of an elaborate Environmental Impact Statement (EIS) for major federal activities that have a significant impact on the quality of the human environment. The historical NEPA process has placed a drastic bottleneck on critical infrastructure, whereby there are evidentiary heavy burdens, lengthy interagency processes, and litigation vulnerability to third parties. During this time frame, the conventional project stakeholder perception of the EIS process was that of a single legal obstacle, a completely bureaucratic undertaking pushed out to the environmental consultants. This siloed mindset decoupled environmental compliance from the main engineering and financial plans of the project and made NEPA compliance a long and expensive process, with an average EIS completion time of 4.5 years and preparation costs often reaching as high as 2 million dollars (U.S. House of Representatives Committee on Science, Space, and Technology, 2026).

However, the regulatory environment has recently experienced a fundamental structural change. The Fiscal Responsibility Act (FRA) of 2023 and the following NEPA Phase 2 reforms set up stringent statutory deadlines for environmental reviews, with an Environmental Assessment (EA) and an EIS having one-year and two-year limits, respectively (ICF, 2026; U.S. Department of the Interior, 2026). Although these condensed timelines are meant to speed up deployment, they change the risk profile of infrastructure developers. When the reviewing agency is legally required to have a fixed two-year deadline and the environmental models submitted by a developer on aspects such as thermal management or water consumption are found to be inadequate, the agency may have no administrative capacity to work with the developer on the design through an iterative process. Therefore, the main developer risk has changed from a long bureaucratic delay to the risk of rejection of the project or an unfavourable Record of Decision (ROD). In the case of high-density data centre deployments, permit denial is a direct conversion of extreme capital expenditure (CapEx) leakage, which puts developers at the mercy of fluctuating material prices, interest rates, and the threat of technological obsolescence before the facility has even been excavated (Baker McKenzie, 2025).

A radical change in the approach to project management practices is indispensable to endure this ruthless regulatory landscape. The hypothesis of this study is that environmental compliance should not be a legal mandate but a project management activity that should be undertaken comprehensively. To achieve this, the study proposes the integration model of Compliance-Value-Risk (CVR) model. Care should be taken to clearly differentiate this predictive, strategic framework from the traditional application of the acronym in global construction management, whereby the phrase CVR is globally accepted to mean "Cost Value Reconciliation–a post facto financial audit methodology that is applied to measure actual costs against project budgets. On the other hand, the suggested CVR model functions upstream in the design and contracting phases to respond proactively to the regulatory onus to counteract the downstream profit margins, which traditional accounting methodologies follow.

In particular, the CVR framework assesses the effectiveness of two main executive interventions: value engineering (VE) and strategic risk allocation (SRA). The concept of value engineering, which has traditionally been applied only as a post-design cost-reduction tool, must be redefined to focus on environmental compliance. Through VE-based strategies, especially when implemented in the conceptual design phase, project teams can optimize cooling technologies and energy use to ensure that the strict NEPA evidentiary thresholds are perfectly met on the first submission (Dell'Isola, 1997; Strategic Value Solutions, n.d.). Simultaneously, strategic risk allocation is applied based on strong Engineering, Procurement, and Construction (EPC) contracts that allow the fair sharing of the financial risk of residual regulatory friction among stakeholders. Agile contractual structures with specific force majeure clauses and conditions specific to compliance can protect the developer and keep the project afloat in case the EIS encounters unforeseen legal issues (Aon n.d.).

Although the need to approach the problem in question with an integrated approach is obvious, the existing academic literature is fragmented. Environmental law scholars frequently discuss NEPA jurisprudence separately, and the literature on construction management places a lot of emphasis on VE and EPC contracting and does not properly discuss the limitations of federal regulations. Thus, to help fill this critical gap, the following research question is answered in this study: To what degree can strategic risk allocation and value engineering be used to help mitigate NEPA environmental compliance costs in high-density data centre rollouts? By systematically breaking down this question, this research provides a theoretical plan for project directors and shows how rigorous stewardship of the environment and sophisticated methods of project delivery can turn the cost of compliance from a debilitating barrier into a calculated and thus manageable certainty.

LITERATURE REVIEW & THEORETICAL FRAMEWORK

The Regulatory Bottleneck: Navigating NEPA's Evidentiary Standards

A critical analysis of the available literature demonstrates a deep conflict between the rapid growth of digital infrastructure and the process requirements of federal environmental laws. The spread of Artificial Intelligence (AI) and Hyperscale Computing has radically changed the design and operation requirements of data centres. With an increase in rack power densities to accommodate more sophisticated graphics processing units (GPUs), the demand for energy and cooling has increased. According to the Clemmer et al. (2026), the unrestrained expansion of data centres places a huge burden on the power grids in the area, which exposes people to the likelihood of higher utility rates, health expenditures, and climatic effects fuelled by electricity generation that relies on fossil fuels. Consequently, high-density data centres often initiate the National Environmental Policy Act (NEPA) by funding the project federally, through federal land use, or through federal water permits.

Under NEPA, major actions by the federal government must include the creation of an Environmental Impact Statement (EIS). The literature emphasizes that the standards of evidence that need to be met to meet an EIS have emerged as a crippling regulatory bottleneck in the United States. Project sponsors must provide exhaustive predictive information on three main environmental footprints: Power Usage Effectiveness (PUE), Water Usage Effectiveness (WUE), and Carbon Usage Effectiveness (CUE). Grimm, Green Nylen, and Kiparsky (2026) highlight the high level of regulatory scrutiny of data centre water consumption, especially in water-stressed areas such as California, where cooling systems require large volumes of water, and a more complex federal and state permitting process is needed under the Clean Water Act (CWA).

Previously, the amount of proof needed to meet these metrics made the process of doing so burdensome, with the average EIS completion time extending up to 4.5 years (U.S. House of Representatives Committee on Science, Space, and Technology, 2026). However, the Fiscal Responsibility Act of 2023 and NEPA Phase 2 changes have fundamentally changed the regulatory landscape. Congress has, however, now put in place stringent statutory deadlines with a one-year limit on an Environmental Assessment (EA) and a two-year limit on an EIS (ICF, 2026; U.S. Department of the Interior, 2026). Although intended to speed up deployment, such tight timelines drastically change the character of regulatory risk. No longer is the major threat to developers a lengthy delay, but instead, an untimely project rejection is. With their statutory clock ticking, agencies do not have the bandwidth to review, negotiate, or remediate facilities based on flawed designs, or to do so iteratively. If the resource models of a data centre cannot promptly meet federal thresholds, the agency can simply make a negative Record of Decision (ROD). In this way, the existing literature suggests that NEPA compliance requires technical flawlessness at the time of submission and is an adamant wall to the deployment of infrastructure.

Theoretical Underpinnings: Transaction Cost Economics and Principal-Agent Theory

To gain a complete understanding of the financial and operational repercussions of these regulatory bottlenecks, this study is based on two basic economic theories: Transaction Cost Economics (TCE) and Principal-Agency Theory.

Transaction Cost Economics (TCE)

The TCE was initially developed by Coase and extended by Williamson, and it assumes that there are friction or transaction costs in a transaction beyond the mere cost of production. TCE offers a solid conceptual framework for the cost of compliance in this case study. The costs of transiting through NEPA are high because of the transaction costs caused by the limited rationality and unpredictability of regulations. Through the TCE lens, developers are exposed to severe asset specificity in the development of a data centre; once enormous Capital Expenditure (CapEx) is allocated towards the purchase of land and bespoke infrastructure, the developer is very susceptible to regulatory hold-ups. Hence, Value Engineering (VE) can be considered a tool for reducing transaction costs. The friction of environmental audits is minimized by actively designing sustainable integrations during the design phase, ensuring the proper approval of the EIS within the new statutory deadlines, and lowering the cost of transactions as a whole of regulatory compliance (Dell'Isola, 1997; Strategic Value Solutions, n.d.).

Principal-Agent Theory

As TCE helps explain the cost of the regulatory burden, principal–agency theory sheds light on the distribution of the cost. This theory was developed by Jensen and Meckling and analyses the relationship between a project owner or developer (principal) and an agent (Engineering Procurement and Construction (EPC) contractor). A fundamental failure in risk preferences between the infrastructure rollout team and the end consumer is common in contemporary infrastructure rollouts, and information asymmetry only contributes to this failure to a significant extent. The EPC contractor is also generally more technically knowledgeable in areas such as the precise manufacturing lead times of Original Equipment Manufacturers (OEMs) in the manufacture of advanced direct-to-chip liquid cooling, closed-loop immersion cooling units, Battery Energy Storage System (BESS) components, or even Small Modular Reactors (SMRs). The developer, on the other hand, has a better understanding of the local zoning plans and the specific stimulus behind the environmental permits of the local zoning plans before issuing a **Notice to Proceed (NTP)**

In the case of a NEPA injunction or adverse Record of Decision (ROD) that stops a project, conventional lump-sum contracts fail. In a strict lump-sum system, an antagonistic contractor may strategically exploit a regulatory hold-up to conceal their own supply chain breakdowns and claim that the environmental stoppage is the only reason for the schedule slipping. According to Aon (n.d.), to successfully implement infrastructure projects, they should be aligned with the contract early and with Strategic Risk Allocation (SRA). To deal with this information asymmetry, developers must abandon rigid lump-sum contracts in Favor of joint delivery models, such as Construction Manager at Risk (CMAR) or Progressive Design-Build (PDB). The models rely on open-book accounting and joint risk registers to align the principal and agent so that risks can be managed openly and fairly with the assistance of specific Force Majeure clauses, Conditions Precedent and Liquidated Damages (LDs), which are calculated thoughtfully (Baker McKenzie, 2025).

The Gap: Bridging the Silos of Environmental Law and Construction Management

Although these issues are increasingly pressing, an overall scan of the existing literature reveals an interdisciplinary gap. The jurisprudence of NEPA, the complexity of its procedures, and its local effects have been carefully examined by scholars in the field of environmental law and public policy (e.g., McGrath, 2023; Grimm et al., 2026). Nevertheless, they do not often discuss the impact of these legal frameworks on internal budgeting, contracting, and engineering implementation by developers who have to navigate them.

However, the literature on construction management and engineering seriously dwells on Value Engineering (VE) and Engineering Procurement and Construction (EPC) contracting. The literature on VE is full of works that centre on Lifecycle Costing (LCC) and how to eliminate unnecessary expenses to balance Capital Expenditure (CapEx) with long-term Operational Expenditure (OpEx) (Dell'Isola, 1997), whereas project management reports examine the dynamics of the supply chain and the structuring of contracts. However, these disciplines consider regulatory compliance and Environmental Social and Governance (ESG) commitments as static external constraints, rather than dynamic variables that can be adjusted using strategic management.

The available literature views environmental law and construction management as two separate domains. The existing body of knowledge cannot acknowledge that effective work with an EIS to implement a multi-million-dollar data centre necessitates deep integration of the two disciplines. Thus, the main gap that this study aims to address is the lack of an integrated, executive-level framework. This study fills this gap by combining the hard evidentiary requirements of the NEPA with the tactical uses of value engineering and EPC risk allocation to propose a comprehensive model in which environmental compliance is handled as an inseparable and integral engineering and financial approach rather than a legal appurtenance.

The Gap: Bridging the Silos of Environmental Law and Construction Management

Although these challenges have become increasingly urgent, an interdisciplinary vacuum remains evident in a thorough analysis of the literature. Jurisprudence, procedural complexities, and local effects of NEPA have been carefully examined by scholars in the fields of environmental law and public policy (e.g., Grimm, Green Nylen, and Kiparsky, 2026; McGrath, 2023). However, they seldom discuss the impact of these legal structures on the internal budgeting, contracting, and engineering implementation of the developers that must navigate through them.

Conversely, the literature in construction management and engineering delves into value engineering and EPC contracting. The literature on VE pays much attention to lifecycle cost analysis and the removal of unneeded spending (Dell'Isola, 1997), and project management reports cover the dynamics of supply chains and contract structuring (Aon, n.d.; Baker McKenzie, 2025). However, regulatory compliance is viewed as a fixed external factor and not as a variable that can be changed as part of strategic management.

The available literature considers environmental law and construction management as separate entities. The existing literature does not understand that there must be a synthesis of the two disciplines to be successful in navigating an EIS to the extent of a multimillion-dollar data centre. Hence, the first gap this study aims to address is the lack of an integrated executive-level framework. By combining the harsh evidentiary requirements of the NEPA with the strategic use of value engineering and EPC risk allocation, this study fills the gap and proposes a comprehensive model in which environmental compliance is handled as an integrated engineering and financial solution, and not as a legal side note.

METHODOLOGY

This study uses a qualitative, theoretical approach to conduct systematic research on the overlap between federal environmental regulations and the advanced management of infrastructure projects. Because high-density data centres designed with the explicit purpose of supporting artificial intelligence are a fast-evolving type of asset, there is very little empirical data about these types of centres in the long term, including the regulatory costs that may be involved in their operation. In turn, the conceptual modelling approach is the most rigorous short-term approach to assess how the paradigms of project management could evolve to address such contemporary environmental challenges.

To develop a sound theoretical background, this analysis synthesizes the existing literature in the three traditionally distinct fields of environmental jurisprudence, value engineering (VE), and commercial risk management. Recent regulations in the National Environmental Policy Act (NEPA), environmental impact statement (EIS) guidelines, and congressional evaluations at the federal level are used to define regulatory parameters and minimum compliance costs (U.S. Department of the Interior, 2026; U.S. House of Representatives). In the case of strategic interventions, the research is based on classical literature and contemporary analyses of VE and commercial contracts. The methodology does not consider VE as a means of financial reduction; instead, it uses it as a functional-analysis framework. This study considers how conventional VE steps - starting with information collection and brainstorming to lifecycle cost analysis - can be reused to attain stringent sustainability measures effectively (Dell'Isola, 1997; Wao, 2014). Moreover, the study uses up-to-date industry statistics about Engineering, Procurement, and Construction (EPC) contracting and other alternative delivery models to chart the dynamics of strategic risk allocation in high-stakes settings (Aon, n.d.; Baker McKenzie, 2025; Washington, 2025).

The essence of this methodological approach is to develop a robust conceptual model. In this context, the rigorous evidentiary specifications of an EIS in terms of power usage, carbon emissions, and water footprints are considered key variables contributing to increasing compliance costs. The study then plots the interaction of the independent variables, which are the strategies of VE integration and EPC risk allocation, in mitigating these burdens. This is a hypothetical experiment of how federal environmental reviews could be affected in their early stages by VE to change their course of action by meeting regulatory requirements before they become legal suits. It then breaks down the manner in which a particular contractual structure, including the use of phased conditions precedents and shared risk assessment, can protect the developer against the financial risks of residual regulatory delays.

Methodological Limitations and Empirical Triangulation

Although the conceptual synthesis offered a much-needed background blueprint, the lack of practical constraints in any theoretical model must be recognized. Several critics have lamented that construction management research is overly dependent on interpretative paradigms that are not empirically tested. Because the actual clash of hyperscale computing requirements with the new statutory deadlines of NEPA Phase 2 is a relatively new phenomenon, longitudinal data are still being developed.

Thus, to completely test the hypothesis of a compliance dividend, as postulated in this model, subsequent studies should use data triangulation. In particular, future research ought to conduct quantitative comparative studies comparing the actual NEPA approval schedules of data centre projects using traditional lump-sum, design-bid-build contracts with those using Progressive Design-Build models with front-loaded value engineering. Finally, by recognizing these shortcomings as we integrate different paradigms into one conceptual model, this study is able to go beyond isolated observations. It devises a thorough, long-range, starting point that project directors can use to change NEPA compliance from an unpredictable legal obstacle into a predictable, integrated, engineering, and financial process.

Deconstructing the Environmental Hurdle (The Problem)

EIS Evidentiary Burdens

To fully appreciate the economic and time costs of the National Environmental Policy Act (NEPA), we must first dismantle the exact evidentiary costs imposed on contemporary infrastructure developers in the United States. The change to artificial intelligence (AI) has substituted traditional server farms with hyperscale and high-density data centres. These facilities attract unprecedented electrical loads. In the United States alone, data centres consumed 183 terawatt-hours (TWh) of electricity in 2024, which is more than four percent of the total amount of electricity that the national grid could generate (U.S. House of Representatives Committee on Science, Space, and Technology, 2026). When a project as large as this one has led to federal control, the resultant Environmental Impact Statement (EIS) has turned out to be a mere compliance checklist. Rather, it turns out to be a tiring scientific justification of the footprint of the facility’s resources.

At this point, federal agencies and environmental regulators demand rigorous technical demonstrations by project sponsors in terms of power generation and thermal management. Developers cannot simply promise efficiency; they must present detailed predictive models that compute Power Usage Effectiveness (PUE), Carbon Usage Effectiveness (CUE), and Water Usage Effectiveness (WUE) (Innovation for Cool Earth Forum, 2025). To enable high-density cooling, conventional air-based HVAC systems must be compromised to meet federal resource conservation requirements. This leaves developers with the obligation to design and defend the feasibility of advanced systems, such as direct-to-chip liquid cooling or closed-loop immersion systems in court.

To demonstrate that such highly developed systems will not indefinitely drain local water aquifers, costly hydrological research and engineering projections will be necessary. In water-stressed areas, such as California, the permits required to be obtained according to the Clean Water Act Section 404 permit regulations will require detailed evidence that the cooling system at the facility will not negatively affect the local water quality and quantity (Grimm et al., 2026). Likewise, developers must demonstrate that their power generation plans comply with federal anti-pollution requirements, and in many cases, the inclusion of renewable microgrids to counteract the huge carbon footprint of ongoing activities is necessary (Union of Concerned Scientists, 2026).

In the past, such a volume of technical evidence could take the form of a sluggish bureaucratic procedure, and an EIS took an average of 4.5 years to prepare and cost more than $2 million to prepare (U.S. House of Representatives Committee on Science, Space, and Technology, 2026). However, this has changed with the introduction of the Fiscal Responsibility Act of 2023 and the ensuing NEPA Phase 2 reforms, which radically changed the dynamics. Congress has now taken the stern statutory deadlines and enacted a two-year limit to complete an EIS (U.S. Department of the Interior, 2026). Although intended to speed up deployment, compressed timelines are counterintuitive, with the developer’s risk increasing as a result of shorter timelines. Agencies under a strict statutory clock cannot trade off or refreeze poor facility designs through iterative processes. Should the provided environmental models not meet federal standards at once, the greatest threat to the developer will cease to be a lengthy wait, but an early dismissal of the project and a negative Record of Decision (ROD).

Federal vs. Local Friction

The mass of the federal EIS process makes it inherently difficult to relate projects to local municipalities. A clear jurisdictional conflict arises when federal environmental requirements conflict with local zoning regulations and local stakeholder interests.

A developer may suggest constructing special on-site power to meet the high standards of NEPA regarding grid stability and emissions, such as gas turbines, or erecting large evaporative cooling towers. Although these solutions theoretically meet federal EIS demands for operational reliability, they can often provoke dramatic local opposition. Municipal zoning boards and local communities resist high-density data centres because of the perceived air pollution in the area, ambient noise produced by cooling devices, and enormous burden on municipal water resources (Innovation for Cool Earth Forum, 2025).

Modern statistics and legal tendencies show an enormous increase in organized, well-financed third-party litigation focused on this jurisdictional conflict (McGrath, 2023). For example, in Virginia, a world leader in the development of data centres, several lawsuits have been filed against the cumulative environmental effects of the Digital Gateway, a hyperscale project of 2,100 acres. Similarly, in Minnesota, the Project Skyway has been subject to hard-fought litigation by environmental activist groups on whether their environmental mitigation strategies can be enforced. Moreover, Grimm et al. (2026) observed that such tensions have recently escalated in Memphis, where the installation of methane gas turbines to create an xAI computing plant received strong community resistance and legal challenges regarding air quality.

The project director suffers a crippling paradox by this geography. The engineering solutions that are required to sail over the federal NEPA hurdle usually compound local zoning hurdles. The developer finds himself in a jurisdictional tug of war: to make changes to the facility design to please a local city council could invalidate the technical demonstrations made earlier to the federal EIS, and the project would have to begin anew. Lastly, the literature demonstrates that without a single strategy to reconcile these conflicting regulatory demands, high-density data centre projects are placed in a death spiral of redesign, political battles and catastrophic schedule overruns.

Value Engineering for Compliance (Solution Variable 1)

Redefining VE: Shifting from Traditional Cost-Cutting to Legal Environmental Compliance

Traditionally, value engineering (VE) has been poorly defined in the construction and infrastructure sectors as a crude tool for post-design cost reduction, and is sometimes derogatively called value stripping. According to Dell'Isola (1997), most traditional project delivery methodologies do not enable the use of programmed input to provide total quality control or value assurance; rather, VE is considered a reaction to overestimated designs and ensures their alignment with strict capital budgets. However, in the highly controlled environment of the mass rollout of data centres, this outdated paradigm is fundamentally inadequate.

To overcome the deep regulatory bottlenecks detected in the previous sections, we be rebranded to align with the practice of advanced systems engineering. The current guidelines issued by the Federal Highway Administration (n.d.) and the U.S. Department of Défense (2025) state that VE should serve as a tool to enhance total capability, performance, and safety, as opposed to merely lowering initial spending. Hence, VE will no longer be a fiscal scalpel; it will be a strategic tool to realize legal environmental compliance and not ruin the project’s return-on-investment (ROI).

Importantly, the success of this intervention depends on when it is implemented. Wao (2014) and Anthony (2025) affirmed that a good VE process should be implemented as soon as possible, at the 0 to 30 percent design completion stage. When VE is not implemented at the early design stage, the project choices considered under the National Environmental Policy Act (NEPA) have already been determined, and the developer is unable to apply engineering innovations to circumvent regulatory drag. Through functional analysis in the first NEPA scoping phase, project directors can modify the objective function of VE to be not the lowest initial cost but the maximum regulatory viability (Strategic Value Solutions, n.d.). This proactive congruency will ensure that the technical requirements of the data centre are a direct response to the evidentiary burdens of the Environmental Impact Statement (EIS) and that the project design is readily defensible to environmental litigation, as well as regulatory backlash.

Techno-Commercial Feasibility: Evaluating Sustainable Integrations via Lifecycle Costing

The main challenge in implementing a higher level of sustainable technologies to meet NEPA requirements is the high increase in initial Capital Expenditure (CapEx). The requirements of artificial intelligence in the form of high-density computing architectures necessitate thermal management and active power generation. MarketsandMarkets (2025) stresses that the growing power needs of contemporary racks make it incredibly difficult to obtain a balanced coolant supply, necessitating sophisticated piping systems and liquid cooling architectures such as direct-to-chip or closed-loop immersion systems. Amoabeng and Choi (2016) also noted that a conventional cooling system typically consumes over one-third of all energy used in a data centre; thus, thermal control is the first point of focus in terms of minimizing energy consumption and policy regulation.

The developers of these advanced systems will have to use Lifecycle Costing (LCC) as the financial engine of their VE strategy to overcome the CapEx barrier. Benesch (n.d.) points out that an accurate LCC analysis includes not only the first cost of the facility but also its maintenance, operation, agency, and user costs over the useful life of the facility. When compared using a limited and short-term CapEx model, the addition of a closed-loop water recycling system, Battery Energy Storage System (BESS), or renewable microgrid may appear costly to the sponsor of a project. Nevertheless, such integrations have deep techno-commercial viability when assessed using comprehensive life cycle costing (LCC) methodologies.

To begin with, these greener technologies drastically reduce Operation Expenditure (OpEx) through the life of the facility. Wenzel et al. (2023) showed that the further development of hybrid and free cooling systems opens significant opportunities to save resources, greatly decreasing not only the specific electricity consumption but also the freshwater consumption. The Innovation for Cool Earth Forum (2025) is a firm proponent of the quick uptake of waterless cooling systems and solid clean power as a means of reducing the environmental footprint in resource-strained areas. The direct integration of these systems can enhance the water Usability Effectiveness (WUE) and Power Usability Effectiveness (PUE) of a facility, which can significantly reduce the monthly utility costs by a large margin.

Second, and most importantly, to answer the research question, a huge compliance dividend is the result of the integration of these technologies. Halawa (2024) observes that although such common measures of traditional economics as Levelized Cost of Electricity (LCOE) are widely used, they often do not reflect the catastrophic costs of project delays, which are systemic in nature. With the new law on statutory reviews of the EIS, the fine for delivering a faulty or polluting design has ceased to be a slackening bureaucratic postponement; it is a simple project cancellation. With front-loaded VE, to incorporate sustainable technologies that mathematically exceed NEPA environmental thresholds, developers effectively inoculate the risk of pre-emptive rejection and resultant third-party litigation. When a highly sustainable design passes the NEPA process in 18 months, compared to the traditional design, which is outright rejected or subjected to years of litigation on appeal, the CapEx premium of the sustainable technology is fully recovered. Simply put, stringent value engineering will turn the fixed cost of being legally compliant into a financial benefit that will make the infrastructure project not only legally compliant but also commercially profitable.

EPC Contractual Risk Allocation (Solution Variable 2)

Structuring for Regulatory Shock: Mitigating Information Asymmetry

Although value engineering is the main technical tool to proactively meet federal environmental thresholds, it cannot remove the lack of predictability of the National Environmental Policy Act (NEPA) review process. Even the most sustainably designed high-density data centres can be prone to an emergency interagency rub against the docket or even localized third-party lawsuits. Consequently, project directors must introduce a secondary defensive variable: strategic risk allocation (SRA). In the framework of mega-project development, SRA is conducted with the careful organization of the Contract of Engineering, Procurement and Construction (EPC).

Traditionally, infrastructure developers have depended on the use of traditional firm fixed-price or firm lump-sum contracts. Under this archaic model, the project owner (the principal) tries to transfer the totality of the financial and time risks to the agent (the contractor). However, according to modern economic literature, this model is essentially flawed when applied to the modern regulatory environment because of a high level of information asymmetry. The EPC contractor involved in hyperscale implementations can often be better informed about supply chain susceptibilities (e.g., the manufacturing lead time of more sophisticated liquid cooling parts or switchgears). However, the developer is better informed about the particular triggers of their environmental permits and local zoning restrictions.

A strict lump-sum contractor is forced to opportunistically seek to cover the failure of his or her supply chain by taking advantage of the regulatory delay, which can be brought about by an unexpected NEPA injunction or denial of a permit, causing a project to stall and the contractor to begin pressing the owner with aggressive claims (Aon n.d.). To buffer these regulatory shocks on high-density data centre rollouts, developers must shift towards collaborative, agile contracting models. Progressive Design-Build (PDB) or Construction Manager at Risk (CMAR) models use joint risk assessments and open-book accounting, where the contracting parties work together to determine the project-specific vulnerability at the early design-build stage (Black Bull Construction Group, n.d.; Washington, 2025). Developers nurture a robust contractual environment that is capable of bearing the frictions of the EIS process without collapsing by clearly transferring the financial risks of environmental delays to the party that is best suited to address them.

Contractual Architecture: Drafting Specific Conditions Precedent

The architectural structure of the EPC contract must change to the utmost specificity to make this risk-sharing process possible. The most critical change is the strategic application of the conditions precedent. A condition precedent is a legal aspect whereby, prior to the binding of a contract, a party must have a certain event take place before the contractual obligation can be binding. With normal infrastructure deployment, material procurement and site mobilization can be triggered by a simple issuance of a " Notice to Proceed" (NTP), which can result in huge and irreversible capital expenditures (CapEx).

The developer is at great risk if a blanket NTP is issued before finalizing the EIS. If the federal regulators do not accept the environmental models in relation to the water use or power generation of the facility, the developer will still have to pay the contractor the sunk costs. To reduce this, Baker McKenzie (2025) pointed out that data centre contracts must be customized to address intricate regulatory schedules. Project directors can create a conditional release of funding to correspond to NEPA milestones by creating phased preconditions. An example is the case of early funding, which may be under contractual restrictions for site grading and foundation work until a formal issuance of a Record of Decision (ROD) by the federal lead agency. This incremental strategy safeguards the stack of multiple layers of financing offered by institutional investors and infrastructure debt funds, ensuring that high-yield capital is not fully deployed until regulatory certainty is attained (Beckman et al., 2026).

Revising Force Majeure for Regulatory Injunctions

The second essential change to the EPC architecture is that the parameters of force majeure must be redefined. Conventionally, force majeure provisions absolve the two parties of irresolvable, unpredictable circumstances, technically known as Acts of God (e.g., extreme weather or earthquakes). Nevertheless, regulatory threats to project continuity are usually the most critical in scrutinized fields such as AI infrastructure.

The regulatory risk profile has changed fundamentally with the introduction of the Fiscal Responsibility Act and NEPA Phase 2 reforms, which have strict two-year statutory deadlines for the EIS (U.S. Department of the Interior, 2026). When a federal agency issues a sudden adverse ROD because of time constraints in the timeline, or when well-financed third-party litigation stops construction, typical force majeure clauses tend not to be sufficient. Aon (n.d.) recommends that to enhance contractual hygiene, the stakeholders of a project should go out of their way to harmonize their terms to align with foreseeable problems, such as sudden regulatory interference. Thus, the EPC contract should be negotiated intensively to agree on an explicit description of federal permitting rejections, litigations based on NEPA, and municipal zoning rejections as qualifications for force majeure events. This amendment helps the contractor avoid penalizing the developer in instances where there is a delay that is not in the control of the developer and, at the same time, gives the contractor a justifiable extension of time.

Enforcing Supply-Chain Accountability for Environmental Metrics

Finally, strategic risk placement should go beyond the general contractor of the EPC and extend to the supply chain. The EIS of a data centre is certified according to very specific and stringent predictive models of Power Usage Effectiveness (PUE) and Water Usage Effectiveness (WUE) (Baker McKenzie, 2025). Should the facility be constructed and fail to work within such accepted environmental limits, the developer would suffer harsh federal fines, the ability to continue operations, and a devastating reputation blow.

Thus, stringent supply chain accountability needs to be imposed in the EPC contract. Diem et al. (2024) note that current buyer-supplier relationships are not based on transactional relationships but on strategic partnerships that are closely connected to Environmental, Social, and Governance (ESG) concepts. This dynamic must be exploited by project directors to introduce powerful liquidated damages (LDs) directly linked to the environmental performance guarantees of the purchased equipment. If an Original Equipment Manufacturer (OEM) supplies high-density liquid cooling units that do not comply with the water conservation metrics stated in the federal EIS, the EPC framework should impose a financial burden on the underperformance of the supplier, rather than the developer (Baghalzadeh Shishehgarkhaneh et al., 2025; Baker McKenzie, 2025). Through these environmental performance assurances passing down the supply chain, the developer can mathematically assure that the facility is performing as required by the statutory requirements under the federal environmental law, balancing the financial incentives of global manufacturers with the legal requirements under the federal environmental law.

DISCUSSION: THE 'COMPLIANCE-VALUE-RISK' INTEGRATION

The Synthesis: Proposing the CVR Theoretical Model

To provide a conclusive answer to the research question of whether the level of strategic risk allocation (SRA) and value engineering (VE) can reduce environmental compliance costs, this study proposes a model for integrating compliance, value, and risk, called the compliance-value-risk (CVR) integration model. There is an urgent need to clearly differentiate this forecasting and strategic model from the customary use of the acronym in commercial management and surveying. In traditional construction books, "CVR" refers to Cost Value Reconciliation, a post-factum financial audit procedure used to compare the actual cost of construction and the value of work completed to monitor the erosion of margin. In contrast, the suggested compliance value-risk model is used in the upstream stage in the conceptual design and contracting stages. This predictive CVR model proactively guards the downstream profit margins that are followed by more traditional Cost Value Reconciliation reports by neutralizing regulatory burdens long before they become a reality.

The basic assumption of this predictive model of CVR is that environmental compliance, engineering design, and commercial contracting are no longer independent silos in the project life cycle. Treating the National Environmental Policy Act (NEPA) review process as an external, independent obstacle, developers are sure to face a catastrophic schedule slip and capital expenditure (CapEx) hemorrhage. This is rectified in the CVR model, where VE is placed as the offensive technical approach and the Contract of the Engineering, Procurement and Construction (EPC) as the defensive commercial cover.

The synthesis begins in the preconstruction stage. As VE is inherently timed in a comprehensive assessment of infrastructure delivery, an untimely VE study has been identified as the most common cause of missed cost-saving opportunities and the need to execute costly environmental reconsiderations; a VE study is often untimed (usually as the NEPA process is nearing its end), leading to failure to save costs and requiring expensive environmental reconsiderations (Anthony, 2025) VE is forcibly front-loaded within the CVR model. The project team considers sustainable integrations, including advanced closed-loop liquid cooling and renewable microgrids, by conducting rigorous multidisciplinary VE workshops during the first stage of the scoping phase, directly into the baseline architecture. This precocious engineering is a successful way to nullify the apparent evidence of the Environmental Impact Statement (EIS). Once the developer presents an EIS that mathematically shows better Power Usage Effectiveness (PUE) and Water Usage Effectiveness (WUE), the significant chance of continuing interagency friction or warranted third-party litigation is extremely low (Amoabeng & Choi, 2016; McGrath, 2023). Therefore, VE proactively educates and speeds up the filing of the EIS, turning environmental compliance into a bureaucratic stopwatch and engineered guarantee.

However, the CVR model acknowledges the uncertainties in federal regulatory environments. Even a properly designed plant may be vulnerable to an administrative choke point or a malaise of local pressure group lawsuits (Grimm, Green Nylen, and Kiparsky, 2026). In this case, a defence perimeter and SRA that takes the shape of an EPC contract provides it. Should the EIS approval be refused or delayed (unlikely) under the contractual arrangement, that is, the phased conditions precedent and broadly defined force majeure, it will mean that the contractor is not able to initiate devastating claims of delay against the developer. In addition, joint risk assessment methods, including Construction Manager at Risk (CMAR) or Progressive Design-Build, may be used to distribute the risks of regulatory injunctions fairly (Black Bull Construction Group, n.d.; Washington, 2025). By properly coordinating the two variables, the developer can address the environmental needs of the federal government with VE and simultaneously secure the project’s financial viability with the SRA.

The Executive Mandate: Redefining the Project Director

An overall change in project leadership is also necessary for the effective application of the CVR model in construction projects comes to pass. The Project Director (PD) has traditionally been viewed as a professional in the construction industry, who is skilled in balancing the Iron Triangle of cost, scope, and schedule. In this classical model, the PD usually hands over the environmental permitting process to professional consultants and corporate counsel with contractual liability matters. Nevertheless, the advent of high-density AI-driven data centres, which are not only massive but also highly controlled, makes this segmented leadership style deadly and obsolete. The current paper recommends an Executive Mandate, and one way to restructure the Project Director position in the present-day context is to view it as a strategic integrator of law, finance, and engineering, instead of an operational implementer. To cut through these complexities, a leader with a multilayered financing structure and cross-functional knowledge of the overlap between NEPA regulations and hyperscale cooling technologies is needed. A major push is badly needed in the field to improve the skills of the workforce in the specified area to cope with contemporary interdisciplinary challenges, as Pearson et al. (2025) describe in their analysis of the Environmental, Social, and Governance (ESG) principles in the architecture, engineering, and construction (AEC) sectors. The existing PD must be in a position to convert the inflexible statutory wording of an EIS in a federal system to the technical requirements of a mechanical engineering schematic and then implement such measures in the liquidated damages component of an EPC subcontract. Moreover, the PD must play a central mediatory role between the realities on the ground of the construction site and the risk-taking ability of institutional capital. The capital structure of mega-infrastructure projects is more complicated, where commercial banks cover initial construction risk, infrastructure debt funds cover subordinated exposures, and institutional investors cover long-term capital (Beckman et al., 2026). There is an urgent need to demonstrate the utmost predictability of sophisticated financial stakeholders. A Project Director who views NEPA as a legal matter is not in a good position to persuasively convince lenders that the debt serviceability of the project is safe despite the risk of the possibility of years-long injunctions. On the other hand, a Project Director working under the CVR model uses value engineering in the early stage and effective EPC risk allocation to prove to the lenders mathematically that the cost of compliance is not only limited but also charged. Finally, the Executive Mandate compels the Project Director to be more than the desired role of conventional construction management. Their role is supposed to be the key designers of project certainty and a dynamic matching of the ecological needs of the state, the technological needs of artificial intelligence, and the extreme financial needs of global market systems. This integrative position will enable project leadership to overcome the uncertainties caused by existing digital infrastructure implementations to ensure that future utilities are implemented efficiently, profitably, and sustainably.

CONCLUSION

This study aimed to rigorously establish the extent to which strategic risk allocation and value engineering can be practical means to reduce enormous environmental compliance costs in the implementation of high-density data centres in the rollout of the National Environmental Policy Act (NEPA). The results convincingly illustrate that these new paradigms of project management, when strategically combined, have the potential to fundamentally defuse the time and money costs of federal environmental review. The old and disjointed paradigm, which considers an Environmental Impact Statement as a one-dimensional bureaucratic obstacle, dealt only with the legal counsel that needs to be abandoned. This study confirms that environmental compliance should be a fundamental and integrated project management role. Developers can meet the cumbersome federal evidentiary standards by looking to the future instead of the past through the proposed predictive compliance value-risk model. Value engineering, as a technical frontier, integrates important resource-saving technologies in the early stages of design to ensure irreducible regulatory acceptance and avoid early rejection of the project under harsh new statutory deadlines.

Simultaneously, strategic risk allocation is a business buffer with agile contractual architecture to shield the project's financial viability against any remaining regulatory friction.

The implications of this research are dire and tactical for coders going forward in the vulture-like and extremely competitive realm of artificial intelligence infrastructure. Industry leaders ought to know that attempting to impose outdated and inefficient infrastructure designs through the highly examined federal review process is an easy path to schedule meltdowns and catastrophic spurts in capital expenditure. The main lesson that the sector can learn is that project leadership must be redefined. Project directors must transform themselves into strategic integrators beyond the operational implementation of traditional operations to ensure that there is a harmonious linkage of the statutory provisions of environmental law with the physical reality of sophisticated thermal management systems and the inflexible edges in sophisticated debt structures. Moreover, system developers must capitalize on collaborative delivery to jointly spread the risk of regulatory unpredictability on their supply chain partners instead of imposing adversarial lump-sum risk transfers. When environmental sustainability is considered a key measure of commercial soundness, as opposed to grudging acquiescence to federal regulatory authorities, developers can depend on attaining the breakneck pace-to-market that the artificial intelligence industry demands.

Although this paper presents a sound theoretical foundation for working around tricky federal environmental mandates, there is a need to recognize the natural constraints of purely theoretical and qualitative modelling. Since the immediate collision of hyperscale computing needs with the accelerated statutory deadlines of new environmental reforms is a relatively young phenomenon, longitudinal data are particularly deficient. Thus, the next generation of scholarship should shift towards conceptual modelling for specific empirical triangulation. Researchers will have to go out of their way to measure the exact financial effects of the measures suggested in this study. The discipline needs actual on-the-job case studies that quantify the precise accelerations of schedules and savings of capital costs achieved when the explicit deployment of front-loaded value engineering is made. In particular, quantitative comparisons of the real approval timelines of projects with the use of the traditional lump-sum contracting and the projects with the use of Progressive Design-Build models will be invaluable. Building these theoretical paradigms of project management based on hard empirical evidence would provide an irrefutable evidence-based playbook for building the next generation of sustainable and legally viable critical infrastructure.

REFERENCES

Amoabeng, K. O., & Choi, J. M. (2016). Review on cooling system energy consumption in internet data centers. *International Journal of Air-Conditioning and Refrigeration, 24*(4), 1630008.

Anthony, M. H. (2025). *A comprehensive study of SCDOT's application of the value engineering process* [Certified Public Manager project]. South Carolina Department of Transportation.

Aon. (n.d.). *Managing the top 3 risks in infrastructure projects: What you need to know*. Retrieved from https://www.aon.com/en/insights/articles/managing-the-top-3-risks-in-infrastructure-projects-what-you-need-to-know

Baghalzadeh Shishehgarkhaneh, M., Moehler, R. C., Fang, Y., Hijazi, A. A., & Aboutorab, H. (2025). A comprehensive taxonomy of supply chain risks in construction project management: A systematic literature review. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction, 17*(4). https://doi.org/10.1061/JLADAH.LADR-1241

Baker McKenzie. (2025). *Data centers unlocked: What's new and what matters*. Retrieved from https://www.bakermckenzie.com/en/insight/publications/2025/12/data-centers-unlocked

Benesch. (n.d.). *Value methodology*. Retrieved from https://www.benesch.com/services/value-methodology/

Black Bull Construction Group. (n.d.). *Construction manager at risk (CMAR): Expert project delivery services for federal projects*. Retrieved from https://blackbullcg.com/

Beckman, S., Clements, P., Le Bret, M., & Ricciardelli, A. (2026). Infrastructure debt: Alternative credit to finance the future. CFA Institute Research Foundation.

Dell'Isola, A. (1997). *Value engineering in the construction industry* (3rd ed.). R.S. Means Company.

Diem, D. A. R., Marimin, Machfud, & Anggraeni, E. (2024). Service quality, business ethics, and governance of buyer-supplier relationship to enhance competitiveness: Critical literature review. Jurnal Teknologi Industri Pertanian, 34(3), 257.

Federal Highway Administration. (n.d.). *Value engineering - Design*. U.S. Department of Transportation. Retrieved April 23, 2026, from https://www.fhwa.dot.gov/ve/

Grimm, M., Green Nylen, N., & Kiparsky, M. (2026). *Regulating data center water use in California*. Center for Law, Energy & the Environment, UC Berkeley School of Law.

Halawa, E. (2024). Sustainable energy: Concept and definition in the context of the energy transition—A critical review. *Sustainability*, *16*(4), 1523.

ICF. (2026). *NEPA implementation: What project sponsors need to know*. Retrieved from https://www.icf.com/insights/environment/project-sponsor-eis-nepa-compliance

Innovation for Cool Earth Forum. (2025). *Sustainable data centers roadmap: Findings and recommendations*. Retrieved from https://icef.go.jp/wp-content/themes/icef_new/pdf/roadmap/icef2025_roadmap%20Oct%209.pdf

MarketsandMarkets. (2025). Data center cooling market report 2025-2032. Retrieved from https://www.marketsandmarkets.com/Market-Reports/data-center-cooling-solutions-market-1038.html

McGrath, C. (2023). Three’s a crowd: Conflicts of interest in third-party preparation of environmental impact statements and evolving agency responsibility under NEPA. *Hastings Environmental Law Journal*, *29*(2), 165–190.

Pearson, Y. E., Alexander, Q. G., Cropps, T. A., & Thornton, T. A. W. (2025). Opportunities for advancing ESG principles through academic–workforce collaborations. *Journal of Management in Engineering*, *41*(4), 05025001. https://doi.org/10.1061/JMENEA.MEENG-6566

Strategic Value Solutions. (n.d.). *Value engineering*. Retrieved from https://svs-inc.com/services/value-engineering/

Clemmer, S., Chavez, M. F., Dotson, S., Gignac, J., Sattler, S., & Shaver, L. (2026). Data center power play: How clean energy can meet rising electricity demand while delivering climate and health benefits. Union of Concerned Scientists. https://doi.org/10.47923/2026.16051

U.S. Department of Defense. (2025). *Value engineering: A guidebook of best practices and tools* (SD-24). Office of the Under Secretary of Defense for Research and Engineering.

U.S. Department of the Interior. (2026). National Environmental Policy Act implementing regulations. *Federal Register*, *91*, 8738–8762.

U.S. House of Representatives, Committee on Science, Space, and Technology. (2026). *Powering America's AI future: Assessing policy options to increase data center infrastructure* [Hearing charter].

Wao, J. O. (2014). *Value engineering methodology to improve building sustainability outcomes* [Doctoral dissertation, University of Florida].

Washington, L. (2025). Design-build fosters collaboration, flexibility. *Construction Dive*. Retrieved from https://www.constructiondive.com/news/design-build-fosters-collaboration-flexibility/743617/

Wenzel, P. M., Mühlen, M., & Radgen, P. (2023). Free cooling for saving energy: Technical market analysis of dry, wet, and hybrid cooling based on manufacturer data. *Energies, 16*(9), 3661.