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A Data-Driven Framework for Agile Prioritization of Sustainable Energy Infrastructure Projects Using Stakeholder Value, Risk, and Delivery Capacity Metrics in Regulated Industrial Environments

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Abstract: The transition toward low-carbon and resource-efficient industrial systems has increased investment in sustainable energy infrastructure while intensifying the challenge of selecting and sequencing projects under capital, regulatory, technical, and organizational constraints. Conventional project-prioritization methods often emphasize financial return or strategic alignment without adequately integrating stakeholder value, multidimensional risk, delivery capacity, regulatory readiness, and sustainability performance within a single adaptive decision framework. This study developed and applied a data-driven framework for the agile prioritization of sustainable energy infrastructure projects in regulated industrial environments. The framework evaluated candidate projects across five principal decision dimensions: stakeholder value, project risk, delivery capacity, regulatory readiness, and sustainability contribution. Heterogeneous project indicators were standardized, weighted, and aggregated using a multi-criteria decision analysis structure to generate integrated priority scores, while risk-adjustment and capacity-constraint mechanisms prevented strategically attractive but poorly executable projects from receiving disproportionate priority. An agile reprioritization component was incorporated to update project rankings as costs, risks, resource availability, regulatory conditions, and stakeholder requirements changed. The empirical evaluation applied descriptive statistics, normalization, weighting, composite scoring, sensitivity analysis, scenario analysis, ranking-stability assessment, and benchmark comparison with established prioritization approaches. The results showed that projects with the highest stakeholder or sustainability value did not necessarily achieve the highest overall priority when project risk, delivery capacity, and regulatory readiness were incorporated. Waste-heat recovery achieved the highest baseline Integrated Agile Priority Score, followed by solar photovoltaic generation and the energy-efficiency retrofit, while carbon capture and green hydrogen ranked lower because of comparatively higher risk, weaker delivery capacity, and lower regulatory readiness. Dynamic reprioritization further showed that project rankings changed materially when implementation conditions improved, confirming the responsiveness of the framework to evolving portfolio conditions. The principal contribution of the study is an integrated and transparent prioritization architecture that links strategic value with execution feasibility, sustainability performance, and regulatory constraints while retaining the flexibility required for dynamic portfolio management. The framework provides a structured basis for more defensible capital allocation, improved traceability of investment decisions, stronger alignment between sustainability objectives and organizational capability, and more effective portfolio governance in regulated energy-intensive industries.

Keywords: *Sustainable Energy Infrastructure; Agile Prioritization; Stakeholder Value; Project Risk; Delivery Capacity; Regulated Industries; Multi-Criteria Decision Analysis; Project Portfolio Management.*

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I. INTRODUCTION

➢ *Background of the Study*

The global transition toward lower-carbon, more resilient, and resource-efficient energy systems is reshaping the scale and composition of infrastructure investment. Sustainable energy infrastructure now encompasses renewable electricity generation, energy storage, industrial electrification, energy-efficiency upgrades, low-carbon fuels, grid modernization, waste-heat recovery, carbon-management systems, and supporting digital infrastructure. The International Energy Agency (IEA) identifies energy investment as a central indicator of the direction and pace of energy-system transformation and reports that capital allocation is increasingly influenced by energy security, technological change, financing conditions, policy priorities, and regional market dynamics [1].

For regulated industrial organizations, however, the expansion of sustainable energy investment creates a portfolio-management problem rather than merely an investment-selection problem. Organizations may simultaneously consider projects that differ substantially in capital intensity, technology maturity, implementation duration, expected emissions reduction, operational benefit, regulatory exposure, stakeholder acceptance, resource requirements, and dependence on existing infrastructure. These alternatives therefore cannot be assessed reliably through a single economic measure. International Organization for Standardization (ISO) guidance on portfolio management recognizes that portfolio-management principles must be adapted to the organizational and operating context in which projects and programmes are undertaken [2], [29].

Sustainable energy decisions are inherently multi-dimensional. A project with a strong financial return may have limited sustainability value, while another project with substantial emissions-reduction potential may be constrained by technology risk, regulatory uncertainty, insufficient engineering capacity, or long implementation lead times. Similarly, a technically mature project may have weak stakeholder support, whereas a strategically important project may compete for scarce capital and specialist resources with mandatory compliance projects. Early and subsequent research on sustainable energy decision-making has consequently emphasized the use of Multi-Criteria Decision Analysis (MCDA) to integrate economic, technical, environmental, and social considerations that cannot readily be reduced to a single criterion [3], [4].

The complexity is greater in regulated industrial environments because project priority is influenced by more than value creation. Regulatory approval, environmental permitting, safety requirements, technical standards, statutory deadlines, grid-connection conditions, emissions limits, and organizational governance requirements can affect whether a project is executable and when it can enter implementation. Portfolio prioritization must therefore distinguish between the intrinsic attractiveness of a project and its practical readiness for execution. In this context, delivery capacity is an important decision variable because capital availability alone does not ensure successful implementation. Engineering capability, competent personnel, contractor availability, supply-chain readiness, organizational workload, technical maturity, and management capacity collectively determine whether a project can be delivered within its intended cost, schedule, and performance envelope.

The sustainability dimension further complicates project comparison because environmental, economic, technical, and social indicators often operate on different measurement scales and may conflict. Renewable and sustainable energy studies have therefore increasingly employed MCDA methods to formalize trade-offs among heterogeneous criteria [4], [5]. Robustness research has also demonstrated that project or technology rankings can vary when criterion weights change, indicating that sensitivity analysis should form part of a credible prioritization process rather than being treated as an optional supplementary exercise [5], [30].

Conventional project prioritization commonly relies on techniques such as Net Present Value (NPV), Internal Rate of Return (IRR), payback period, strategic scoring, expert judgment, or simple weighted matrices. These methods remain useful but can become inadequate when decisions involve interacting financial and non-financial objectives, regulatory restrictions, uncertain implementation conditions, and rapidly changing portfolio constraints. A static score calculated at project initiation may become obsolete if project cost increases, regulatory approval is delayed, organizational capacity changes, stakeholder expectations shift, or a new sustainability target alters strategic value. The resulting decision problem is therefore not only one of ranking projects correctly at a single point in time, but also of updating priorities systematically as conditions evolve.

Adaptive project-management approaches provide a useful basis for addressing this requirement. ISO 21502:2020 recognizes predictive, incremental, iterative, adaptive, hybrid, and agile delivery approaches as valid depending on the nature of the project and its outputs [6]. Although agile methods originated largely in environments characterized by short development cycles, the underlying principles of iterative review, rapid incorporation of new information, and priority adjustment can be extended conceptually to infrastructure portfolio governance. In such an application, agility does not imply that physical infrastructure projects are executed using software-style sprints. Rather, it refers to the ability of the portfolio decision system to re-evaluate and reorder projects when their value, risk, readiness, or resource requirements materially change [32].

A data-driven prioritization framework is therefore required to convert project information into standardized, traceable, and periodically updateable decision metrics. Such a framework should combine stakeholder value, project risk, delivery capacity, regulatory readiness, and sustainability contribution while maintaining sufficient transparency for management review and regulatory scrutiny. It should also allow project rankings to be tested under alternative assumptions and scenarios. The central premise of this study is that sustainable energy infrastructure portfolios can be prioritized more effectively when strategic desirability is evaluated jointly with implementation feasibility and regulatory constraints rather than through isolated financial or strategic criteria.

➢ *Problem Statement*

Sustainable energy infrastructure portfolios contain heterogeneous projects whose benefits, risks, technical characteristics, implementation requirements, and regulatory obligations are not directly comparable. An industrial energy-efficiency retrofit, for example, may require limited capital and have a short implementation period, while an industrial-scale renewable generation facility, energy-storage project, carbon-capture installation, or electrification programme may involve substantially different cost structures, approval pathways, technical risks, resource demands, and stakeholder impacts. Direct comparison using a single financial indicator can therefore obscure important differences in project value and feasibility.

Existing prioritization practices frequently place disproportionate emphasis on financial metrics or high-level strategic alignment. While these criteria are essential, they do not adequately capture the broader set of conditions that determine whether sustainable infrastructure projects should be implemented immediately, deferred, redesigned, or rejected. Research on sustainable energy decision-making has shown that economic, environmental, technical, and social criteria frequently interact and that structured multi-criteria approaches are required to evaluate such trade-offs [3], [4]. Nevertheless, many prioritization models remain relatively static and do not explicitly integrate stakeholder value, multidimensional risk, regulatory readiness, and organizational delivery capacity into a unified project-level score.

Another limitation arises from uncertainty in criterion importance. Different stakeholders may assign different weights to financial return, emissions reduction, safety improvement, strategic importance, social benefit, or technical readiness. Changes in weighting can materially alter the relative ranking of energy alternatives, making robustness assessment necessary when using MCDA-based prioritization [5]. Without sensitivity and scenario analysis, a project ranking may appear precise while actually being highly dependent on subjective weighting assumptions.

Regulated industrial environments create an additional challenge because portfolio decisions must often respond rapidly to changing regulatory requirements, operating constraints, equipment conditions, funding availability, supply-chain disruptions, or corporate sustainability targets. Static annual or periodic prioritization exercises may be too slow to reflect these changes. A project that was previously attractive may become less feasible following a permitting delay or increase in implementation risk, while another may become more urgent because of a statutory requirement, new resource availability, or an accelerated decarbonization target.

The problem addressed in this study is therefore the absence of an integrated, transparent, repeatable, and adaptive framework capable of comparing heterogeneous sustainable energy infrastructure projects while accounting simultaneously for stakeholder value, project risk, delivery capacity, regulatory readiness, and sustainability contribution. The framework must not only generate an initial project ranking but must also support systematic reprioritization when the underlying project or organizational conditions change.

➢ *Aim of the Study*

The aim of this study is to develop a data-driven framework for agile prioritization of sustainable energy infrastructure projects using stakeholder value, risk, and delivery capacity metrics within regulated industrial environments.

➢ *Research Objectives*

The specific objectives are to:

- Identify measurable indicators of stakeholder value, project risk, and delivery capacity relevant to sustainable energy infrastructure projects.
- Develop a standardized data architecture for comparing heterogeneous sustainable energy infrastructure projects.
- Formulate an integrated project-prioritization model based on normalized and weighted decision metrics.
- Incorporate regulatory readiness and sustainability considerations into the project-prioritization process.
- Develop an agile ranking mechanism capable of updating project priorities when project, organizational, or regulatory conditions change.
- Evaluate the robustness of the proposed prioritization framework using sensitivity and scenario analysis.
- Compare the proposed framework with conventional project-prioritization approaches.

➢ *Research Questions*

The study addresses the following research questions:

- Which measurable indicators most effectively represent stakeholder value, project risk, and delivery capacity in sustainable energy infrastructure portfolios?
- How can heterogeneous quantitative and semi-quantitative project metrics be normalized and integrated into a common prioritization framework?
- How do regulatory readiness and sustainability constraints influence the relative priority of sustainable energy infrastructure projects?
- How can project rankings be dynamically updated when project conditions, organizational capacity, or regulatory requirements change?
- How sensitive are project rankings to changes in criterion weights and uncertainty in the underlying input data?
- How does the proposed data-driven framework compare with conventional project-prioritization methods in terms of transparency, robustness, adaptability, and decision usefulness?

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➢ *Significance of the Study*

This study is significant because it addresses a practical gap between strategic sustainability ambition and the organizational capability required to convert such ambition into executable infrastructure investments. By integrating stakeholder value, risk, delivery capacity, regulatory readiness, and sustainability performance, the proposed framework is intended to provide a more comprehensive basis for project prioritization than approaches that rely mainly on financial attractiveness or strategic scoring.

The framework is also expected to improve transparency in project selection. Each project can be assessed against explicitly defined criteria, normalized using documented procedures, weighted according to a specified decision model, and subjected to sensitivity analysis. This structure improves the traceability of portfolio decisions and makes it easier for technical managers, executives, project sponsors, sustainability specialists, and governance bodies to understand why one project receives greater priority than another.

A second contribution concerns resource allocation. Sustainable infrastructure programmes frequently compete for limited capital, engineering personnel, project-management capacity, specialist contractors, shutdown windows, and procurement resources. Incorporating delivery capacity directly into the prioritization process can reduce the likelihood that organizations approve more projects than can realistically be delivered. This is consistent with portfolio-management principles that emphasize selection and management of project groupings within the organizational context.

The proposed agile reprioritization mechanism also provides practical value by allowing management decisions to respond to new information. Rather than treating priority as a fixed project characteristic, the framework considers priority as a dynamic decision outcome that may change when stakeholder value, project risk, resource capacity, regulatory status, or sustainability performance changes. This enables periodic portfolio review to become a structured analytical process rather than an ad hoc reassessment.

From a methodological perspective, the study contributes by linking established MCDA principles with adaptive project-portfolio management. Existing sustainable energy literature demonstrates the suitability of multi-criteria methods for comparing alternatives characterized by conflicting economic, technical, environmental, and social objectives, while robustness studies indicate the importance of testing rankings against changes in criterion weights. The proposed framework extends these principles by explicitly incorporating delivery capacity and agile reprioritization into the decision architecture.

Finally, the framework may support governance and regulatory accountability in industrial environments by providing a documented decision trail. This is particularly relevant where investments must be justified not only in terms of expected returns but also in relation to safety, sustainability commitments, statutory obligations, resource constraints, and stakeholder expectations.

➢ *Scope of the Study*

The study focuses on portfolio-level prioritization of sustainable energy infrastructure projects within regulated industrial environments. Sustainable energy infrastructure is interpreted broadly to include renewable energy generation, industrial energy-efficiency improvements, energy storage, electrification, waste-heat recovery, low-carbon fuel systems, grid-support infrastructure, carbon-management projects, and related technologies that contribute to improved energy and environmental performance.

The analytical scope is centered on five principal decision dimensions: stakeholder value, project risk, delivery capacity, regulatory readiness, and sustainability contribution. Financial and schedule indicators are incorporated where relevant but are not treated as the sole determinants of project attractiveness. Both quantitative and semi-quantitative indicators may therefore be included in the framework, provided that the measurement scales, normalization procedures, and weighting rules are clearly defined.

The study concentrates on prioritization rather than detailed engineering design, procurement strategy, construction scheduling, or operational optimization of individual projects. The unit of analysis is the candidate infrastructure project within an organizational portfolio. The proposed model therefore supports decisions concerning relative priority, sequencing, conditional approval, deferment, or exclusion rather than replacing project-specific techno-economic feasibility studies.

The framework is also designed for dynamic application. Project scores may be updated when key conditions change, including capital availability, risk exposure, regulatory status, delivery resources, stakeholder requirements, or sustainability targets. This adaptive feature is consistent with the broader recognition of iterative and adaptive management approaches in contemporary project-management guidance.

II. LITERATURE REVIEW

➢ *Sustainable Energy Infrastructure and Industrial Decarbonization*

Sustainable energy infrastructure comprises physical, technological, and supporting systems that enable energy to be generated, converted, transmitted, stored, distributed, and consumed with progressively lower environmental impacts and improved economic and operational efficiency. Within industrial environments, the concept extends beyond renewable power installations to include energy-efficiency retrofits, process electrification, energy storage, low-carbon fuels, waste-heat recovery, carbon capture technologies, grid-support systems, and digital energy-management infrastructure. The Intergovernmental Panel on Climate Change (IPCC) identifies energy and material efficiency, fuel switching, process electrification, low-carbon electricity,

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circularity, alternative feedstocks, and Carbon Capture and Storage (CCS) as major components of deep industrial decarbonization [7].

Industrial decarbonization is particularly challenging because energy-related emissions are embedded within production systems designed around long-lived assets, process heat requirements, continuous operations, and established fuel and material supply chains. Consequently, decarbonization usually requires a portfolio of complementary interventions rather than a single technology. Energy-efficiency measures can reduce energy demand and operating costs, while renewable electricity and electrification can progressively displace fossil-fuel consumption. For energy-intensive processes that cannot be completely electrified, alternative fuels, hydrogen, or carbon capture may be required [7]. The resulting investment portfolio therefore includes projects with different technology maturity levels, capital requirements, implementation periods, emissions-reduction potentials, and operating implications.

Energy efficiency remains one of the most immediately deployable industrial decarbonization pathways. Relevant projects include high-efficiency motors, variable-speed drives, process optimization, waste-heat recovery, efficient compressed-air systems, advanced process control, improved thermal insulation, and energy-management systems. International Organization for Standardization (ISO) 50001 provides a systematic management framework through which organizations can establish energy objectives, use measured information to understand energy consumption, monitor performance, and pursue continual improvement [8]. Such projects frequently offer shorter implementation periods than major generation or carbon-management infrastructure, but their prioritization still depends on the magnitude, persistence, scalability, and strategic importance of the expected benefits.

Renewable energy integration enables industrial facilities to reduce dependence on carbon-intensive electricity and fuels through technologies such as solar photovoltaic generation, wind energy, renewable power-purchase arrangements, biomass systems, and hybrid generation. Renewable integration is nevertheless affected by land availability, intermittency, grid connection, transmission capacity, storage requirements, technology suitability, and regulatory approval. These considerations demonstrate why a Levelized Cost of Energy (LCOE) or similar cost indicator alone cannot fully characterize project value. Vanegas-Cantarero et al. [23], for example, developed a multi-criteria framework for offshore renewable energy projects specifically to move decision-making beyond LCOE by incorporating wider economic, environmental, social, technical, and enabling considerations.

Electrification is another important pathway, particularly where fossil-fuel-based process heat, mechanical drives, or auxiliary systems can be replaced by electrical technologies supplied increasingly from low-carbon sources. However, electrification may increase peak electrical demand and require upgrades to substations, transformers, distribution networks, protection systems, and grid connections. Its attractiveness is therefore dependent not only on projected emissions savings but also on electrical infrastructure capacity, power-system reliability, tariff structure, operational flexibility, and future electricity-carbon intensity.

Carbon Capture, Utilization, and Storage (CCUS) is especially relevant to industrial processes where emissions originate from chemical reactions as well as fuel combustion. Cement, lime, chemicals, steel, and other difficult-to-abate sectors may therefore require carbon capture alongside energy efficiency, electrification, fuel switching, and material-efficiency measures [7]. CCUS projects, however, are typically infrastructure-intensive and may involve capture facilities, compression, transport pipelines or shipping, storage characterization, monitoring systems, permitting, and long-term liability considerations. This produces a project-risk and delivery-capacity profile substantially different from conventional energy-efficiency projects.

Energy storage and grid-support infrastructure further increase the flexibility of low-carbon industrial systems. Battery Energy Storage Systems (BESS), thermal storage, flexible loads, demand-response systems, power-quality equipment, and microgrids can support renewable integration, peak-load management, resilience, and continuity of supply. Their value therefore includes operational and strategic benefits that may not be reflected adequately in direct financial returns. Sustainable infrastructure prioritization must consequently evaluate project benefits across multiple dimensions and recognize interactions among individual projects.

Taken together, industrial decarbonization involves a heterogeneous portfolio in which energy-efficiency improvements, renewable generation, electrification, CCUS, storage, and supporting grid infrastructure compete for capital and organizational resources while also potentially complementing one another. This reinforces the need for a portfolio-level decision framework rather than independent project appraisal.

➤ *Project Portfolio Management in Regulated Industrial Environments*

Project Portfolio Management (PPM) concerns the coordinated evaluation, selection, prioritization, balancing, and control of groups of projects in pursuit of organizational objectives. ISO 21504:2022 defines portfolio-management guidance as applicable across organizational types and emphasizes adaptation of portfolio practices to the organizational environment [2]. The portfolio perspective differs from individual project management because the primary decision is not simply how to execute a project successfully, but which combination of projects should receive organizational resources and how priorities should change over time.

Portfolio selection normally requires simultaneous consideration of strategic alignment, expected value, resource requirements, dependencies, risk, timing, and portfolio balance. In regulated industrial environments, these considerations are supplemented by statutory requirements, permits, technical codes, environmental conditions, safety obligations, operational continuity requirements, and internal governance thresholds. Projects may therefore possess different degrees of discretion. A regulatory compliance project may have relatively modest direct financial return but nevertheless require immediate implementation, whereas a commercially attractive project may be deferred because of unresolved licensing or engineering constraints.

Capital allocation is central to portfolio formation because the number of technically desirable projects typically exceeds available financial resources. However, restricting portfolio selection to capital constraints provides only a partial representation of execution feasibility. Engineering specialists, shutdown windows, procurement personnel, contractors, construction supervision, technical reviewers, and operational support may also constitute binding constraints. Portfolio selection must therefore consider both financial and non-financial resource capacity.

Strategic alignment connects project selection to organizational objectives. Sustainable energy projects may support objectives related to cost reduction, energy security, emissions reduction, regulatory compliance, operational resilience, corporate sustainability, or stakeholder commitments. ISO portfolio-management principles emphasize alignment of portfolios with organizational objectives [2], while empirical PPM research has shown that the portfolio process involves continual evaluation of competing initiatives rather than a one-time optimization exercise [12], [14].

Portfolio balancing further requires organizations to avoid excessive concentration in projects with similar risk, resource demand, technology maturity, or implementation timing. For example, approving several large decarbonization projects that simultaneously require the same engineering discipline or shutdown period may produce a portfolio that appears attractive numerically but is operationally infeasible. Modern portfolio decision analysis therefore treats resource allocation and multiple project selection as an integrated decision problem [21].

Governance is particularly important where investment decisions must withstand audit, executive scrutiny, regulatory review, or stakeholder challenge. A defensible system should make the decision criteria, weighting assumptions, data sources, constraints, and approval logic visible. This requirement motivates the use of standardized and traceable metrics rather than undocumented managerial preference alone.

➢ *Agile Project Prioritization*

Agile decision-making emphasizes short feedback cycles, responsiveness to new information, iterative planning, and the ability to revise priorities as circumstances evolve. ISO 21502:2020 recognizes predictive, iterative, incremental, adaptive, hybrid, and agile approaches as legitimate project-management approaches depending on the characteristics of the work [36]. The relevance of agility to infrastructure portfolios lies primarily in adaptive governance rather than in transferring software development practices directly to construction or industrial projects.

Infrastructure investments typically possess long design, procurement, construction, commissioning, and regulatory lead times. Once major capital commitments have been made, changes may be expensive. Agile prioritization should therefore occur predominantly at portfolio decision gates, during project development, and before irreversible commitments. The central objective is to maintain a current ordering of candidate and developing projects based on updated evidence.

Traditional portfolio planning may establish annual capital programmes in which approved rankings remain relatively stable until the next planning cycle. Such an approach can become problematic when energy prices, equipment condition, regulations, capital availability, technology costs, or organizational priorities change rapidly. Petit [32] showed that uncertainty in dynamic environments creates a need for mechanisms that sense changing conditions and reorganize portfolio decisions. More recent research links dynamic capabilities directly with project portfolio agility and success, emphasizing the importance of the ability to identify changes and reconfigure portfolio resources [13].

The concept of a project backlog can be adapted cautiously from agile practice. For infrastructure management, the backlog represents a governed pipeline of candidate projects rather than a list of software development tasks. Each candidate can maintain current information on expected stakeholder value, risk, cost, delivery capacity, regulatory status, sustainability contribution, and dependency conditions. As these values change, the prioritization algorithm can recalculate rankings and place projects into categories such as accelerate, maintain, reassess, defer, or remove.

Infrastructure prioritization nevertheless differs fundamentally from software prioritization. Software features are often divisible, incrementally deliverable, and relatively inexpensive to reorder. Major industrial infrastructure projects may be physically indivisible, subject to permitting, long-lead procurement, contractual commitments, and shutdown constraints. Consequently, agile infrastructure prioritization must incorporate governance thresholds and commitment states so that dynamic ranking does not imply uncontrolled changes to projects already under construction.

Hoffmann et al. [11] demonstrated that alignment, efficiency, and agility can create competing requirements within portfolio management and that these tensions require explicit design principles rather than unrestricted flexibility. This insight is relevant to regulated infrastructure because agility must coexist with formal controls, compliance assurance, and capital discipline. The proposed framework therefore interprets agility as controlled dynamic

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reprioritization based on updated data, not as continual arbitrary restructuring of an approved portfolio.

- *Stakeholder Value in Infrastructure Decision-Making*

Stakeholder value represents the benefits, costs, expectations, and consequences that infrastructure projects create for parties capable of affecting, or being affected by, project decisions. Relevant stakeholders in regulated industrial environments may include investors, executive management, employees, engineering and operations personnel, regulators, customers, local communities, suppliers, contractors, utilities, financial institutions, and environmental or governmental bodies.

Stakeholder identification is necessary because different groups evaluate project value differently. Investors may emphasize financial return and risk exposure; operations personnel may prioritize reliability and maintainability; regulators may focus on compliance; communities may emphasize environmental and social impacts; and sustainability functions may prioritize emissions reduction and long-term environmental performance. Consequently, stakeholder value is multidimensional rather than synonymous with financial value.

The influence and interest of individual stakeholders also differ. Some stakeholders possess formal approval authority, others provide critical technical or financial resources, while others can affect project legitimacy and acceptance. Cuppen et al. [9], examining large-scale energy infrastructure, demonstrated that stakeholders can hold materially different perspectives on project value and that systematic engagement can reveal these competing viewpoints [9].

Economic stakeholder value may be represented by expected savings, revenue, productivity gains, avoided penalties, reduced fuel consumption, or improved asset utilization. Environmental value may include greenhouse-gas reduction, reduced air emissions, improved energy efficiency, lower water or resource intensity, and reduced waste. Social value can incorporate employment, public health implications, community benefits, fairness, and broader social acceptance. Operational value may include reliability, process stability, energy security, maintainability, flexibility, and resilience.

Regulatory and community acceptance can strongly affect project feasibility. A technically and financially attractive project may face substantial delays if its social or environmental effects are contested or inadequately addressed. The importance of stakeholder engagement in large-scale energy infrastructure therefore supports inclusion of stakeholder acceptance within formal prioritization rather than treating it solely as a communication activity [39].

A useful stakeholder-value metric must nevertheless avoid double-counting. For example, emissions reduction should not receive full weight simultaneously under environmental stakeholder value and sustainability contribution unless the model deliberately distinguishes stakeholder perception from measured environmental performance. The framework developed in this study therefore treats stakeholder value as perceived or strategic benefit to identified stakeholder groups, while sustainability contribution represents independently measurable environmental or energy-performance outcomes [38], [40].

- *Risk Assessment for Sustainable Energy Projects*

Risk assessment evaluates uncertainty that can affect project objectives, including cost, schedule, technical performance, regulatory compliance, environmental outcomes, safety, and expected benefits. ISO 31000:2018 establishes a general process comprising risk identification, analysis, evaluation, treatment, monitoring, review, and communication [15], [36]. For sustainable energy investments, risk assessment is especially important because projects frequently combine new technologies, long operating lives, policy dependence, capital intensity, and complex stakeholder interfaces.

Technical risk concerns the probability that a technology, design, integration concept, or equipment configuration will not achieve required performance. Such risk may arise from immature technology, uncertain scale-up, poor compatibility with existing equipment, unproven operating conditions, or inadequate technical data. Technology maturity therefore has direct implications for both project risk and organizational delivery capability.

Financial risk includes capital-cost escalation, interest-rate exposure, revenue uncertainty, energy-price volatility, exchange-rate effects, financing availability, and deviations in expected savings. Renewable projects may additionally depend on tariff structures, incentives, contractual arrangements, or future electricity-market conditions [37], [35].

Schedule risk concerns uncertainty in project duration and milestone achievement. Delays may arise from engineering complexity, permitting, long-lead equipment, interconnection studies, contractor performance, financing, shutdown availability, site constraints, and commissioning problems. Schedule risk is particularly important where project value depends on meeting statutory deadlines or corporate emissions targets.

Regulatory risk concerns uncertainty regarding permits, environmental approvals, energy-market rules, technical standards, taxation, emissions requirements, carbon pricing, and future policy conditions. In highly regulated environments, regulatory risk can alter both project economics and basic project eligibility.

Environmental risk includes unintended impacts on land, water, biodiversity, air quality, waste generation, and surrounding communities. Such impacts can create additional permitting requirements, mitigation costs, project redesign, or reputational consequences.Supply-chain risk has become increasingly important for technologies dependent on specialized equipment, critical materials, globally concentrated manufacturing, or limited qualified vendors.

Delayed transformers, batteries, control systems, turbines, capture equipment, or specialized construction materials can significantly alter project schedules and economics.

Health, Safety, and Environmental (HSE) and operational risks must also form part of infrastructure evaluation. Construction interfaces with operating plants, electrical systems, pressure equipment, rotating machinery, high-temperature processes, hazardous chemicals, confined spaces, and working at height can produce substantial implementation risks. Operational risks may persist after commissioning through equipment reliability, process interactions, maintenance requirements, or unintended consequences for production.

Abba et al. [10] reviewed renewable-energy investment risks and demonstrated the need for holistic approaches that capture multiple risk categories rather than evaluating financial uncertainty alone. Their framework reinforces the relevance of integrating technical, economic, political, social, and other risk dimensions into renewable-energy investment decisions [10].

Risk aggregation requires care. A simple arithmetic average can conceal a single intolerable risk because a very high regulatory or safety exposure may be numerically offset by several low-risk dimensions. The proposed framework should therefore combine composite risk scoring with threshold or veto conditions for critical risks. This approach is consistent with regulated decision environments where certain legal, safety, or technical conditions cannot legitimately be compensated for by financial or sustainability benefits [36], [43].

➢ *Delivery Capacity and Organizational Readiness*

Delivery capacity represents an organization's practical ability to convert an approved project into an operating asset within required cost, schedule, quality, safety, and performance constraints. It differs from project attractiveness because a project can offer substantial value while exceeding available organizational capacity.

Workforce competence is a fundamental component. Sustainable energy infrastructure may require specialists in electrical power systems, process engineering, civil and structural engineering, automation, environmental management, carbon systems, renewable technologies, commissioning, contracting, and project controls. A portfolio containing several simultaneous projects that require the same scarce specialists may therefore be impossible to execute effectively even if sufficient capital is available [45], [50].

Engineering capacity includes both capability and workload. Internal engineering teams must provide project definition, design review, standards compliance, interface management, procurement support, construction oversight, and commissioning. External consultants can supplement this capacity, but their availability, familiarity with plant systems, and integration into organizational governance remain relevant [51], [44].

Capital availability is another delivery constraint. Portfolio decisions must distinguish between total approved capital and the timing of capital demand. Two projects with similar lifecycle expenditure may impose very different annual cash-flow requirements. Financial feasibility therefore requires alignment between project schedules and available investment envelopes.

Supply-chain capability includes vendor availability, logistics, manufacturing capacity, procurement lead times, spare-parts strategy, and exposure to single-source suppliers. Contractor capacity similarly concerns the availability of organizations with the required technical competence, safety performance, equipment, certifications, and experience.

Technology maturity influences both risk and delivery readiness. Mature technologies generally provide more reliable cost, schedule, and performance estimates, whereas emerging technologies may require demonstration, piloting, vendor development, or additional engineering contingency. Technology-readiness concepts therefore provide a useful supporting indicator when evaluating execution capability.

Project-management capability concerns the organization's ability to define scope, control schedule and cost, manage interfaces, administer contracts, control risks, maintain documentation, and transition completed assets into operations. PPM information systems can improve portfolio transparency and decision-making, but their benefits depend on the maturity of the underlying portfolio processes [14], [47].

Organizational readiness integrates these individual elements. It considers whether leadership commitment, governance structures, operating units, support functions, data systems, procedures, resources, and change-management processes are sufficiently prepared to implement the project. Bechtel et al. [13] link portfolio agility to dynamic capabilities, reinforcing the idea that organizations must be able not only to identify valuable projects but also to reconfigure resources in response to changing priorities.

Delivery capacity should therefore be incorporated as an independent decision dimension rather than assumed implicitly. This prevents the prioritization model from consistently selecting technically attractive projects that cannot be executed within the organization's actual resource envelope.

➢ *Regulatory and Compliance Considerations*

Regulatory requirements influence project feasibility from concept development through operation. Relevant approvals may include environmental permits, construction authorization, grid interconnection, land-use approval, emissions permits, water abstraction or discharge approval, hazardous-material requirements, occupational safety obligations, and sector-specific operating licenses. The exact requirements vary by jurisdiction and technology, making regulatory context a project-specific variable rather than a universal constant.

Environmental permitting requires projects to demonstrate that impacts have been identified and managed in accordance with applicable requirements. ISO 14001:2026 provides a systematic framework for environmental-management systems, including the management of environmental aspects, legal obligations, performance monitoring, and continual improvement [16]. While ISO certification itself does not replace statutory permitting, environmental-management maturity can improve the organization's ability to identify and manage project-related compliance obligations.

Safety and technical standards create additional constraints. Energy infrastructure may involve electrical protection, pressure systems, fuel handling, hazardous areas, batteries, structural loading, fire protection, process safety, and grid-code compliance. Projects failing to demonstrate conformity with mandatory requirements may be unsuitable for approval regardless of their calculated financial attractiveness.

Compliance burden can therefore be represented using indicators such as number of required approvals, expected permitting duration, complexity of technical studies, statutory consultation requirements, unresolved compliance conditions, and probability of approval delay. These indicators should not be interpreted solely as undesirable costs. Rigorous regulatory review can also reduce environmental, technical, and safety risks when incorporated appropriately into project development[48], [52].

Approval uncertainty is especially important during early project stages. A project may appear economically attractive under the assumption of timely approval but lose strategic value if permitting delays its operation by several years. Regulatory readiness should therefore capture both current approval status and remaining approval uncertainty.

Within the proposed framework, regulatory readiness is treated as both a scored criterion and a potential screening constraint. Minor permitting activities may reduce a project score, whereas the absence of a legally indispensable approval may render the project temporarily ineligible. This prevents compensatory MCDA logic from allowing exceptionally high economic or sustainability value to outweigh a non-negotiable regulatory requirement [55], [40].

➢ *Multi-Criteria Decision Analysis for Project Prioritization*

Multi-Criteria Decision Analysis (MCDA) provides formal methods for evaluating alternatives against multiple, potentially conflicting criteria. Sustainable energy project prioritization is particularly suitable for MCDA because financial, technical, environmental, social, regulatory, and organizational variables cannot be meaningfully represented using a single natural unit [3], [4].

Weighted scoring is among the simplest approaches. Each project receives a standardized performance score for each criterion, which is multiplied by the criterion weight and aggregated. The attraction of weighted scoring lies in transparency and ease of explanation. Its limitations include sensitivity to normalization method, compensatory behavior, subjectivity in criterion weighting, and potential double-counting between correlated variables. SMARTS and SMARTER, developed by Edwards and Barron [20], provide structured multiattribute utility procedures for weighting and aggregating competing criteria [20].

The Analytic Hierarchy Process (AHP) structures a decision problem hierarchically and derives relative priorities using pairwise comparisons. Saaty [17] formalized AHP as a method for decomposing complex decisions into criteria and subcriteria and synthesizing judgments into priorities [17]. AHP is advantageous where expert judgment is important and relative importance is easier to express pairwise than directly. However, the number of comparisons increases substantially with the number of criteria, and results can be influenced by judgment consistency and model structure.

The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) ranks alternatives according to their relative distance from an ideal best and ideal worst solution. Its conceptual appeal lies in preferring an alternative that simultaneously approaches desirable criterion values and avoids undesirable ones. Behzadian et al. [18] documented the extensive application of TOPSIS across diverse decision domains [18]. TOPSIS nevertheless remains sensitive to normalization, weighting, and the distribution of alternatives in the decision matrix.

The Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) is an outranking approach that uses criterion-specific preference functions and pairwise comparison of alternatives. Brans and Vincke [19] developed PROMETHEE to rank alternatives under multiple criteria without requiring all performance differences to be represented through a single utility function [19]. Its ability to define preference and indifference behavior is valuable, although the method requires additional parameter choices that decision-makers must understand and justify.

Value-based decision models transform criterion performance into value or utility measures before aggregation. Such methods are particularly useful when the decision-maker's preference is nonlinear. For example, the value associated with increasing regulatory readiness from 90% to 100% may differ fundamentally from an equivalent numerical increase at a low level of readiness.

No single MCDA method is universally superior. Method selection should reflect the structure of the decision, type of data, degree of compensation permitted among criteria, stakeholder understanding, computational requirements, and need for sensitivity analysis. Reviews of sustainable-energy MCDA consistently identify weighting sensitivity, methodological diversity, and differences between ranking techniques as important considerations [49], [56]. The framework proposed in this research therefore favors a transparent normalized weighted architecture for its primary priority score, supplemented by benchmark comparison against established MCDA methods rather than

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assuming that one algorithm provides an objectively definitive ranking.

➢ *Data-Driven Decision-Support Approaches*

Data-driven decision support converts heterogeneous project information into structured evidence that can be updated, analyzed, and communicated systematically. A data-driven portfolio system requires consistent variable definitions, common measurement scales, documented data provenance, appropriate treatment of missing values, and controlled updating procedures.

Data normalization is essential because project indicators may be measured in monetary units, percentages, time, tonnes of carbon-dioxide equivalent, ordinal ratings, probabilities, or engineering quantities. Normalization transforms these measures onto comparable scales while preserving whether high or low values are desirable. Poor normalization can distort relative project differences and therefore alter ranking outcomes.

Decision dashboards can provide an operational interface between the analytical model and portfolio governance. Relevant displays may include current ranking, risk profile, regulatory readiness, resource consumption, sustainability contribution, sensitivity results, and changes from the preceding review cycle. Evidence from PPM information-system research indicates that improved information transparency can support portfolio decision processes, although system benefits depend on organizational process maturity [41], [52].

Optimization methods extend ranking by identifying the combination of projects that maximizes portfolio value subject to constraints. These constraints may include capital budgets, engineering hours, contractor capacity, regulatory eligibility, maximum portfolio risk, minimum sustainability performance, or project interdependencies. Portfolio Decision Analysis (PDA) has developed specifically to support selection of multiple alternatives under resource constraints and multiple attributes [51], [58].

Predictive analytics can estimate quantities that are not yet known with certainty, including likely cost escalation, schedule delay, project failure, energy savings, or benefit realization. Costantino et al. [27], for example, demonstrated the use of an Artificial Neural Network (ANN) for project selection based on critical success factors, illustrating the potential for historical project data to supplement conventional expert scoring [27].

More recent literature identifies Artificial Intelligence (AI) and Machine Learning (ML) as increasingly relevant to project-management decision support, particularly in forecasting, risk analysis, planning, classification, and optimization [28]. Nevertheless, predictive accuracy does not eliminate the need for interpretability. In regulated capital-investment decisions, managers may need to explain why a project was prioritized, which variables influenced the result, and how changes in assumptions affect the recommendation. Consequently, an opaque predictive model should not automatically replace transparent MCDA.

Dynamic decision-support systems combine updated data with repeatable analytical rules. Bilgin et al. [29] developed a decision-support system for construction project portfolio management that integrates project characteristics into portfolio-level decision processes [29]. This illustrates the wider movement from periodic spreadsheet-based ranking toward integrated portfolio information environments.

For the present study, data-driven decision support therefore encompasses both analytics and governance. The system must store relevant data, standardize project measures, calculate priority scores, test scenarios, identify constraints, and preserve a transparent record of why rankings changed.

➢ *Empirical Review*

Empirical research on sustainable energy and project portfolio selection demonstrates considerable methodological diversity but also reveals recurring themes relevant to the proposed framework.

Renewable-energy ranking studies frequently employ MCDA because technology alternatives differ simultaneously in economic, environmental, social, and technical performance. Ramezanzade et al. [26] applied fuzzy MCDA methods to renewable-energy project ranking, demonstrating the usefulness of structured decision methods where evaluation criteria contain uncertainty and linguistic judgments [26]. Parvaneh and Hammad [24] similarly evaluated power-generation technologies using multiple sustainability criteria, confirming that selection can change when economic, environmental, social, and technical dimensions are considered jointly rather than in isolation [24].

Vanegas-Cantarero et al. [23] examined offshore renewable-energy alternatives and explicitly argued for evaluation beyond LCOE. Their framework incorporated wider enabling and sustainability considerations, including factors linked to supply-chain development and capacity building [23]. This is particularly relevant to the present research because it demonstrates that the technically lowest-cost energy option may not necessarily provide the strongest overall project value.

Godoy et al. [25] employed multi-criteria analysis for energy planning in Ecuador and integrated diverse evaluation dimensions to support broader energy-planning decisions [25]. Such studies show the suitability of MCDA for energy systems in which policy, technology, sustainability, and socioeconomic considerations interact.

Project portfolio research has meanwhile addressed strategic alignment, uncertainty, resource limitations, and robustness. Petit [12] found that portfolio management in dynamic environments requires mechanisms for responding to uncertainty rather than assuming stable project conditions.

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Bechtel et al. [13] subsequently linked dynamic organizational capabilities with portfolio agility and portfolio success. These findings support periodic recalculation of priority rather than treating a project's initial ranking as permanent.

Mahmoudi et al. [22] proposed a project portfolio selection framework incorporating organizational resilience and stakeholder judgments through a robust ordinal prioritization approach. The work illustrates the movement from basic scoring toward portfolio-selection methods that explicitly handle uncertainty and organizational strategy [22]. Portfolio decision research also demonstrates the importance of resource constraints. Liesiö et al. [21] describe PDA as a family of methods designed for multiple selection decisions where projects compete for limited resources and decision-maker preferences may be incomplete or uncertain [21]. Such approaches are more appropriate than independent ranking when selecting one project changes the resources available for other projects.

Risk-based energy research reinforces this point. Abba et al. [10] found that renewable-energy investments are affected by interconnected risk categories requiring holistic treatment. This supports the inclusion of risk as a multi-dimensional construct rather than a single generic risk rating.

The empirical literature therefore provides strong foundations for individual components of the proposed framework: MCDA for sustainability, structured energy-technology ranking, risk assessment, resource-constrained portfolio selection, stakeholder evaluation, and dynamic portfolio management. What remains less developed is their integration into a single transparent system designed specifically for regulated sustainable-energy infrastructure portfolios.[59], [50]

- *Research Gaps*

The literature reveals six principal gaps that motivate the proposed framework.

First, existing sustainable-energy decision models commonly integrate economic, environmental, social, and technical criteria but give less explicit attention to organizational delivery capacity as an independent portfolio-prioritization dimension. Studies such as Vanegas-Cantarero et al. [23] acknowledge enabling conditions and supply-chain considerations, while broader portfolio research addresses resource constraints [21], yet there remains a need to translate workforce availability, engineering capability, contractor readiness, capital timing, and organizational workload into systematic project-level prioritization metrics.

Second, many MCDA applications produce a static ranking based on a decision matrix constructed at a particular point in time. This structure is valuable for initial selection but does not inherently specify when and how rankings should be recalculated. Research on dynamic portfolios demonstrates that uncertainty and changing environmental conditions require sensing and reconfiguration mechanisms [12], [13]. The gap therefore concerns the integration of MCDA with an explicit agile reprioritization cycle.

Third, regulatory readiness is frequently embedded within broader risk or policy criteria rather than treated as both a measurable performance dimension and a potential eligibility constraint. In regulated industrial environments, this is problematic because some approvals are non-compensatory. A project should not become executable simply because high economic value mathematically offsets the absence of a mandatory approval.

Fourth, existing project-ranking frameworks often evaluate stakeholder value and sustainability impact without clearly distinguishing the two. Stakeholder perceptions, strategic expectations, and community acceptance are not equivalent to quantified emissions reduction or energy savings. A more precise framework should maintain conceptual separation while allowing both to influence priority.

Fifth, there is insufficient integration of ranking robustness and management usability. Sensitivity analysis has demonstrated that changes in criterion weights can materially alter sustainable-energy rankings [5]. A prioritization framework intended for executive or regulatory use should therefore report not only a nominal rank but also the stability of that rank under plausible changes in weights and project assumptions.

Sixth, emerging AI and ML approaches can improve prediction but may reduce interpretability if used without transparent decision logic [27], [28]. For regulated infrastructure investment, the most appropriate architecture may therefore be hybrid: predictive analytics may estimate uncertain inputs, while a transparent MCDA and constraint model determines the final priority.

The identified gap can consequently be summarized as the absence of a transparent, repeatable, capacity-aware, regulation-sensitive, and dynamically updateable decision framework that integrates stakeholder value, multidimensional risk, delivery capability, and sustainability performance for sustainable energy infrastructure portfolios.

- *Conceptual Framework*

The conceptual framework proposed in this study organizes project prioritization as a sequential but updateable decision process:

Project Data Inputs → Metric Standardization → Stakeholder Value Assessment → Risk Assessment → Delivery Capacity Assessment → Regulatory and Sustainability Screening → Integrated Priority Score → Agile Reprioritization → Portfolio Decision

The first stage, Project Data Inputs, captures raw quantitative and semi-quantitative information for each candidate project. The data may include capital expenditure, expected energy savings, emissions reduction, stakeholder assessments, risk ratings, project duration, engineering

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requirements, regulatory status, technology maturity, workforce demand, and resource availability. The quality of subsequent prioritization is conditional on the completeness, consistency, and currentness of these inputs.

The second stage, Metric Standardization, converts heterogeneous measurements to comparable dimensionless scales. This step is required because monetary benefits, risk probabilities, ordinal judgments, time requirements, and sustainability metrics cannot be aggregated directly. Standardization also establishes criterion directionality so that higher normalized values consistently represent either greater desirability or greater risk, as explicitly defined.

The third stage, Stakeholder Value Assessment, estimates the strategic, economic, operational, environmental, social, and acceptance-related value perceived by relevant stakeholders. The stakeholder-value metric is intended to represent the breadth of project benefit rather than financial return alone.

The fourth stage, Risk Assessment, quantifies technical, financial, schedule, regulatory, environmental, supply-chain, health and safety, and operational uncertainties. Critical risks may also be subject to threshold conditions to prevent unacceptable risks from being mathematically compensated for by high benefits.

The fifth stage, Delivery Capacity Assessment, evaluates whether sufficient engineering capability, workforce competence, capital, contractor support, supply-chain readiness, project-management capability, and organizational bandwidth are available to implement the project.The sixth stage, Regulatory and Sustainability Screening, establishes whether mandatory approvals and minimum sustainability conditions have been satisfied. Regulatory readiness can influence the numerical score while absolute compliance requirements function as eligibility constraints.

The seventh stage, Integrated Priority Score, combines the normalized decision dimensions using documented weights and aggregation rules. The score provides the baseline ordering of projects but is not interpreted as an immutable decision.The eighth stage, Agile Reprioritization, introduces time dependence. When material changes occur in cost, stakeholder value, risk, regulatory status, capacity, or sustainability performance, affected indicators are updated and project scores are recalculated. This creates an auditable mechanism for dynamic prioritization rather than reliance on discretionary ranking changes.

The final stage, Portfolio Decision, converts the analytical results into management actions. Depending on priority, constraints, and portfolio balance, projects may be accelerated, approved, conditionally approved, sequenced, deferred, reassessed, or removed. Portfolio-level resource constraints are then used to ensure that the selected set of projects remains implementable.

Conceptually, the framework therefore separates three questions that are often conflated in conventional project selection: Is the project valuable? Is the project sufficiently safe, compliant, and sustainable? Can the organization actually deliver it? Only after these questions have been addressed jointly is the project assigned an actionable portfolio priority. This structure provides the theoretical foundation for the mathematical formulation and prioritization algorithm developed in Section 3.

III. MATERIALS AND METHODS

- *Research Design*

The study adopted a quantitative decision-support design for prioritizing sustainable energy infrastructure projects in regulated industrial environments. The methodology integrated Multi-Criteria Decision Analysis (MCDA), project-risk assessment, organizational delivery-capacity assessment, regulatory screening, sustainability evaluation, portfolio optimization, sensitivity analysis, and scenario analysis.

Multi-Criteria Decision Analysis was selected because the assessed energy infrastructure projects contained economic, technical, environmental, regulatory, organizational, and stakeholder attributes that could not be compared directly using a single measurement scale [3], [4].

The framework addressed three sequential questions for each candidate project: how much value the project created, what level of risk and regulatory exposure it presented, and whether the organization possessed sufficient capability and resources to deliver it. Project priority was therefore represented as the combined outcome of stakeholder value, sustainability contribution, project risk, delivery capacity, regulatory readiness, and mandatory eligibility.

The methodological sequence comprised project identification, data acquisition, preprocessing, normalization, criterion weighting, decision-dimension scoring, integrated priority calculation, regulatory screening, portfolio optimization, agile reprioritization, benchmark comparison, and robustness analysis.

- *Sustainable Energy Project Portfolio Definition*

The unit of analysis was a candidate sustainable energy infrastructure project, denoted by P_i, where $i = 1,2, \dots, n$, and n represented the total number of projects in the assessed portfolio.

The portfolio included projects involving renewable electricity generation, electrical and thermal energy storage, waste-heat recovery, industrial electrification, energy-efficiency improvement, carbon capture, utilization and storage, low-carbon fuel systems, grid modernization, and hydrogen-production or utilization infrastructure.

Projects were included when sufficient information was available concerning their expected benefits, capital requirements, implementation duration, sustainability

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contribution, principal risks, regulatory requirements, and delivery-resource needs.

Projects under irreversible contractual or construction commitments were retained for monitoring where relevant. However, agile reprioritization was applied principally to projects that remained within the identification, screening, design, or investment-selection stages.

➢ *Data Architecture and Variable Definition*

Project data were organized into six groups: stakeholder value, project risk, delivery capacity, regulatory readiness, sustainability contribution, and supporting financial and schedule indicators.

Table 1 Principal Variables Used in the Project-Prioritization Framework

Decision dimension	Representative variables	Direction of preference
Stakeholder value	Strategic alignment, economic benefit, social value, operational improvement, stakeholder acceptance	Higher preferred
Project risk	Technical, financial, schedule, regulatory, market, environmental, safety, and supply-chain risk	Lower preferred
Delivery capacity	Workforce availability, technical competence, capital availability, contractor capability, supply-chain readiness, technology maturity	Higher preferred
Regulatory readiness	Permit status, approval progress, compliance completeness, regulatory lead time	Higher preferred
Sustainability contribution	Greenhouse-gas reduction, energy savings, renewable-energy contribution, resource efficiency, waste reduction	Higher preferred
Supporting indicators	Capital expenditure, operating expenditure, implementation duration, net present value, benefit–cost ratio	Criterion dependent

Monetary variables were converted to a common currency and price basis. Greenhouse-gas reductions were expressed in tonnes of carbon-dioxide equivalent per year (tCO_2e/year), while energy savings were expressed in megawatt-hours per year (MWh/year).

The five principal decision indices were the Stakeholder Value Index (SVI), Project Risk Index (PRI), Delivery Capacity Index (DCI), Regulatory Readiness Index (RRI), and Sustainability Contribution Index (SCI). Each index was expressed on a dimensionless scale from 0 to 1.

➢ *Data Preprocessing and Normalization*

Project data were examined for completeness, unit consistency, duplicate records, transcription errors, and physically unreasonable values. Missing values associated with mandatory regulatory, safety, environmental, or technical requirements were not automatically imputed because imputation could have incorrectly improved project eligibility. Projects containing material information gaps were returned for additional data collection.

Outliers were reviewed against engineering and project documentation. Legitimate extreme values were retained, while confirmed data-entry and unit-conversion errors were corrected.

For benefit criteria, where a higher value represented better project performance, min–max normalization was performed using:

$$z_{ij} = \frac{x_{ij} - x_{j,\min}}{x_{j,\max} - x_{j,\min}} \tag{1}$$

Where x_{ij} represented the original value of criterion j for project i; $x_{j,\min}$ and $x_{j,\max}$ represented the lower and upper bounds of criterion j, respectively; and z_{ij} represented the normalized criterion value.

For cost criteria, where a lower value was preferred, reverse normalization was applied:

$$z_{ij} = \frac{x_{j,\max} - x_{ij}}{x_{j,\max} - x_{j,\min}} \tag{2}$$

The resulting normalized values ranged from 0 to 1, with values approaching 1 indicating more desirable performance.

Variables representing risk magnitude retained their original direction so that values approaching 1 represented greater risk exposure. Fixed engineering, regulatory, or historically established normalization bounds were used where available. This prevented project scores from changing solely because projects were added to or removed from the comparison set.

➢ *Construction of the Decision-Dimension Indices*

The five decision-dimension indices were calculated through weighted aggregation of their normalized indicators. For project i and decision dimension d, the composite score was calculated as:

$$D_{id} = \sum_{k=1}^{m_d} w_{dk} z_{idk} \tag{3}$$

Where D_{id} represented the composite score of project i for dimension d; m_d represented the number of indicators contained in dimension d; z_{idk} represented the normalized value of indicator k; and w_{dk} represented the corresponding indicator weight.

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The weights within each dimension satisfied:

$$\sum_{k=1}^{m_d} w_{dk} = 1, \qquad w_{dk} \geq 0 \tag{4}$$

Equation (3) was applied separately to calculate the Stakeholder Value Index, Project Risk Index, Delivery Capacity Index, Regulatory Readiness Index, and Sustainability Contribution Index. This common formulation prevented the unnecessary repetition of structurally identical equations.

- *Stakeholder Value Metric*

The Stakeholder Value Index represented the strategic, economic, operational, social, and organizational value associated with each project. Its components included strategic alignment, economic benefit, operational improvement, social impact, stakeholder-perceived environmental value, and stakeholder acceptance.

The stakeholder assessment incorporated executive management, investors, operations personnel, engineering teams, employees, regulators, customers, suppliers, local communities, and other groups materially affected by the proposed infrastructure. Previous energy-infrastructure research had shown that stakeholder groups could hold substantially different perceptions of project value [9].

The Stakeholder Value Index was calculated using Equation (3), with all constituent variables normalized so that higher values represented greater stakeholder value.

Economic benefit incorporated net present value, avoided energy expenditure, productivity improvement, revenue generation, avoided penalties, and reduced maintenance expenditure where these data were available. Operational value included reliability, resilience, maintainability, process stability, energy security, and operational flexibility.

- *Project Risk Metric*

The Project Risk Index represented the combined uncertainty associated with the successful implementation and operation of each project. The risk-assessment process followed the general principles of International Organization for Standardization 31000 [15].

The index incorporated technical, cost, schedule, regulatory, market, environmental, health and safety, and supply-chain risks. Additional risk categories were included where required by the industrial context.

The Project Risk Index was calculated using Equation (3). In contrast to the benefit indices, values approaching 1 represented greater risk exposure.

Critical legal, safety, environmental, cybersecurity, and technical risks were not permitted to disappear through weighted averaging. A project was subjected to separate eligibility screening when any mandatory risk exceeded the organization's approved tolerance, regardless of its aggregated Project Risk Index.

- *Delivery Capacity Metric*

The Delivery Capacity Index measured whether the organization possessed sufficient resources and competence to implement each project within the required cost, schedule, technical, safety, and quality conditions.

The index included workforce availability, engineering capability, capital availability, supply-chain readiness, contractor competence, technology maturity, equipment availability, and organizational workload.

The Delivery Capacity Index was calculated using Equation (3), with values approaching 1 representing stronger delivery capability.

Delivery capacity was evaluated separately from project value because a strategically attractive project could have been temporarily impractical to execute. For example, a high-value electrification project could have required specialist engineering resources that were already committed to another critical program. The Delivery Capacity Index therefore supported resource balancing and implementation sequencing.

- *Regulatory Readiness Metric*

The Regulatory Readiness Index measured the extent to which the permits, approvals, and compliance requirements required for project implementation had been completed.

The assessment incorporated permit status, regulatory-application progress, approval complexity, anticipated approval lead time, compliance completeness, and regulatory uncertainty. Variables such as approval complexity and regulatory lead time were reverse-normalized before aggregation.

Regulatory readiness was distinguished from regulatory risk. Regulatory readiness represented the project's level of preparation at the time of assessment, whereas regulatory risk represented uncertainty concerning the timing or outcome of the regulatory process.

- *Sustainability Contribution Metric*

The Sustainability Contribution Index represented the expected physical and environmental contribution of each project. It included annual greenhouse-gas reduction, annual energy savings, renewable-energy contribution, resource-efficiency improvement, waste reduction, and other measurable environmental benefits.

The Sustainability Contribution Index was calculated using Equation (3). Physical measurements and engineering estimates were used instead of subjective judgments where reliable data were available.

Greenhouse-gas reduction was calculated relative to an approved emissions baseline. Energy savings were similarly measured against a documented reference operating condition and adjusted for relevant production, weather, occupancy, and operating variables.

➢ *Criterion Weight Determination*

Criterion weights were determined using expert judgment, the Analytic Hierarchy Process (AHP), entropy weighting, or a hybrid weighting procedure. The Analytic Hierarchy Process was selected where experienced decision-makers were required to compare the relative importance of criteria systematically [17].

The expert panel incorporated personnel from engineering, operations, finance, sustainability, safety, project management, regulatory affairs, information technology, and executive management.

Entropy weighting provided an objective complement because criteria displaying greater variation across the portfolio contained more information for differentiating projects. Where expert and objective weights were combined, the final criterion weight was calculated as:

$$w_j = \theta w_j^E + (1-\theta) w_j^O, \qquad 0 \le \theta \le 1 \tag{5}$$

Where w_j represented the final weight of criterion j; w_j^E represented the expert-derived weight; w_j^O represented the objective data-derived weight; and θ represented the blending coefficient.

A value of θ approaching 1 assigned greater influence to expert judgment, whereas a value approaching 0 assigned greater influence to the objective weighting method. Because weighting assumptions could materially alter MCDA rankings [5], all final weights were subjected to sensitivity analysis.

➢ *Integrated Agile Priority Score*

The central output of the framework was the Integrated Agile Priority Score (IAPS). The project-benefit component combined stakeholder value and sustainability contribution:

$$B_i = w_V \, \mathrm{SVI}_i + w_S \, \mathrm{SCI}_i, \qquad w_V + w_S = 1 \tag{6}$$

Where B_i represented the combined benefit score of project i; w_V represented the stakeholder-value weight; w_S represented the sustainability-contribution weight; SVI_i represented the Stakeholder Value Index; and SCI_i represented the Sustainability Contribution Index.

The final priority score was calculated as:

$$\boxed{\mathrm{IAPS}_i = 100\, B_i (1 - \lambda\, \mathrm{PRI}_i) \mathrm{DCI}_i \mathrm{RRI}_i E_i} \tag{7}$$

Where IAPS_i represented the Integrated Agile Priority Score of project i; PRI_i represented the Project Risk Index; DCI_i represented the Delivery Capacity Index; RRI_i represented the Regulatory Readiness Index; λ represented the organizational risk-aversion coefficient; and E_i represented the mandatory eligibility factor.

Because all component indices and coefficients ranged from 0 to 1, the Integrated Agile Priority Score had a theoretical range from 0 to 100.

Equation (7) was structured so that a high benefit score could not independently dominate the final ranking. High risk reduced the score, while inadequate delivery capacity or regulatory readiness constrained project priority. The formulation therefore represented both project attractiveness and organizational executability.

➢ *Risk-Adjustment Mechanism*

Risk was incorporated into Equation (7) through the adjustment factor $1 - \lambda \mathrm{PRI}_i$. The risk-aversion coefficient was restricted to $0 \le \lambda \le 1$.

When $\lambda = 0$, project risk did not reduce the priority score. When $\lambda = 1$, the full normalized risk exposure was applied. Intermediate values represented moderate organizational risk aversion.

The value of λ was determined from the organization's risk appetite and was subsequently examined through sensitivity analysis. It was not adjusted merely to produce a preferred ranking.

➢ *Delivery-Capacity Constraint*

Delivery capacity was included multiplicatively in Equation (7). Consequently, a project with strong stakeholder and sustainability benefits but inadequate delivery capability received a reduced near-term priority.

A minimum delivery-capacity threshold was also applied:

$$DCIi < Dmin \Longrightarrow project\ i\ was\ classified\ as\ capacity - constrained \tag{8}$$

Where Dmin represented the minimum acceptable Delivery Capacity Index.

A capacity-constrained project was retained in the strategic portfolio but withheld from immediate execution. Its priority was reconsidered when engineering resources, contractor capability, capital availability, supply-chain conditions, or organizational workload improved.

➢ *Regulatory Constraint and Eligibility Screening*

The eligibility factor prevented mandatory regulatory, legal, safety, environmental, and technical requirements from being treated as ordinary compensatory criteria.

$$E_i = \begin{cases} 1, & \text{if project } i \text{ was legally and technically eligible,} \\ 0, & \text{if a mandatory condition prevented execution.} \end{cases} \tag{9}$$

Projects with incomplete but non-prohibitive regulatory requirements were not automatically assigned $E_i = 0$. Their lower level of preparation was represented by the Regulatory Readiness Index. Only a mandatory prohibition resulted in numerical exclusion.

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Table 2 Regulatory and Execution-Status Classification

Classification	Interpretation	Treatment applied
Immediately executable	Mandatory requirements were satisfied and delivery capacity was adequate	Included in the executable portfolio
Conditionally executable	Remaining conditions could reasonably be completed	Retained in the active portfolio
Deferred pending compliance	Material permits or approvals remained outstanding	Withheld until the requirements were satisfied
Ineligible	A mandatory legal, safety, environmental, or technical condition prevented execution	Excluded from the executable portfolio

- *Agile Reprioritization Algorithm*

Project priority was treated as a dynamic quantity. The change in the Integrated Agile Priority Score between successive review periods was calculated as:

$$\Delta\text{IAPS}_{i,t} = \text{IAPS}_{i,t+1} - \text{IAPS}_{i,t} \quad (9)$$

Where $\text{IAPS}_{i,t}$ represented the score of project i during review period t; $\text{IAPS}_{i,t+1}$ represented the recalculated score during the subsequent period; and $\Delta\text{IAPS}_{i,t}$ represented the resulting score change.

Reprioritization was triggered by material changes in project cost, implementation schedule, technical risk, regulatory requirements, workforce availability, contractor capacity, supply-chain conditions, stakeholder expectations, sustainability targets, and technology maturity.

The procedure involved updating validated project data, recalculating normalized indicators, recomputing the five decision indices, applying Equation (7), screening project eligibility, and revising the portfolio ranking.

A documented justification accompanied each material rank change. This requirement preserved decision traceability and distinguished controlled agile reprioritization from arbitrary portfolio adjustment.

- *Project Priority Classification*

Continuous Integrated Agile Priority Scores were converted into management priority bands.

Table 3 Provisional Integrated Agile Priority Score classification

Integrated Agile Priority Score	Priority classification	Management response applied
80–100	Critical	Accelerated where technically and organizationally feasible
65–<80	High	Included in the near-term implementation program
50–<65	Moderate	Developed, sequenced, or piloted
30–<50	Low	Retained under periodic review
<30	Deferred	Reassessed for timing, value proposition, or project design

The score ranges were treated as provisional methodological thresholds rather than empirically validated limits. They were calibrated using the organization's governance requirements and the distribution of project scores.

Regulatory ineligibility overrode the numerical priority classification.

- *Portfolio Optimization*

Project ranking alone did not ensure that the resulting portfolio was financially and operationally feasible. A binary optimization model was therefore applied after project scoring.

The binary decision variable y_i was assigned a value of 1 when project i was selected and 0 when it was not selected. The portfolio objective was:

$$Max\ Z = \sum_{I=1}^{n} \text{IAPS}i\ yi \quad (11)$$

Where Z represented the total priority value of the selected portfolio.

The optimization was subjected to capital, resource, risk, sustainability, and eligibility constraints:

$$\begin{aligned} &\textstyle\sum_{i=1}^{n} C_i\, y_i \le B, \\ &\textstyle\sum_{i=1}^{n} H_{ik}\, y_i \le H_k^{\max}, k = 1,2,\dots,K, \\ &\textstyle\sum_{i=1}^{n} \text{PRI}_i\, y_i \le R^{\max}, \\ &\textstyle\sum_{i=1}^{n} \text{SCI}_i\, y_i \ge S^{\min}, \\ &y_i \le E_i, \quad i = 1,2,\dots,n, \\ &y_i \in \{0,1\},\ i = 1,2,\dots,n. \end{aligned} \quad (12)$$

In Equation (12), C_i represented the capital requirement of project i; B represented the available capital budget; H_{ik} represented the requirement of project i for resource category k; $H_k^{\max}$ represented the available capacity of resource category k; K represented the number of resource categories; $R^{\max}$ represented the acceptable aggregate portfolio-risk limit; and $S^{\min}$ represented the minimum required sustainability contribution.

Project dependencies were represented as:

$$yi \le yj \quad (13)$$

Equation (13) was applied when project i could not proceed unless enabling project j was also selected.

The optimization process translated the project rankings into a financially and operationally feasible portfolio rather than producing only an ordered project list. This approach was consistent with established resource-constrained portfolio decision principles [21].

➢ *Benchmark Prioritization Methods*

The Integrated Agile Priority Score was compared with established project-prioritization methods to determine how explicit treatment of risk, capacity, sustainability, and regulatory readiness affected the project rankings.

The first benchmark was a conventional weighted score in which normalized criteria were aggregated without explicit regulatory or delivery-capacity constraints. The second benchmark was the Benefit–Cost Ratio:

$$\mathrm{BCR}_i = \frac{\sum_{t=0}^{T_i} \frac{F_{it}^B}{(1+r)^t}}{\sum_{t=0}^{T_i} \frac{F_{it}^C}{(1+r)^t}} \tag{14}$$

Where BCR_i represented the Benefit–Cost Ratio of project i; F_{it}^B represented the benefit cash flow during period t; F_{it}^C represented the corresponding cost cash flow; r represented the discount rate; and T_i represented the project evaluation period.

A Benefit–Cost Ratio greater than 1 indicated that discounted benefits exceeded discounted costs. However, the measure did not independently account for sustainability contribution, organizational capacity, or regulatory readiness.

The remaining benchmarks were risk-adjusted net present value, the Analytic Hierarchy Process [17], and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) [18].

The benchmark comparison was used to determine how different treatments of value, risk, capacity, sustainability, and regulation changed the resulting project order. No benchmark was treated as a universal ground truth.

➢ *Sensitivity and Scenario Analysis*

Sensitivity analysis was conducted to determine whether the project rankings remained stable when uncertain model assumptions changed. The assessed parameters included stakeholder-value weights, sustainability weights, subcriterion weights, the risk-aversion coefficient, delivery-capacity threshold, capital cost, implementation duration, regulatory lead time, project-risk estimates, and expected sustainability benefits.

Criterion weights were initially perturbed by ±10% and ±20% from their baseline values and were subsequently renormalized. Where empirical uncertainty intervals were available, those intervals replaced the provisional perturbation ranges.

Ranking stability was evaluated using Spearman's rank correlation coefficient:

$$\rho = 1 - \frac{6\sum_{i=1}^{n} d_i^2}{n(n^2-1)} \tag{15}$$

Where ρ represented Spearman's rank correlation coefficient; d_i represented the difference between the baseline and perturbed ranks of project i; and n represented the number of projects. Values approaching 1 indicated strong ranking stability, whereas values approaching -1 indicated substantial ranking reversal.

Scenario analysis was conducted to evaluate coherent portfolio-wide changes rather than isolated parameter perturbations.

Table 4 Portfolio-Analysis Scenarios

Scenario	Principal assumption	Analytical purpose
Base case	Reference cost, risk, capacity, and sustainability assumptions	Established the baseline ranking
Capital-constrained	Reduced capital availability	Evaluated funding pressure
High-regulatory-risk	Increased approval uncertainty and delay	Evaluated regulatory exposure
High-carbon-reduction	Greater weight assigned to emissions reduction	Evaluated sustainability priority
Workforce-constrained	Reduced engineering and contractor capacity	Evaluated deliverability
Accelerated decarbonization	More stringent sustainability targets and implementation timelines	Evaluated the portfolio response to accelerated transition requirements

The same candidate projects were retained across the scenarios so that ranking changes resulted from scenario assumptions rather than changes in portfolio composition.

➢ *Statistical Analysis*

Continuous variables were summarized using the mean, standard deviation, median, minimum, maximum, and interquartile range where appropriate. Categorical variables were summarized using frequencies and percentages.

Pearson correlation was used for approximately continuous variables that satisfied linearity and distributional requirements. Spearman correlation was used for ordinal variables, non-normally distributed measurements, and ranking comparisons.

Correlation analysis was also conducted to identify overlapping decision criteria. Strongly correlated variables could otherwise have received excessive influence when both were assigned substantial weights.

Where the size and structure of the project dataset were adequate, regression analysis was used to examine relationships between project characteristics and outcomes such as cost deviation, schedule deviation, implementation success, energy savings, and carbon reduction.

Principal Component Analysis was applied to standardized project variables to identify dominant patterns and potential dimensional redundancy. Analysis of Variance was used to compare continuous outcomes among project categories and scenarios where its assumptions were satisfied. Robust or non-parametric alternatives were applied where the required assumptions were violated.

Statistical significance was evaluated at $p < 0.05$. Exact p-values, confidence intervals, test statistics, and effect sizes were reported where appropriate.

IV. RESULTS AND DISCUSSION

➢ *Project Portfolio Characteristics and Data Quality*

The first stage assessed the diversity and completeness of the project data used in applying the proposed framework. The portfolio comprised nine projects spanning renewable generation, energy storage, heat recovery, electrification, energy efficiency, carbon capture, alternative fuels, grid modernization, and hydrogen infrastructure. The projects differed substantially in technology type, capital intensity, implementation duration, environmental contribution, and organizational complexity. This variation provided an appropriate basis for evaluating project priorities across multiple sustainability, risk, stakeholder, and delivery dimensions within the framework.

Table 5 Characteristics of Candidate Sustainable Energy Infrastructure Projects

Project ID	Candidate project	Project category	CAPEX (US$ million)	Duration (months)	Data completeness (%)
P1	Industrial solar photovoltaic system	Renewable generation	28	18	100
P2	Battery energy storage system	Energy storage	18	14	98
P3	Waste-heat recovery power system	Waste-heat recovery	14	16	100
P4	Industrial process electrification	Electrification	32	24	97
P5	High-efficiency motors and variable-speed-drive retrofit	Energy efficiency	6	10	100
P6	Industrial carbon-capture system	Carbon capture	210	42	94
P7	Alternative-fuel substitution system	Alternative fuels	20	20	98
P8	Internal grid modernization and reinforcement	Grid modernization	24	22	100
P9	Green-hydrogen production and utilization system	Hydrogen infrastructure	95	36	93

The portfolio displayed substantial variation in both capital requirements and implementation duration. Capital expenditure ranged from US$6 million for the energy-efficiency retrofit to US$210 million for the carbon capture project, with a median value of US$24 million. Project implementation duration ranged from 10 to 42 months, with a median of 20 months. These differences demonstrated that project comparison based solely on cost or schedule would not adequately capture the broader factors influencing prioritization decisions.

Mean data completeness across the portfolio was 97.8%. The comparatively lower completeness values recorded for the carbon capture and hydrogen projects reflected their earlier stages of development and the greater uncertainty associated with supplier configuration, permitting requirements, and detailed engineering information. Missing values were concentrated in non-critical planning fields. Mandatory regulatory and safety variables were not imputed, in accordance with the methodology adopted for the study. This ensured that the absence of legal, regulatory, or compliance information did not artificially improve the eligibility or priority position of any project.

The portfolio also exhibited substantial technological heterogeneity. P3 and P5 represented comparatively mature retrofit-type interventions, whereas P6 and P9 represented high-capital decarbonization projects with greater technological, organizational, and implementation demands. These differences enabled the framework to distinguish between projects with strong strategic attractiveness and those with comparatively higher levels of practical executability, thereby providing a more comprehensive basis for prioritization.

➢ *Stakeholder Value Assessment*

Stakeholder value was evaluated to determine the extent to which each project aligned with strategic, economic, environmental, social, operational, and stakeholder-acceptance objectives. The assessment treated stakeholder value separately from measured sustainability contribution to avoid conflating strategic or perceived importance with

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directly measurable environmental performance. This distinction allowed the analysis to capture both the organizational value attributed to each project and its independently assessed sustainability outcomes.

Table 6 Stakeholder-Value Indicators and Stakeholder Value Index

Project	Strategic alignment	Economic benefit	Environmental value	Social impact	Operational improvement	Stakeholder acceptance	SVI
P1 Solar photovoltaic	92	84	94	78	86	82	0.86
P2 Battery storage	82	74	76	70	85	81	0.78
P3 Waste-heat recovery	90	88	91	75	95	89	0.88
P4 Process electrification	89	80	93	76	90	76	0.84
P5 Energy-efficiency retrofit	80	86	72	68	83	67	0.76
P6 Carbon capture	96	79	100	92	89	90	0.91
P7 Alternative-fuel system	84	77	86	82	78	73	0.80
P8 Grid modernization	88	72	76	70	96	90	0.82
P9 Green hydrogen	86	65	98	74	58	63	0.74

Carbon capture recorded the highest Stakeholder Value Index (SVI = 0.91), followed by waste-heat recovery (SVI = 0.88) and solar photovoltaic generation (SVI = 0.86). The carbon capture project achieved a particularly high score because of its strong alignment with deep industrial decarbonization objectives and its substantial potential environmental contribution. However, the high stakeholder-value score did not, by itself, establish carbon capture as the highest-priority project for immediate execution. Its final priority position depended on the combined consideration of risk exposure, implementation readiness, regulatory requirements, and delivery capacity.

Waste-heat recovery exhibited a comparatively balanced stakeholder-value profile. Its strong strategic alignment, economic attractiveness, and operational relevance resulted in an SVI of 0.88. The project therefore combined substantial stakeholder value with direct process-efficiency benefits, strengthening its position within the project portfolio.

The energy-efficiency retrofit recorded an SVI of 0.76 despite its strong economic benefits. Its comparatively lower score resulted from its more limited strategic and environmental transformation potential relative to larger decarbonization projects in the portfolio. The finding demonstrates that projects with comparatively modest scale may receive moderate stakeholder-value scores despite having strong implementation feasibility and delivery potential. This reinforces the need to assess stakeholder value alongside risk, delivery capacity, regulatory readiness, and sustainability performance rather than treating stakeholder value as an independent basis for project prioritization.

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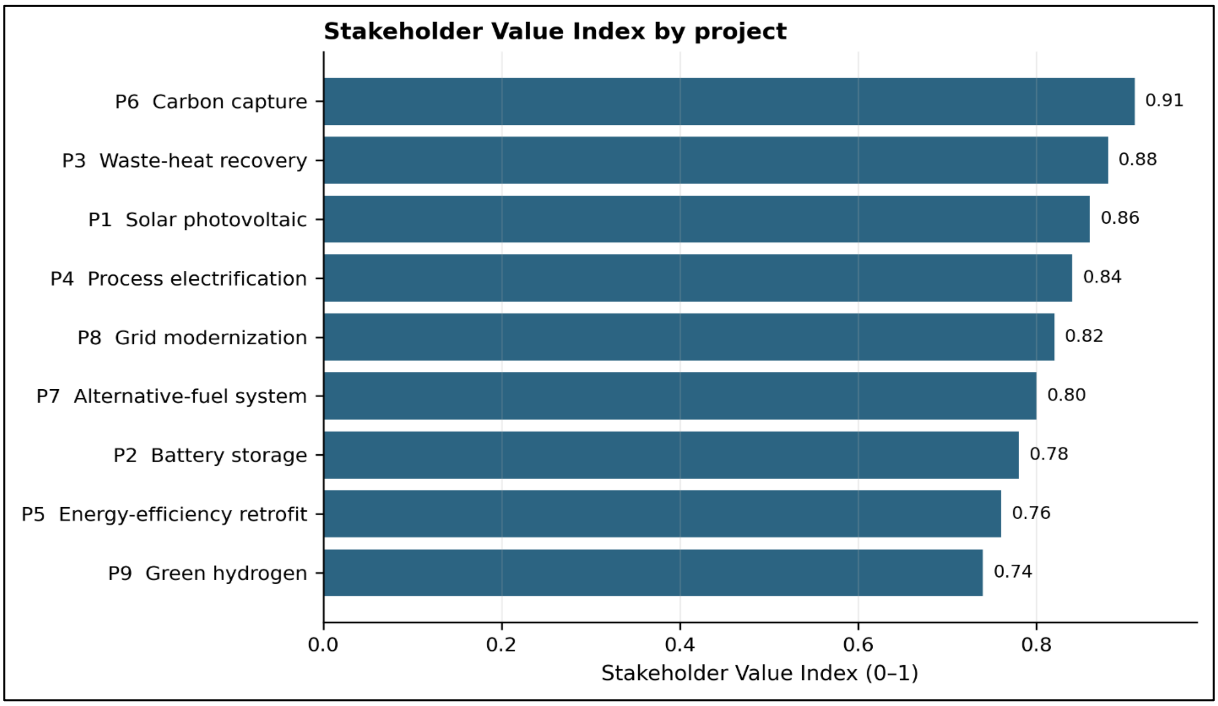

Fig 1 Comparative Stakeholder Value Index of the Sustainable Energy Infrastructure Projects.

The variation observed in stakeholder scores supports the argument presented by Cuppen et al. [9] that large energy-infrastructure projects can generate materially different stakeholder perceptions and priorities. Within the present study, the proposed framework translated these differing stakeholder dimensions into an explicit and measurable value structure, allowing stakeholder considerations to be incorporated systematically into project prioritization rather than remaining solely within qualitative consultation records.

➢ *Project Risk Assessment*

Project-specific risk was subsequently evaluated to determine the extent to which projects with high stakeholder value were also associated with significant implementation uncertainty and exposure. Risk scores were measured on a scale from 0 to 100, with higher scores indicating greater overall project risk. The assessment provided a structured basis for comparing the relative risk profiles of the nine projects and for determining how risk affected their eventual priority positions within the portfolio.

Table 7 Project-Risk Scores and Composite Project Risk Index

Project	**Technical risk**	**Financial/cost risk**	**Schedule risk**	**Regulatory risk**	**Environmental risk**	**Supply-chain risk**	**PRI**
P1 Solar photovoltaic	22	25	30	24	20	47	0.28
P2 Battery storage	38	40	45	36	28	65	0.42
P3 Waste-heat recovery	25	29	32	24	26	50	0.31
P4 Process electrification	44	48	52	46	39	53	0.47
P5 Energy-efficiency retrofit	15	20	18	16	14	49	0.22
P6 Carbon capture	70	68	65	72	55	42	0.62
P7 Alternative-fuel system	32	36	38	41	35	34	0.36
P8 Grid modernization	20	24	27	22	18	39	0.25
P9 Green hydrogen	78	75	72	70	58	55	0.68

Green hydrogen recorded the highest Project Risk Index (PRI = 0.68), followed by carbon capture (PRI = 0.62) and process electrification (PRI = 0.47). The comparatively high risk levels associated with green hydrogen and carbon capture were driven by technology-integration complexity, substantial capital exposure, schedule uncertainty, and regulatory requirements. By contrast, the energy-efficiency retrofit recorded the lowest PRI at 0.22, indicating a comparatively lower level of implementation risk within the evaluated portfolio.

Battery storage recorded a moderate overall risk profile, with supply-chain exposure representing its most significant individual risk dimension. This finding demonstrates the value of decomposing project risk into multiple components rather than relying on a single aggregate judgement. Although a project may be technically mature, it can still remain materially exposed to procurement constraints, supply availability, regulatory classification, lifecycle-cost uncertainty, and other delivery-related factors. The multidimensional risk assessment therefore provided a more complete representation of the actual implementation conditions affecting each project.

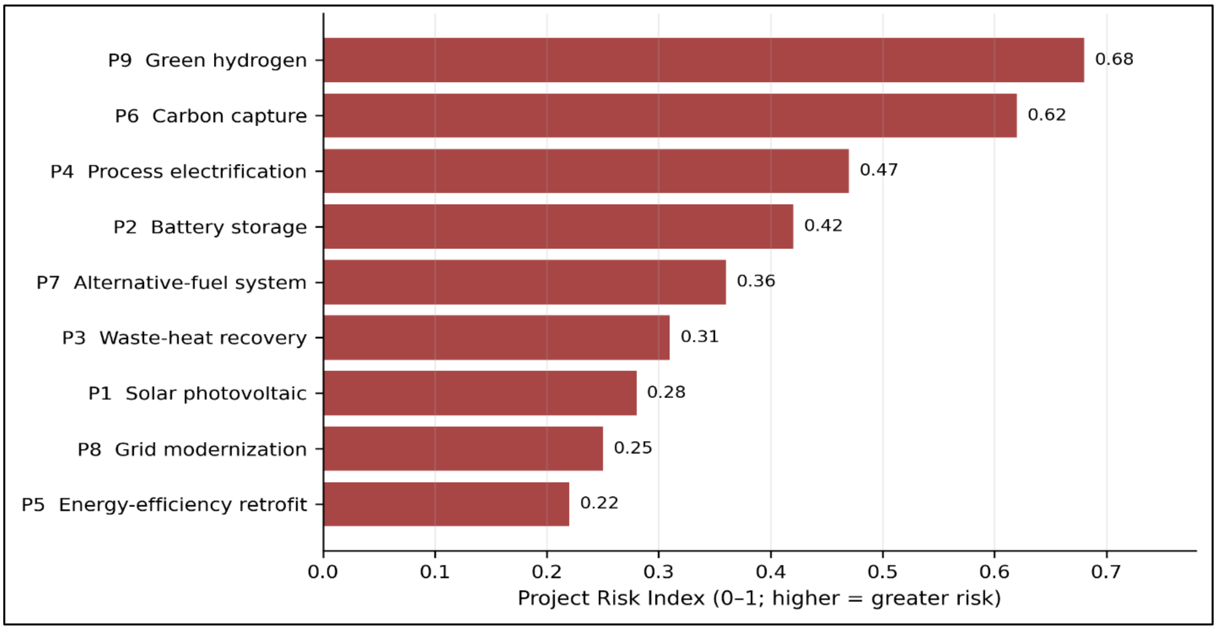

Fig 2 Comparative Project Risk Index for the project portfolio.

The observed risk structure is consistent with the holistic perspective advanced by Abba et al. [10], who emphasized that renewable and low-carbon energy investments are influenced by interconnected technical, economic, policy, and implementation risks. In the present study, the framework captured these interdependencies by assessing distinct risk dimensions before integrating them into the overall Project Risk Index. This approach reduced reliance on a single undifferentiated management judgement and provided a more transparent basis for comparing project risk across the portfolio.

➢ *Delivery Capacity Assessment*

Delivery capacity was evaluated to determine the extent to which the organization possessed the technical expertise, financial resources, workforce capability, contractor support, and supply-chain capacity required to implement each project successfully. This dimension was particularly important because projects with high stakeholder value and strong strategic relevance could still face implementation constraints where organizational capacity was insufficient. The assessment therefore provided an empirical basis for distinguishing projects that were ready for execution from those requiring additional capability development, financing arrangements, contractor engagement, or supply-chain preparation before implementation.

Table 8. Delivery-Capacity Indicators and Delivery Capacity Index

Project	Human-resource availability	Technical competence	Capital availability	Supply-chain readiness	Contractor capacity	Technology readiness	Workload capacity	DCI
P1 Solar photovoltaic	80	82	75	76	74	85	74	0.78
P2 Battery storage	78	80	70	68	72	86	78	0.76
P3 Waste-heat recovery	90	92	85	88	91	84	86	0.88
P4 Process electrification	66	74	60	62	68	72	67	0.67
P5 Energy-efficiency retrofit	88	86	92	80	84	90	68	0.84

P6 Carbon capture	55	62	50	52	58	60	62	0.57
P7 Alternative-fuel system	72	76	68	74	70	75	76	0.73
P8 Grid modernization	84	88	78	80	82	76	79	0.81
P9 Green hydrogen	42	55	38	40	48	45	47	0.45

Waste-heat recovery recorded the highest Delivery Capacity Index (DCI = 0.88), followed by the energy-efficiency retrofit (DCI = 0.84) and grid modernization (DCI = 0.81). The comparatively strong delivery-capacity scores of these projects were associated with mature engineering knowledge, available contractor capability, manageable capital requirements, established technical resources, and greater organizational familiarity with their implementation requirements.

Carbon capture and green hydrogen recorded substantially lower delivery-capacity scores of 0.57 and 0.45, respectively. These findings show that strong strategic importance and stakeholder value did not necessarily correspond with immediate organizational capability for project execution. The principal constraints affecting the two projects included capital availability, access to specialized technical expertise, technology readiness, and supply-chain requirements. Consequently, their lower DCI values reflected identifiable implementation limitations that would need to be addressed before full-scale execution could be undertaken with sufficient organizational and delivery confidence.

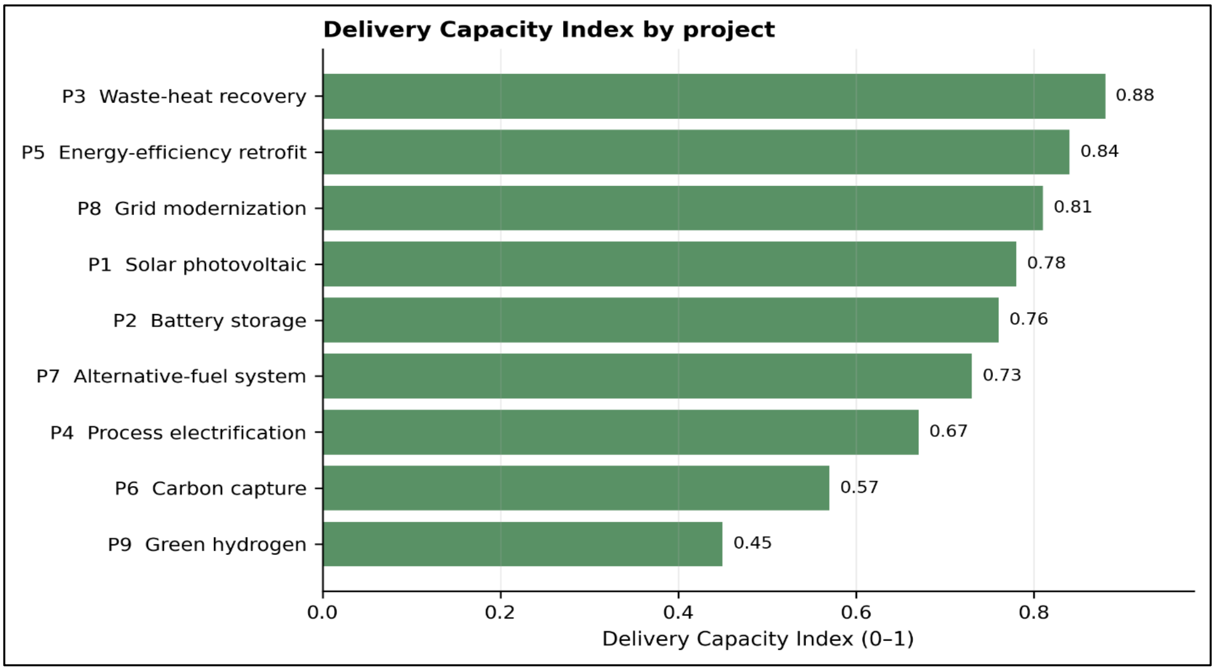

Fig 3 Distribution of Delivery Capacity Index Values Across the Portfolio.

The findings reinforce the importance of assessing delivery capacity as a distinct project dimension rather than subsuming it within the broader risk assessment. Portfolio-management research emphasizes the need to balance project attractiveness against the organizational resources available for implementation. Similarly, dynamic-capability research indicates that organizations must be able to develop, adapt, and reconfigure their capabilities in response to changing project and portfolio priorities. The results obtained in this study support these perspectives by showing that projects with strong strategic value may still face significant execution constraints where the required organizational capabilities are not sufficiently developed.

➢ *Regulatory and Sustainability Performance*

Regulatory readiness and sustainability contribution were assessed as separate but complementary dimensions of low-carbon infrastructure performance. Regulatory readiness captured the extent to which each project satisfied applicable approval, permitting, compliance, and institutional requirements, while sustainability performance reflected the measurable environmental contribution associated with the project. Considering both dimensions was necessary because a project could demonstrate substantial environmental benefit while still facing regulatory constraints that could delay or restrict implementation. The assessment therefore provided a more complete basis for determining the practical suitability and overall priority of each project within the portfolio.

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Table 9 Regulatory-Readiness and Sustainability-Performance Indicators

Project	RRI	GHG reduction ($ktCO_2e$/year)	Energy saving or low-carbon contribution (GWh/year)	Renewable or low-carbon contribution (%)	SCI
P1 Solar photovoltaic	0.90	85	150	38	0.90
P2 Battery storage	0.82	15	45	18	0.72
P3 Waste-heat recovery	0.91	60	120	24	0.84
P4 Process electrification	0.72	110	170	42	0.88
P5 Energy-efficiency retrofit	0.95	35	75	8	0.67
P6 Carbon capture	0.49	650	40	5	0.96
P7 Alternative-fuel system	0.65	120	95	35	0.79
P8 Grid modernization	0.89	20	35	15	0.70
P9 Green hydrogen	0.41	170	130	55	0.93

Carbon capture recorded the highest Sustainability Contribution Index (SCI = 0.96), followed by green hydrogen (SCI = 0.93), solar photovoltaic generation (SCI = 0.90), and process electrification (SCI = 0.88). However, the two projects with the highest sustainability scores also recorded the lowest Regulatory Readiness Index values. Carbon capture recorded an RRI of 0.49, while green hydrogen recorded an RRI of 0.41.

This contrast was central to the performance of the proposed framework. Ranking the projects solely on sustainability contribution would have placed P6 and P9 among the most attractive options. However, an execution-oriented portfolio decision also required consideration of unresolved approvals, permitting complexity, infrastructure dependencies, and implementation readiness. The combined assessment therefore prevented projects with high environmental potential but low regulatory preparedness from being prioritized without adequate consideration of their implementation constraints.

P5 displayed the reverse pattern. Its SCI of 0.67 was lower than those of the major decarbonization projects, while its RRI of 0.95 indicated a comparatively high level of regulatory preparedness and implementation feasibility. This finding demonstrates the importance of distinguishing between environmental potential and readiness to realize that potential when prioritizing sustainable-energy infrastructure investments.

This broader assessment approach is consistent with studies advocating the evaluation of renewable-energy projects beyond single cost-based measures and the incorporation of economic, technical, environmental, and enabling factors into energy-planning and investment decisions.

➢ *Integrated Project Priority Scores*

The Integrated Agile Priority Score was subsequently calculated for each project using Equation (7). The calculation integrated stakeholder value and sustainability contribution, applied the project-risk adjustment, and incorporated delivery capacity and regulatory readiness to produce a consolidated priority score for each project in the portfolio. This enabled the relative attractiveness of the projects to be evaluated using their observed performance across the major decision dimensions rather than on the basis of any single criterion.

Based on the eligibility screening conducted for the portfolio, all nine projects satisfied the basic eligibility requirements for inclusion in the integrated prioritization analysis. However, P6 and P9 remained subject to comparatively significant regulatory-development requirements, which were reflected in their lower regulatory-readiness scores and consequently influenced their overall priority positions.

Table 10. Integrated Agile Priority Scores and Project Rankings

Rank	Project	Benefit score (%)	PRI	DCI	RRI	IAPS	Priority class
1	P3 Waste-heat recovery	86.2	0.31	0.88	0.91	60.5	Moderate
2	P1 Solar photovoltaic	87.8	0.28	0.78	0.90	54.7	Moderate
3	P5 Energy-efficiency retrofit	72.0	0.22	0.84	0.95	52.4	Moderate
4	P8 Grid modernization	76.6	0.25	0.81	0.89	49.7	Low
5	P2 Battery storage	75.3	0.42	0.76	0.82	39.0	Low
6	P4 Process electrification	85.8	0.47	0.67	0.72	33.6	Low
7	P7 Alternative-fuel system	79.6	0.36	0.73	0.65	32.3	Low
8	P6 Carbon capture	93.3	0.62	0.57	0.49	19.6	Deferred
9	P9 Green hydrogen	82.6	0.68	0.45	0.41	11.1	Deferred

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Waste-heat recovery achieved the highest Integrated Agile Priority Score (IAPS) of 60.5, despite not recording the highest individual stakeholder-value or sustainability score. Its leading position resulted from the combined effect of strong stakeholder value, substantial sustainability contribution, manageable project risk, high delivery capacity, and strong regulatory readiness. The result indicates that its overall priority was driven by balanced performance across the principal decision dimensions rather than dominance in a single criterion.

Solar photovoltaic generation ranked second with an IAPS of 54.7. Its strong position was supported by high stakeholder value and sustainability contribution, together with relatively low project risk and strong regulatory readiness. This combination enhanced its overall implementation attractiveness within the evaluated portfolio.

The energy-efficiency retrofit ranked third with an IAPS of 52.4 despite recording a lower benefit score than several of the larger projects. Its priority position was strengthened by low project risk, high delivery capacity, and very strong regulatory readiness. This finding demonstrates that comparatively modest but readily executable interventions can achieve higher overall priority than larger, high-profile projects when their implementation conditions are substantially more favorable.

Carbon capture presented the most pronounced contrast between strategic value and overall project priority. Its benefit score of 93.3 was the highest in the portfolio; however, its IAPS declined to 19.6 because of elevated project risk, comparatively limited delivery capacity, and low regulatory readiness. Green hydrogen exhibited a similar pattern and ranked ninth with an IAPS of 11.1. These findings show that high strategic and environmental value did not automatically translate into immediate implementation priority when significant regulatory, organizational, technical, and delivery constraints were present.

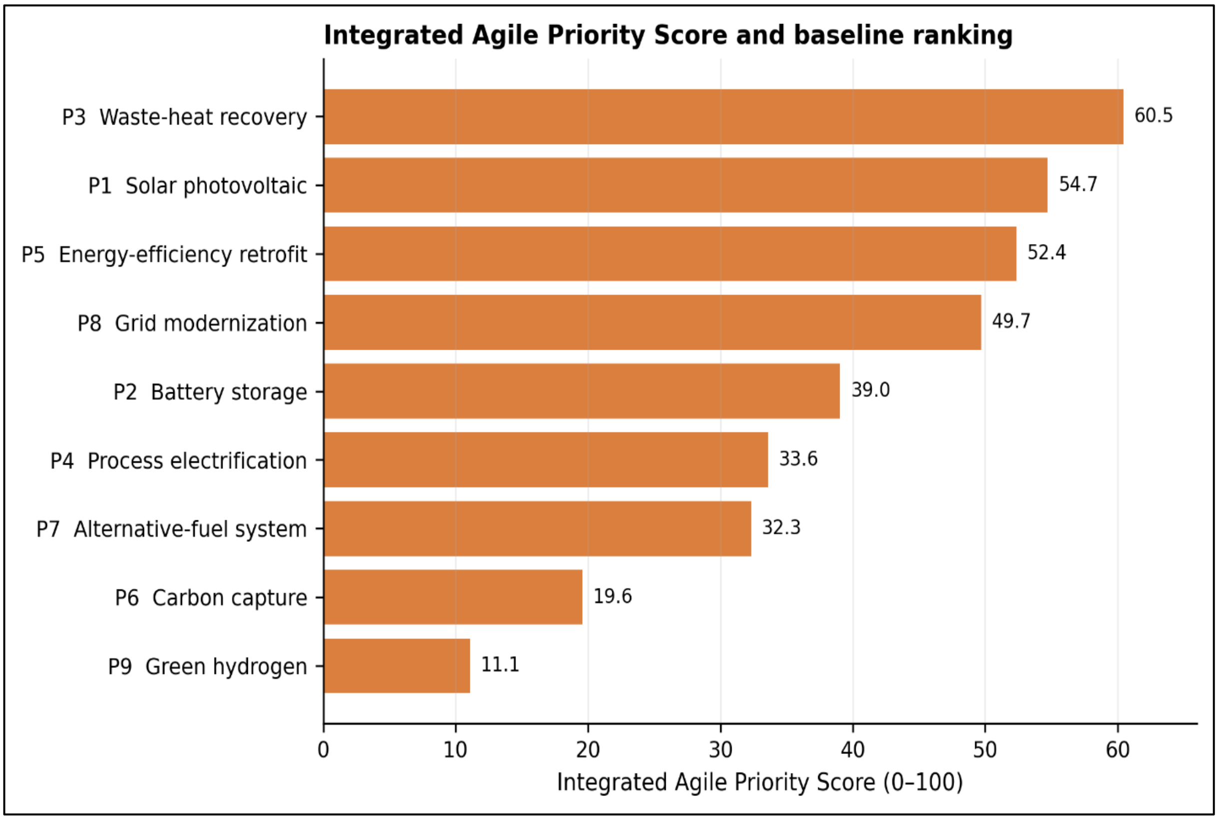

Fig 4 Ranked Integrated Agile Priority Scores for the Sustainable Energy Infrastructure Portfolio.

The findings support the central argument of the study that sustainable infrastructure prioritization should not be based solely on identifying projects with the greatest environmental or financial benefits. Effective portfolio decision-making also requires consideration of project maturity, implementation risk, organizational capability, regulatory preparedness, and overall executability. The results therefore demonstrate the importance of balancing strategic attractiveness with the practical conditions required for successful project delivery.

➢ *Effect of Risk Adjustment on Project Ranking*

The effect of project risk on portfolio ranking was examined by comparing the unadjusted benefit ranking with the ranking obtained after application of the risk-adjustment factor, prior to incorporating delivery-capacity and regulatory-readiness effects. This comparison made it possible to determine how differences in project risk altered the relative positions of the evaluated projects.

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Under the unadjusted benefit ranking, carbon capture occupied first position with a score of 93.3, followed by solar photovoltaic generation with 87.8 and waste-heat recovery with 86.2. Green hydrogen occupied fifth position, largely because of its strong sustainability contribution and strategic value.

After application of the baseline risk-aversion coefficient of 0.40, the ranking changed substantially. Solar photovoltaic generation moved from second to first position, while waste-heat recovery advanced from third to second. Carbon capture declined from first to third position because its comparatively high risk exposure reduced its adjusted benefit score. Process electrification remained in fourth position. Grid modernization improved from seventh to fifth, while green hydrogen declined from fifth to ninth position.

These changes resulted directly from the risk-adjustment component of Equation (7) and demonstrate the measurable influence of project risk on portfolio priority. Projects with strong benefit scores but comparatively high risk exposure experienced downward movements in the ranking, whereas projects with more moderate benefit scores and lower risk profiles improved their relative positions. The result confirms that incorporating risk into the prioritization process materially changes portfolio decisions and provides a more realistic representation of project attractiveness under actual implementation conditions.

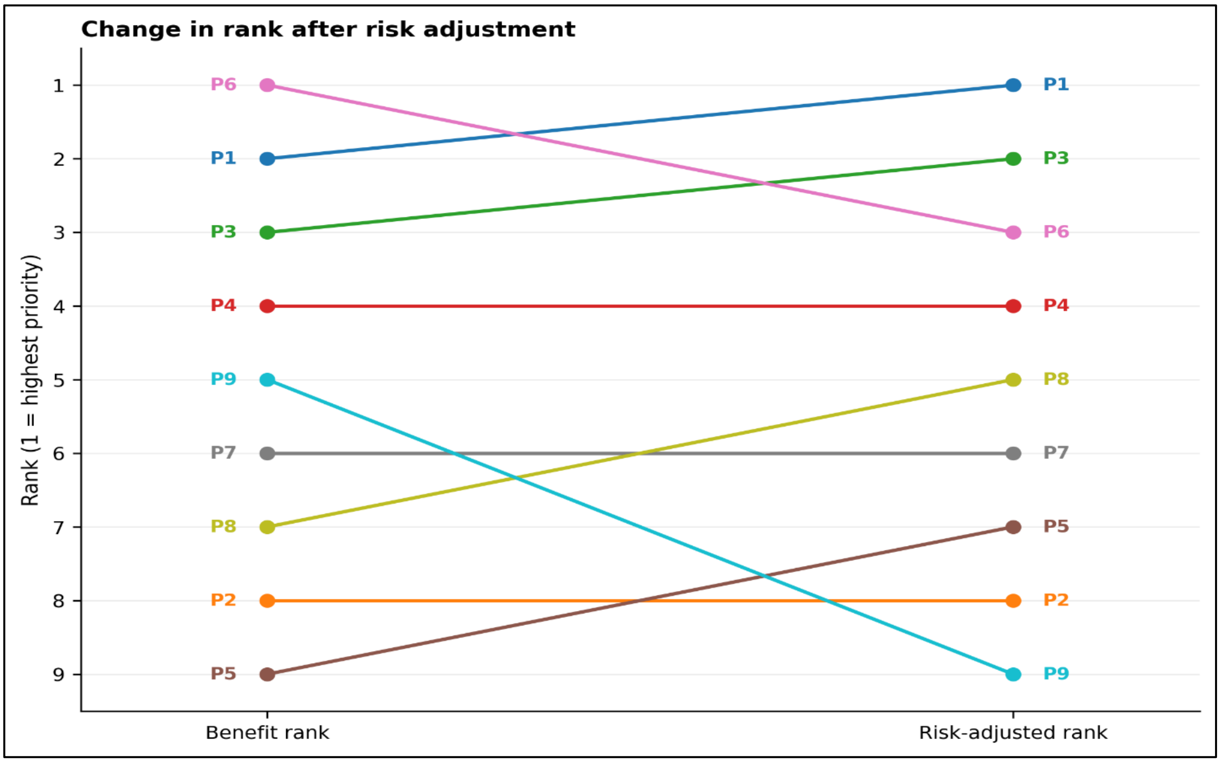

Fig 5 Change in Project Rank Between Unadjusted Benefit Scoring and Risk-Adjusted Prioritization.

The result demonstrates why risk should not be treated merely as descriptive information appended to a value-based ranking. Where uncertainty and exposure are material, incorporating risk into the prioritization model can substantially alter the relative attractiveness of projects. This finding is consistent with the holistic investment-risk perspective reported by Abba et al. [10].

At the same time, the results showed that risk adjustment alone was insufficient to explain the final priority positions of the projects. The incorporation of delivery capacity and regulatory readiness produced further changes in project rankings, confirming that project risk and organizational readiness capture different dimensions of the prioritization problem. Risk reflects uncertainty and potential exposure, whereas delivery capacity and regulatory readiness indicate the extent to which the organization is practically positioned to execute a project successfully.

➤ *Effect of Delivery Capacity on Prioritization*

This subsection examined the relationship between stakeholder value and organizational delivery capacity to determine whether projects regarded as strategically valuable could also be implemented effectively using the available organizational capabilities and resources.

The correlation between the Stakeholder Value Index (SVI) and Delivery Capacity Index (DCI) was weakly positive at approximately 0.16. Given that the portfolio comprised only nine projects, this coefficient was interpreted descriptively rather than inferentially. The observed relationship indicates that stakeholder value and delivery capability did not necessarily increase together across the evaluated projects. Consequently, projects receiving strong stakeholder support or strategic importance could still face substantial organizational constraints affecting their immediate implementation.

Carbon capture provided the clearest example of this divergence. It recorded the highest SVI in the portfolio at 0.91, while its DCI was considerably lower at 0.57. Green hydrogen recorded an SVI of 0.74 and the lowest DCI in the portfolio at 0.45. By contrast, waste-heat recovery combined a high SVI of 0.88 with an equally high DCI of 0.88, indicating both strong stakeholder value and a comparatively strong organizational capacity for implementation.

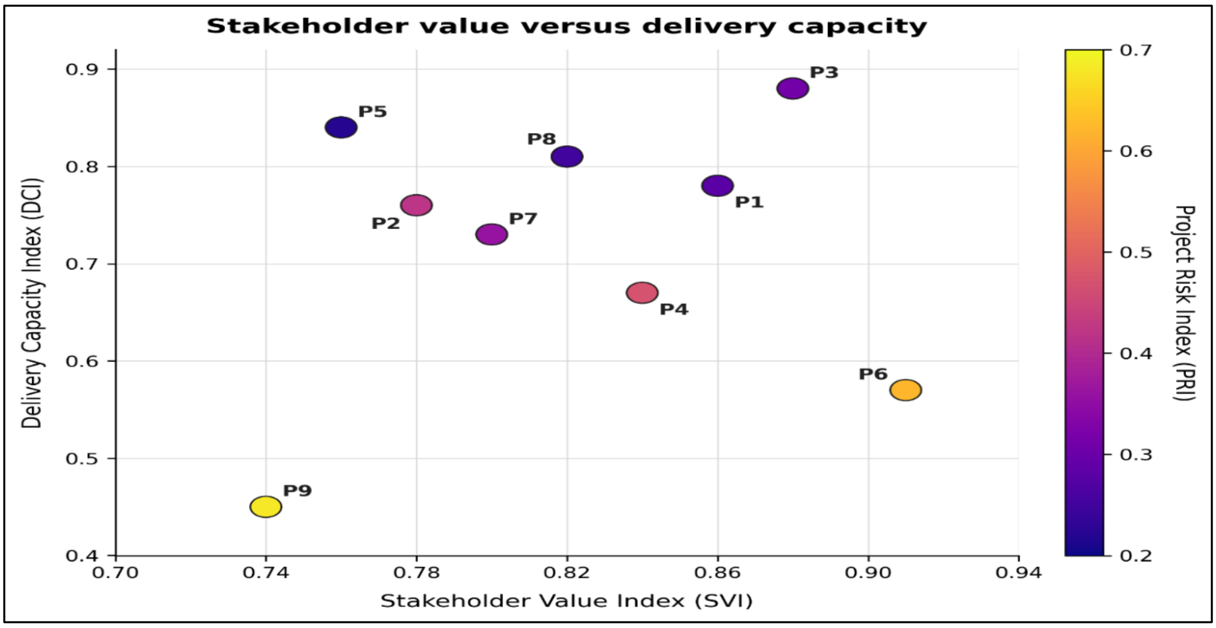

Fig 6 Relationship Between Stakeholder Value Index and Delivery Capacity Index; Marker Color Represents the Project Risk Index.

The findings indicate that project attractiveness and project readiness should be reported as distinct dimensions during executive portfolio reviews. A project with high stakeholder value but constrained delivery capacity does not necessarily require rejection. Instead, the identified capacity limitations can inform targeted management actions, including capability development, additional capital allocation, specialist contractor engagement, workforce development, supply-chain strengthening, or appropriate rescheduling until critical implementation constraints have been addressed.

This treatment is consistent with Portfolio Decision Analysis, which recognizes that project-selection decisions must account for competing priorities and limitations in organizational resources [21].

➢ *Agile Reprioritization Under Changing Conditions*

Agile reprioritization was assessed using updated project information obtained during a subsequent portfolio-review cycle. The revised assessment captured changes in technology maturity, regulatory progress, contractor availability, project risk, and organizational delivery capacity. Updating these variables enabled the framework to determine how changes in actual project conditions affected relative portfolio priorities over time.

The most substantial changes were recorded for process electrification, battery storage, alternative fuels, carbon capture, and green hydrogen. These projects experienced notable changes in one or more of the variables influencing their priority scores. For process electrification, for example, the Project Risk Index decreased from 0.47 to 0.32, while the Delivery Capacity Index increased from 0.67 to 0.84 and the Regulatory Readiness Index increased from 0.72 to 0.90. These changes reflected improved implementation conditions and consequently affected the project's relative priority within the updated portfolio assessment.

Table 11 Baseline and dynamically updated project rankings

Project	Baseline IAPS	Baseline rank	Updated IAPS	Updated rank	Rank change
P1 Solar photovoltaic	54.7	2	54.7	3	−1
P2 Battery storage	39.0	5	52.0	5	0
P3 Waste-heat recovery	60.5	1	56.9	2	−1
P4 Process electrification	33.6	6	57.6	1	+5
P5 Energy-efficiency retrofit	52.4	3	52.4	4	−1
P6 Carbon capture	19.6	8	37.8	8	0
P7 Alternative-fuel system	32.3	7	50.2	6	+1
P8 Grid modernization	49.7	4	49.7	7	−3
P9 Green hydrogen	11.1	9	21.0	9	0

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Process electrification experienced the largest change, moving from sixth to first. The increase did not arise from a change in its basic technology category but from improved implementation conditions. Lower risk, higher delivery capacity, and stronger regulatory readiness increased its IAPS from 33.6 to 57.6.

Carbon capture increased from 19.6 to 37.8 after improvements in capacity and regulatory status, but it remained eighth because significant implementation barriers persisted. This is an important feature of the framework: improving one project characteristic does not automatically produce an unrealistic jump in priority if other constraints remain material.

The demonstration reflects the type of portfolio adaptation discussed by Petit [12] and Bechtel et al. [13], where changing conditions require organizations to sense new information and reconfigure portfolio priorities.

➢ *Scenario Analysis*

Scenario analysis evaluated whether portfolio decisions remained appropriate under materially different organizational and strategic conditions.

Under the base case, waste-heat recovery remained first because it provided the most balanced combination of value, risk, capacity, and readiness.

Under the capital-constrained scenario, the energy-efficiency retrofit became the strongest investment candidate because of its low capital requirement and relatively high priority score. Waste-heat recovery also remained attractive because its IAPS was high relative to its capital demand. Capital-intensive carbon capture and hydrogen were strongly disadvantaged.

Under the high-regulatory-risk scenario, projects with established regulatory pathways, particularly energy efficiency, waste-heat recovery, solar generation, and grid modernization, became more attractive relative to emerging infrastructure.

In the high-carbon-reduction scenario, the relative attractiveness of carbon capture, hydrogen, electrification, and alternative fuels increased because of their higher sustainability contributions. However, carbon capture and hydrogen did not automatically become the leading projects because their capacity and regulatory constraints remained significant. This illustrates the non-compensatory behavior intentionally built into the framework.

The workforce-constrained scenario favored projects with established engineering competencies and lower specialist-resource requirements. Energy efficiency and grid modernization consequently became more attractive than projects requiring substantial new technical capability.

Finally, under an accelerated-decarbonization scenario that combined higher sustainability ambition with deliberate improvements in regulatory readiness and delivery capacity, process electrification moved into the leading position, consistent with the dynamic results presented in Table 11.

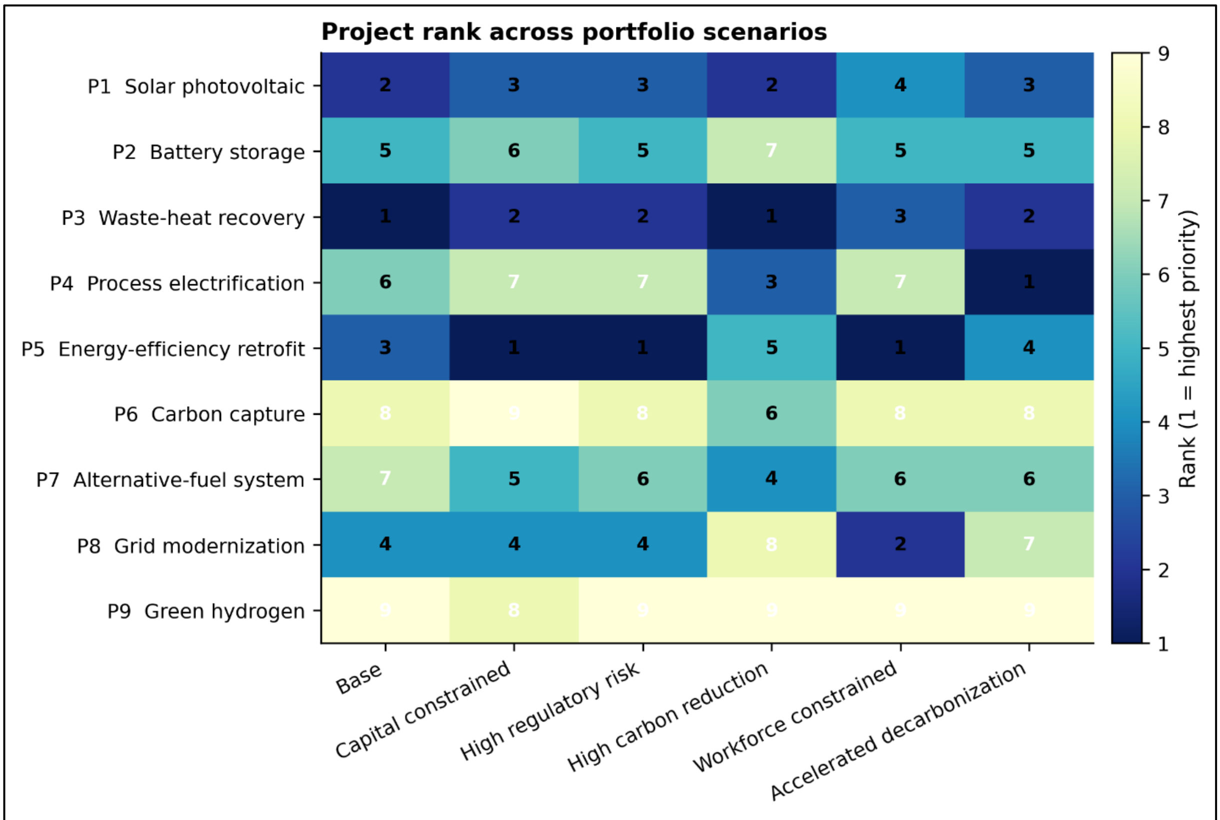

Fig 7 Changes in Project Ranking Across the Six Portfolio Scenarios; Rank 1 Represents the Highest Priority.

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The scenario results showed that the framework does not assume that one permanent project ranking exists. Rather, the preferred sequence depends on organizational conditions and strategic priorities. This characteristic is important in regulated industrial environments where capital availability, policy requirements, and resource conditions may change between portfolio-review cycles.

➢ *Sensitivity Analysis*

Sensitivity analysis evaluated whether small changes in weighting assumptions produced disproportionate changes in project ranking.

Changes in the relative stakeholder-value and sustainability weights around the baseline did not alter the ordering of the nine projects. Similarly, changing the risk-aversion coefficient from 0.40 to 0.32 or 0.48 left the baseline rank order unchanged, producing a Spearman rank correlation of 1.00 relative to the baseline ranking.

The ranking was more sensitive to project-specific changes in delivery capacity and regulatory readiness. A 20% improvement in the delivery capacity of grid modernization, for example, was sufficient to move P8 from fourth to second position. A 20% improvement in either delivery capacity or regulatory readiness also improved the position of process electrification and the alternative-fuel system, although the magnitude of the change was smaller.

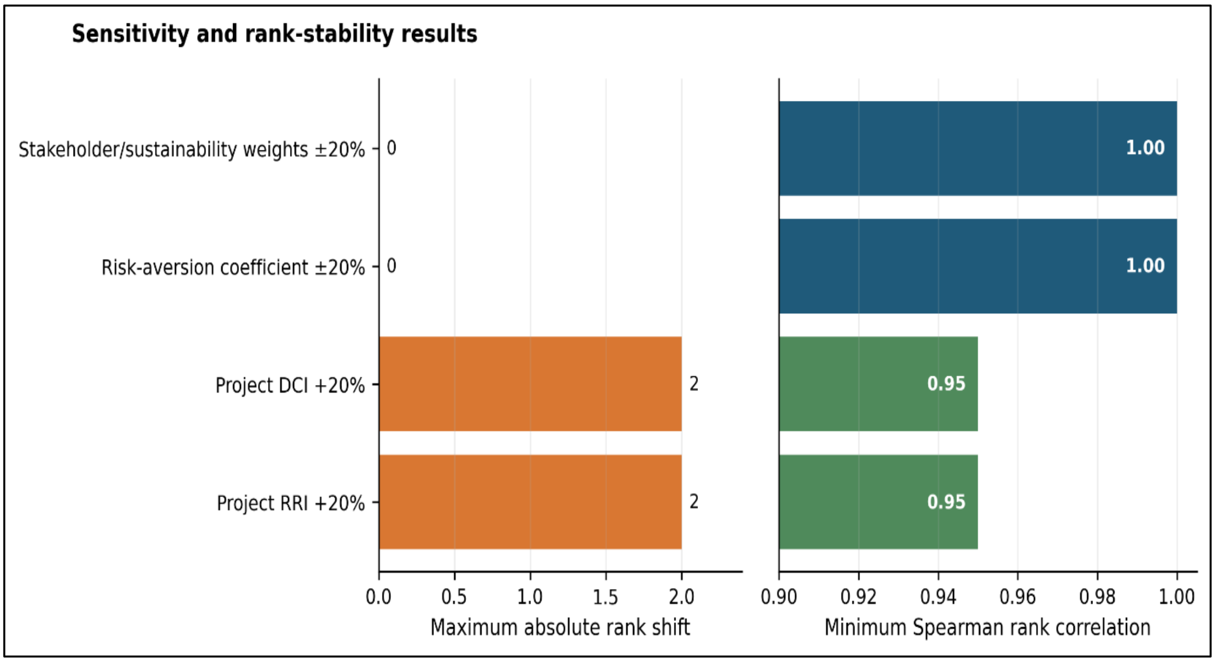

Fig 8 Sensitivity of Project Ranking to Criterion Weights, Risk-Aversion Assumptions, Delivery Capacity, and Regulatory Readiness.

This pattern is analytically useful. It indicates that the framework is not excessively unstable under modest changes in preference weights, while remaining responsive to meaningful improvements in project executability. Sensitivity testing is necessary because MCDA studies have demonstrated that changes in criterion weights can alter energy rankings.

➢ *Correlation and Multivariate Relationships*

Correlation analysis was used descriptively to examine relationships among the five principal composite indices. Because the dataset contains only nine projects, statistical significance testing was not interpreted as empirical evidence.

The strongest relationship was observed between delivery capacity and regulatory readiness, with a correlation of approximately 0.95. This reflected the constructed tendency for mature projects to possess both greater organizational readiness and more advanced approval status. Project risk was strongly negatively associated with delivery capacity and regulatory readiness, with correlations of approximately −0.94 in both cases.

The Sustainability Contribution Index was positively associated with project risk at approximately 0.72 and negatively associated with delivery capacity at approximately −0.68. In theportfolio, this occurred because the projects offering the largest transformational decarbonization benefits, particularly carbon capture and hydrogen, were also among the least mature and most difficult to deliver.

The relationship between SVI and SCI was moderate at approximately 0.48, indicating that stakeholder value and quantified sustainability contribution were related but not identical.

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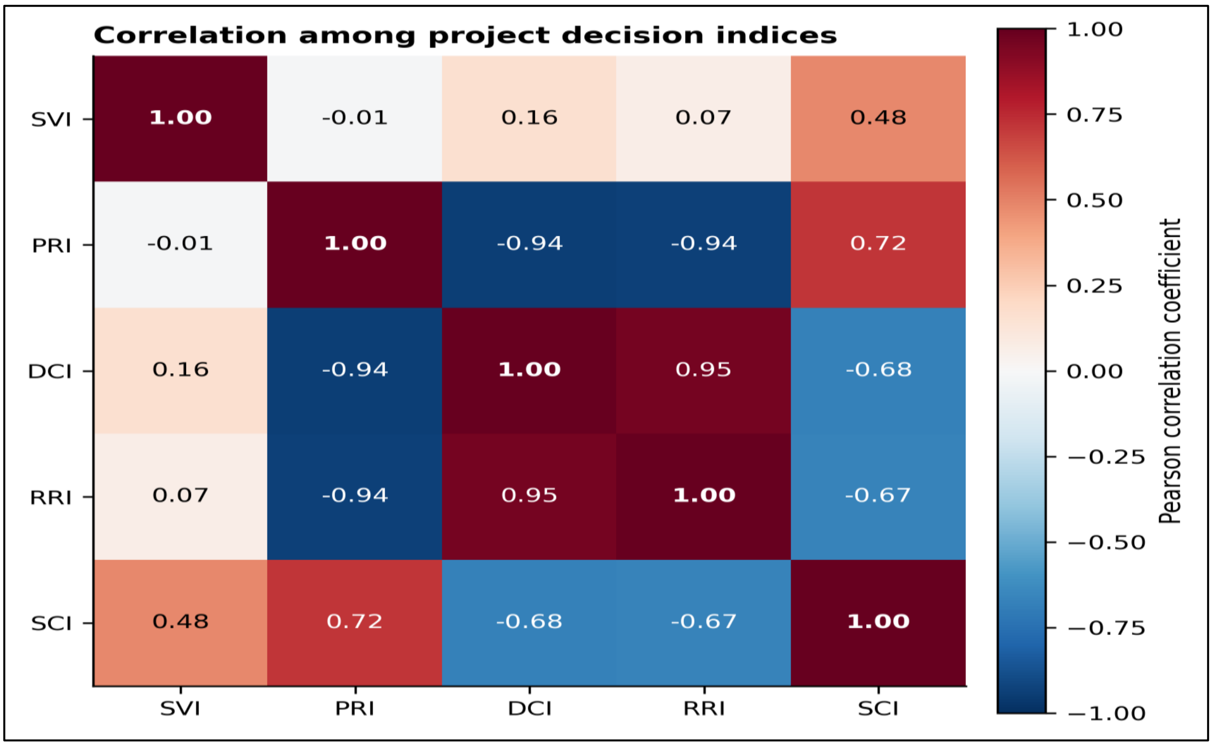

Fig 9 Correlation Heatmap of the Five Composite Decision Indices.

Principal Component Analysis (PCA) was also conducted as an exploratory demonstration. The first principal component accounted for approximately 69.3% of standardized variance, while the second accounted for 25.8%. Together, the first two components represented approximately 95.1% of the variance.

The first component was characterized by positive contributions from project risk and sustainability ambition and negative contributions from delivery capacity and regulatory readiness. It therefore represented an ambition-versus-readiness axis. Carbon capture and hydrogen appeared strongly toward the high-risk/high-sustainability end, whereas energy efficiency, waste-heat recovery, and grid modernization appeared toward the more execution-ready end.

The second principal component was dominated by stakeholder value and, to a lesser extent, sustainability contribution. This dimension separated projects with strong perceived strategic value from those whose portfolio attractiveness depended more heavily on execution readiness.

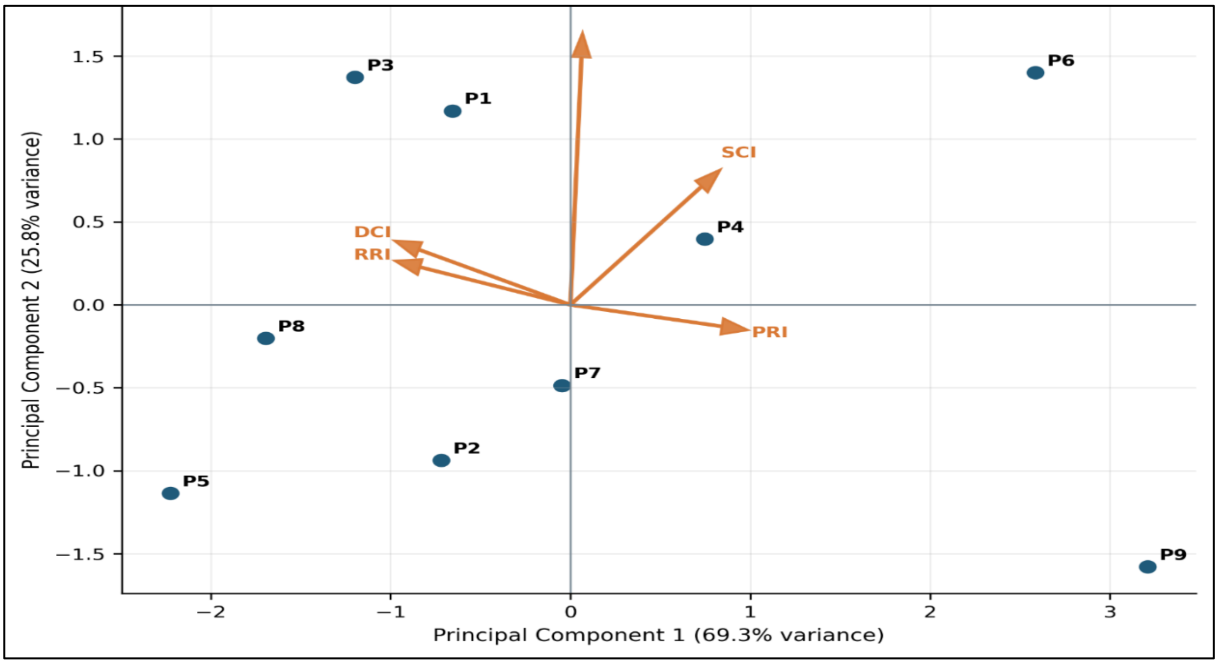

Fig 10 Exploratory Principal-Component Score and Loading Biplot for the Five Composite Decision Dimensions.

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The PCA should not be generalized beyond the demonstration because nine observations are insufficient for a robust empirical multivariate model. Its purpose here is to illustrate how the framework may reveal structural relationships when applied subsequently to a larger real project portfolio.

➢ *Benchmark Comparison*

The proposed framework was compared with simple weighted scoring, Benefit-Cost Ratio (BCR), risk-adjusted Net Present Value, AHP, and TOPSIS. The comparison was intended to determine whether alternative prioritization logics produced materially different project sequences.

Table 12 Comparison of Rankings Produced by Alternative Prioritization Methods

Project	IAPS rank	Simple weighted rank	BCR rank	Risk-adjusted NPV rank	AHP rank	TOPSIS rank
P1 Solar photovoltaic	2	2	3	2	2	1
P2 Battery storage	5	5	6	5	6	5
P3 Waste-heat recovery	1	1	2	1	1	2
P4 Process electrification	6	6	7	7	5	7
P5 Energy-efficiency retrofit	3	3	1	3	3	4
P6 Carbon capture	8	8	9	8	8	8
P7 Alternative-fuel system	7	7	5	6	7	6
P8 Grid modernization	4	4	4	4	4	3
P9 Green hydrogen	9	9	8	9	9	9

The IAPS ranking correlated strongly with the simple weighted model because both used common normalized project characteristics. The Spearman correlation was 1.00. Correlation with AHP and risk-adjusted NPV ranking was approximately 0.98, with TOPSIS approximately 0.95. The largest divergence occurred with BCR, where the rank correlation was approximately 0.88.

The BCR method ranked the low-capital energy-efficiency retrofit first because the method strongly rewards benefit relative to investment cost. This ranking is economically defensible but provides less explicit treatment of regulatory readiness and organizational capacity.

TOPSIS placed solar photovoltaic generation first and grid modernization third. These differences demonstrate that project ranking is partly method dependent, consistent with the broader MCDA literature [4], [5], [17], [18].

The purpose of the proposed framework is therefore not to claim that conventional methods are mathematically incorrect. Its contribution lies in making risk, regulatory readiness, delivery capacity, and agile updating explicit within the decision architecture.

➢ *Framework Performance and Robustness*

Framework performance was assessed in terms of discrimination, stability, responsiveness, transparency, and interpretability.

The baseline IAPS ranged from 11.1 to 60.5, a spread of 49.4 points. This range demonstrated adequate discrimination among projects and avoided compression of all candidates into a narrow scoring interval.

Ranking stability was high under moderate global changes in weighting and risk-aversion assumptions. Conversely, the framework responded substantially when project-specific conditions improved, as shown by the movement of process electrification from sixth to first after simultaneous improvements in risk, capacity, and regulatory readiness.

This behavior is desirable because a robust portfolio framework should resist insignificant parameter noise while responding to material changes in real project conditions.

Transparency was also preserved because each final score could be traced to five interpretable components: stakeholder value, sustainability contribution, risk, delivery capacity, and regulatory readiness. Unlike an opaque predictive model, the reason for a project moving upward or downward can therefore be explained to investment committees, regulators, engineers, and other decision-makers.

The architecture consequently supports both analytical consistency and management interpretability, an important requirement for portfolio-information systems.

➢ *Practical Implications for Regulated Industrial Environments*

The results have several practical implications for industrial organizations managing sustainable-energy portfolios.

For capital planning, the framework provides a means of distinguishing projects that are strategically attractive from projects that are sufficiently mature to receive immediate capital. Investment committees can therefore avoid committing disproportionate resources to high-profile projects whose implementation conditions remain weak.

For sustainability investment governance, the framework prevents carbon-reduction potential from operating as the sole determinant of priority. Carbon capture

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and hydrogen, for example, may remain strategically important even when their near-term execution scores are low. Their low IAPS can instead signal the need for targeted capability development, regulatory engagement, or feasibility work.

For compliance management, the Regulatory Readiness Index makes approval status visible within the portfolio process. Mandatory legal conditions remain subject to eligibility screening rather than being offset mathematically by high financial or environmental benefits.

For resource allocation, the DCI identifies projects competing for scarce engineering, contractor, procurement, shutdown, or financial capacity. Portfolio managers can therefore sequence projects according to actual organizational bandwidth.

For portfolio-review meetings, the agile component provides a structured basis for updating project rankings rather than relying on subjective changes in management preference. A project that changes rank must have an identifiable underlying change in value, risk, capacity, sustainability contribution, or regulatory status.

For executive decision support, the IAPS can function as a concise summary metric while preserving access to its underlying dimensions. This is useful because executives require an interpretable portfolio overview without losing the technical justification behind project recommendations.

➢ *Comparison with Previous Studies*

The results were broadly consistent with several themes reported in previous studies on project prioritization, sustainable-energy investment, and portfolio decision-making.

First, the findings support the argument that sustainable-energy investment decisions require multidimensional evaluation rather than reliance on purely economic criteria. Wang et al. [3] and Kumar et al. [4] identified Multi-Criteria Decision Analysis (MCDA) as an appropriate approach for integrating conflicting economic, environmental, social, and technical objectives. The findings of the present study extend this perspective by showing that delivery capacity and regulatory readiness also materially influence project priority and should therefore be incorporated explicitly into the evaluation process.

Second, the finding that high sustainability potential does not necessarily translate into immediate investment priority is consistent with the broader shift beyond Levelized Cost of Energy (LCOE)-based evaluation. Vanegas-Cantarero et al. [23] demonstrated the importance of considering technical, social, economic, environmental, and enabling factors when evaluating renewable-energy alternatives. The results of the present study similarly showed that projects with strong environmental performance could rank lower when regulatory, risk, or implementation constraints remained significant.

Third, the risk-assessment findings align with Abba et al. [10], who emphasized the multidimensional nature of renewable-energy investment risk. The substantial decline in the relative priority of carbon capture and green hydrogen after application of the risk-adjustment factor demonstrates the practical importance of incorporating risk directly into the project-selection process. The results indicate that risk should form an integral part of the prioritization model rather than being considered only after value or financial assessment has been completed.

Fourth, the results obtained under capacity-constrained conditions are consistent with the principles of Portfolio Decision Analysis [21], in which project selection is influenced by finite organizational resources and competing implementation demands. The present framework operationalized this principle through the Delivery Capacity Index and subsequently incorporated budget and workforce constraints into portfolio-level assessment. This allowed project attractiveness to be evaluated alongside the organization's actual capability to execute the selected investments.

Fifth, the dynamic reprioritization findings correspond with research on portfolio management under changing and uncertain conditions. Petit [12] emphasized the need for portfolio-management mechanisms that can respond to changes in the operating environment, while Bechtel et al. [13] linked dynamic organizational capabilities with portfolio agility. The results of the present study demonstrated this relationship quantitatively, as changes in project risk, regulatory readiness, and delivery capacity produced measurable changes in project priority across successive portfolio-review conditions.

Finally, the benchmark comparison showed that alternative MCDA methods did not produce identical project rankings, which is consistent with findings reported in the broader MCDA literature [5], [17], [18]. This variation reinforces the importance of benchmark comparison and sensitivity analysis when interpreting portfolio-prioritization results. Rather than relying on a single ranking as an absolute decision outcome, the framework provides a structured basis for assessing the stability of project priorities under different methodological assumptions and decision conditions.

V. CONCLUSION AND RECOMMENDATIONS

➢ *Summary of Major Findings*

This study developed and applied a data-driven framework for the agile prioritization of sustainable energy infrastructure projects in regulated industrial environments. The framework integrated five principal decision dimensions: stakeholder value, project risk, delivery capacity, regulatory readiness, and sustainability contribution. The analysis of the project portfolio showed how these dimensions interacted to influence the relative attractiveness, implementation readiness, and overall priority of the evaluated sustainable energy infrastructure projects.

The stakeholder-value assessment showed that projects with strong decarbonization potential could generate substantial strategic, environmental, operational, and organizational value even when they were not immediately positioned for execution. Carbon capture, waste-heat recovery, and solar photovoltaic generation recorded comparatively high stakeholder-value scores, whereas smaller interventions such as energy-efficiency retrofits recorded lower strategic scores despite favorable economic and implementation characteristics. The findings therefore showed that stakeholder value alone was insufficient for determining final project priority.

The risk assessment materially altered the relative attractiveness of several projects. Capital-intensive and technologically demanding alternatives, particularly carbon capture and green hydrogen, recorded higher technical, financial, schedule, and regulatory risks than more mature efficiency- and grid-related projects. Application of the risk-adjustment mechanism consequently reduced the relative priority of projects with substantial sustainability potential but comparatively high implementation uncertainty. The findings confirmed the importance of evaluating project risk as a multidimensional factor rather than relying on a single generalized risk rating.

Delivery capacity emerged as an important determinant of practical executability. Waste-heat recovery, energy-efficiency retrofits, solar photovoltaic generation, and grid modernization recorded comparatively stronger implementation conditions because of mature engineering capability, greater technology readiness, contractor availability, manageable resource requirements, and stronger organizational familiarity. Carbon capture and green hydrogen, by contrast, required substantially greater technical, financial, supply-chain, and organizational capability. The findings therefore established that project prioritization should account explicitly for available implementation capacity rather than strategic attractiveness alone.

Regulatory readiness also exerted a substantial influence on project priority. Projects with established approval pathways and relatively limited permitting complexity maintained stronger implementation positions, whereas projects requiring extensive environmental approvals, technical studies, or less mature regulatory arrangements received lower near-term priorities despite their potentially high sustainability benefits. Separating regulatory readiness from regulatory risk proved valuable because a project could have an identifiable regulatory pathway while still being insufficiently advanced for immediate execution.

When the five decision dimensions were integrated, the resulting ranking favored projects that combined stakeholder and sustainability benefits with manageable risk, sufficient delivery capacity, and strong regulatory readiness. Waste-heat recovery ranked first under the baseline assessment, followed by solar photovoltaic generation and the energy-efficiency retrofit. Carbon capture and green hydrogen ranked considerably lower despite their strong decarbonization potential because of higher risk, weaker delivery capacity, and lower regulatory readiness.

The sensitivity analysis showed that moderate changes in criterion weights and risk-aversion assumptions did not substantially destabilize the baseline project ranking. More pronounced changes occurred when project-specific delivery capacity or regulatory readiness improved. This finding indicated that the framework was comparatively stable under modest changes in decision preferences while remaining responsive to material changes in actual project conditions.

Scenario analysis further showed that no single project ranking remained preferable under every operating condition. Capital constraints favored comparatively low-cost and execution-ready projects, stronger decarbonization requirements improved the relative positions of technologies with higher emissions-reduction potential, and workforce constraints favored projects requiring fewer specialist resources. The findings therefore confirmed the importance of dynamic reprioritization as organizational, regulatory, resource, and strategic conditions changed.

- *Conclusion*

The study concluded that the prioritization of sustainable energy infrastructure projects in regulated industrial environments is fundamentally a multidimensional and dynamic decision problem. Conventional approaches based mainly on financial returns, strategic alignment, or isolated sustainability indicators can provide important information, but they do not adequately distinguish between projects that are strategically attractive and those that are sufficiently mature, compliant, resourced, and executable under prevailing organizational conditions.

The findings further established that stakeholder value and sustainability contribution should be assessed alongside project risk, delivery capacity, and regulatory readiness. The proposed Integrated Agile Priority Score provided a transparent mechanism for combining these dimensions while preventing high-value projects from automatically receiving high implementation priority when their risk exposure, regulatory status, or organizational capability requirements made immediate execution less feasible.

Application of the framework differentiated effectively among execution-ready projects, strategically important but capacity-constrained investments, higher-risk transformational projects, and projects requiring additional regulatory, technical, financial, or organizational development before implementation. The analysis also showed that project rankings changed when material project conditions changed, thereby supporting controlled, evidence-based, and agile portfolio reprioritization.

The sensitivity and scenario analyses showed that the framework remained relatively stable under modest variations in assumptions while responding appropriately to substantive changes in project conditions. This characteristic is important because an effective prioritization system should not generate substantial rank reversals from minor changes in model parameters, but should respond when risk exposure, resource availability, regulatory readiness, delivery capacity, or strategic priorities change materially.

The study therefore concluded that the proposed framework provides a structured basis for improving transparency, traceability, resource allocation, regulatory consideration, and sustainability alignment in industrial project portfolio management. Its principal methodological contribution lies in the integration of stakeholder value, project risk, delivery capability, regulatory readiness, and sustainability contribution within a single adaptive prioritization architecture.

The empirical application of the framework to the evaluated project portfolio further showed that project priority cannot be determined reliably from environmental benefit, strategic importance, or financial attractiveness alone. Projects that combined strong value with lower risk, adequate organizational capability, and regulatory preparedness achieved stronger overall priority positions. Conversely, projects with substantial decarbonization potential but significant implementation constraints received lower near-term priority until those constraints were reduced. The framework therefore provides a practical basis for distinguishing long-term strategic importance from immediate implementation priority.

➢ *Recommendations*

Based on the findings of the study, industrial organizations should establish standardized portfolio-assessment procedures in which sustainable energy infrastructure proposals are evaluated using common definitions, measurement scales, scoring criteria, and data-quality requirements. Financial indicators should remain important, but they should be evaluated alongside stakeholder value, sustainability contribution, project risk, regulatory readiness, and delivery capacity.

Project portfolio managers should periodically review project priorities rather than treating an initial ranking as permanent. Reassessment should be undertaken when significant changes occur in capital availability, project cost, schedule assumptions, regulatory requirements, supply-chain conditions, technology maturity, stakeholder expectations, contractor availability, or workforce capacity.

Sustainability managers should quantify environmental benefits using measurable indicators wherever practicable. These should include greenhouse-gas reduction, energy savings, renewable-energy contribution, resource-efficiency improvement, and waste reduction. Such indicators should remain analytically distinct from stakeholder perceptions to reduce the possibility of double-counting sustainability benefits within the decision model.

Regulatory and compliance functions should be involved from the early stages of project evaluation, particularly for projects involving emerging technologies, emissions changes, grid interconnection, hazardous materials, carbon transport and storage, or significant environmental impacts. Mandatory regulatory requirements should function as eligibility conditions rather than ordinary weighted criteria that could be offset by high economic or sustainability scores.

Engineering decision-makers should explicitly assess whether adequate specialist competence, contractor capacity, capital, shutdown availability, technology maturity, and supply-chain support exist before a project is scheduled for execution. Where a strategically important project records a low Delivery Capacity Index, management should establish a targeted capability-development plan rather than automatically rejecting the project.

Organizations should conduct sensitivity and scenario analyses before major portfolio approvals. Projects whose rankings change substantially under relatively small changes in model assumptions should receive additional management review because their apparent priority may depend excessively on uncertain input values or weighting decisions.

Finally, portfolio decisions should not be based solely on the numerical priority score. The Integrated Agile Priority Score should support, rather than replace, engineering judgment, regulatory review, financial analysis, governance requirements, and executive accountability.

➢ *Practical Implementation of the Framework*

Practical implementation of the proposed framework should begin with the establishment of a centralized project database containing validated and current information for every candidate sustainable energy infrastructure project. The database should contain project descriptions, capital requirements, implementation durations, economic indicators, stakeholder-value measures, sustainability metrics, risk assessments, delivery-resource requirements, regulatory status, project dependencies, and data-quality information.

Each project should have designated data owners responsible for maintaining and validating specific groups of variables. Finance personnel should validate financial and capital information; engineering teams should maintain technical, resource, and delivery-capacity data; sustainability personnel should verify energy and environmental benefits; and regulatory or compliance personnel should maintain permit, approval, and compliance information.

Project scores should be recalculated periodically through defined portfolio-review cycles. Monthly, quarterly, or stage-gate reviews may be used depending on portfolio size, project maturity, and the rate at which relevant project conditions change. Event-triggered reassessment should also be undertaken when significant developments occur, including cost escalation, permit approval, technology failure, supply-chain disruption, major schedule changes, or substantial changes in organizational capacity.

A portfolio-management dashboard should display, at minimum:

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- The current Integrated Agile Priority Score;
- Current project rank and change from the preceding review;
- Stakeholder Value Index;
- Project Risk Index;
- Delivery Capacity Index;
- Regulatory Readiness Index;
- Sustainability Contribution Index;
- Capital requirement;
- Regulatory eligibility;
- Principal limiting factor; and
- Recommended portfolio action.

Automated reprioritization rules may be incorporated into the decision-support system so that validated changes in project variables trigger recalculation of the relevant indices and overall priority score. Such automation should not, however, constitute automatic investment authorization. Final capital allocation and project approval should remain subject to established organizational governance procedures.

Governance thresholds should also be established for minimum delivery capacity, maximum acceptable risk exposure, minimum regulatory readiness, capital approval, and mandatory executive review of projects experiencing significant changes in ranking.

The recommended implementation cycle is therefore:

Project registration → Data validation → Metric normalization → Index calculation → Integrated priority scoring → Eligibility screening → Portfolio optimization → Management review → Approval, sequencing, or deferment → Periodic update → Reprioritization

This implementation structure would enable the framework to function as a continuing portfolio-governance mechanism rather than as a one-time project-ranking exercise.

➢ *Future Research*

Future research should extend the empirical assessment of the proposed framework using additional project portfolios from regulated industrial organizations. Such studies should examine whether the calculated project indices and rankings remain consistent across different organizational settings and how well priority positions correspond with realized cost performance, schedule performance, sustainability benefits, implementation success, and subsequent management decisions.

Longitudinal studies should also examine how project priorities evolve over extended implementation periods. Tracking the same projects across multiple portfolio-review cycles would provide further evidence on the responsiveness of the framework to changes in project maturity, risk exposure, regulatory progress, resource availability, and realized performance.

Future studies could investigate machine-learning-assisted prioritization using historical project information to estimate cost overruns, schedule delays, implementation difficulties, or benefit realization. These predictive outputs could subsequently be incorporated into the transparent prioritization framework while preserving interpretability and management oversight.

Real-time project-risk forecasting should also be explored using continuously updated engineering, procurement, schedule, financial, regulatory, and supply-chain information. Dynamic Bayesian methods could be investigated for updating project-risk probabilities as new evidence becomes available during project development and execution.

Stochastic portfolio optimization provides another potential extension of the framework. Instead of representing capital cost, duration, energy savings, emissions reduction, and resource availability solely as fixed values, future models could represent selected variables using probability distributions and evaluate portfolio performance under uncertainty.

Future research may also examine the integration of digital-twin technologies. Digital representations of industrial facilities could improve the estimation and continuous updating of project benefits and operational impacts, particularly for electrification, grid modernization, energy storage, process integration, and energy-efficiency projects.

Multi-organization studies should be undertaken to determine how the framework performs across organizations with different governance structures, risk appetites, technological portfolios, resource capacities, and regulatory environments. Such studies would provide further evidence regarding the transferability and robustness of the proposed approach.

Cross-sector comparative studies could further assess the applicability of the framework in industries such as cement, steel, chemicals, petroleum refining, mining, manufacturing, utilities, and transportation infrastructure. Such research would help distinguish broadly applicable prioritization variables from criteria requiring sector-specific adaptation.

Future research should therefore build on the empirical findings of the present study through broader organizational samples, longitudinal portfolio observations, realized project outcomes, advanced uncertainty modelling, and comparison between framework-generated priorities and subsequent investment decisions.

REFERENCES

[1]. International Energy Agency, *World Energy Investment 2026*. Paris, France: IEA, 2026.

[2]. International Organization for Standardization, *ISO 21504:2022, Project, Programme and Portfolio*

Management—Guidance on Portfolio Management. Geneva, Switzerland: ISO, 2022.

[3]. J.-J. Wang, Y.-Y. Jing, C.-F. Zhang, and J.-H. Zhao, "Review on multi-criteria decision analysis aid in sustainable energy decision-making," *Renewable and Sustainable Energy Reviews*, vol. 13, no. 9, pp. 2263–2278, 2009. doi: 10.1016/j.rser.2009.06.021.

[4]. A. Kumar, B. Sah, A. R. Singh, Y. Deng, X. He, P. Kumar, and R. C. Bansal, "A review of multi criteria decision making (MCDM) towards sustainable renewable energy development," *Renewable and Sustainable Energy Reviews*, vol. 69, pp. 596–609, 2017. doi: 10.1016/j.rser.2016.11.191.

[5]. M. Sahabuddin and I. Khan, "Multi-criteria decision analysis methods for energy sector's sustainability assessment: Robustness analysis through criteria weight change," *Sustainable Energy Technologies and Assessments*, vol. 47, Art. no. 101380, 2021. doi: 10.1016/j.seta.2021.101380.

[6]. International Organization for Standardization, *ISO 21502:2020, Project, Programme and Portfolio Management—Guidance on Project Management*. Geneva, Switzerland: ISO, 2020.

[7]. Intergovernmental Panel on Climate Change, *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, P. R. Shukla et al., Eds. Cambridge, UK and New York, NY, USA: Cambridge University Press, 2022. doi: 10.1017/9781009157926.

[8]. International Organization for Standardization, *ISO 50001:2018, Energy Management Systems—Requirements with Guidance for Use*. Geneva, Switzerland: ISO, 2018.

[9]. E. Cuppen, M. G. C. Bosch-Rekveldt, E. Pikaar, and D. C. Mehos, "Stakeholder engagement in large-scale energy infrastructure projects: Revealing perspectives using Q methodology," *International Journal of Project Management*, vol. 34, no. 7, pp. 1347–1359, 2016. doi: 10.1016/j.ijproman.2016.01.003.

[10]. Z. Y. I. Abba, N. Balta-Ozkan, and P. Hart, "A holistic risk management framework for renewable energy investments," *Renewable and Sustainable Energy Reviews*, vol. 160, Art. no. 112305, 2022. doi: 10.1016/j.rser.2022.112305.

[11]. D. Hoffmann, F. Ahlemann, and S. Reining, "Reconciling alignment, efficiency, and agility in IT project portfolio management: Recommendations based on a revelatory case study," *International Journal of Project Management*, vol. 38, no. 2, pp. 124–136, 2020. doi: 10.1016/j.ijproman.2020.01.004.

[12]. Y. Petit, "Project portfolios in dynamic environments: Organizing for uncertainty," *International Journal of Project Management*, vol. 30, no. 5, pp. 539–553, 2012. doi: 10.1016/j.ijproman.2011.11.007.

[13]. J. Bechtel, C. Kaufmann, and A. Kock, "The interplay between dynamic capabilities' dimensions and their relationship to project portfolio agility and success," *International Journal of Project Management*, vol. 41, no. 4, Art. no. 102469, 2023. doi: 10.1016/j.ijproman.2023.102469.

[14]. A. Kock, B. Schulz, J. Kopmann, and H. G. Gemünden, "Project portfolio management information systems' positive influence on performance—The importance of process maturity," *International Journal of Project Management*, vol. 38, no. 4, pp. 229–241, 2020.

[15]. International Organization for Standardization, *ISO 31000:2018, Risk Management—Guidelines*. Geneva, Switzerland: ISO, 2018.

[16]. International Organization for Standardization, *ISO 14001:2026, Environmental Management Systems—Requirements with Guidance for Use*. Geneva, Switzerland: ISO, 2026.

[17]. T. L. Saaty, "How to make a decision: The analytic hierarchy process," *European Journal of Operational Research*, vol. 48, no. 1, pp. 9–26, 1990. doi: 10.1016/0377-2217(90)90057-I.

[18]. M. Behzadian, S. K. Otaghsara, M. Yazdani, and J. Ignatius, "A state-of-the-art survey of TOPSIS applications," *Expert Systems with Applications*, vol. 39, no. 17, pp. 13051–13069, 2012. doi: 10.1016/j.eswa.2012.05.056.

[19]. J. P. Brans and P. Vincke, "A preference ranking organisation method: The PROMETHEE method for multiple criteria decision-making," *Management Science*, vol. 31, no. 6, pp. 647–656, 1985. doi: 10.1287/mnsc.31.6.647.

[20]. W. Edwards and F. H. Barron, "SMARTS and SMARTER: Improved simple methods for multiattribute utility measurement," *Organizational Behavior and Human Decision Processes*, vol. 60, no. 3, pp. 306–325, 1994. doi: 10.1006/obhd.1994.1087.

[21]. J. Liesiö, A. Salo, J. M. Keisler, and A. Morton, "Portfolio decision analysis: Recent developments and future prospects," *European Journal of Operational Research*, vol. 293, no. 3, pp. 811–825, 2021. doi: 10.1016/j.ejor.2020.12.015.

[22]. A. Mahmoudi, M. Abbasi, and X. Deng, "A novel project portfolio selection framework towards organizational resilience: Robust Ordinal Priority Approach," *Expert Systems with Applications*, vol. 188, Art. no. 116067, 2022. doi: 10.1016/j.eswa.2021.116067.

[23]. M. M. Vanegas-Cantarero, S. Pennock, T. Bloise-Thomaz, H. Jeffrey, and M. J. Dickson, "Beyond LCOE: A multi-criteria evaluation framework for offshore renewable energy projects," *Renewable and Sustainable Energy Reviews*, vol. 161, Art. no. 112307, 2022. doi: 10.1016/j.rser.2022.112307.

[24]. F. Parvaneh and A. Hammad, "Application of multi-criteria decision-making (MCDM) to select the most sustainable power-generating technology," *Sustainability*, vol. 16, no. 8, Art. no. 3287, 2024. doi: 10.3390/su16083287.

[25]. J. C. Godoy, R. Cajo, L. S. Mesa Estrada, et al., "Multi-criteria analysis for energy planning in Ecuador: Enhancing decision-making through comprehensive evaluation," *Renewable Energy*, vol. 241, Art. no. 122278, 2025. doi: 10.1016/j.renene.2024.122278.

[26]. M. Ramezanzade, H. Karimi, K. Almutairi, H. X. Ao, J. Saebi, A. Mostafaeipour, and K. Techato, "Implementing MCDM techniques for ranking renewable energy projects under fuzzy environment: A case study," *Sustainability*, vol. 13, no. 22, Art. no. 12858, 2021. doi: 10.3390/su132212858.

[27]. F. Costantino, G. Di Gravio, and F. Nonino, "Project selection in project portfolio management: An artificial neural network model based on critical success factors," *International Journal of Project Management*, vol. 33, no. 8, pp. 1744–1754, 2015. doi: 10.1016/j.ijproman.2015.07.003.

[28]. M. E. Nenni, F. De Felice, C. De Luca, and A. Forcina, "How artificial intelligence will transform project management in the age of digitization: A systematic literature review," *Management Review Quarterly*, vol. 75, pp. 1669–1716, 2025. doi: 10.1007/s11301-024-00418-z.

[29]. G. Bilgin, I. Dikmen, M. T. Birgonul, and B. Ozorhon, "A decision support system for project portfolio management in construction companies," *International Journal of Information Technology & Decision Making*, vol. 22, no. 2, pp. 705–735, 2023. doi: 10.1142/S0219622022500821.

[30]. Ilesanmi, M. O., Okoh, O. F., Balogun, S. A., and Ijiga, O. M. (2024). Data-driven portfolio optimization for utility-scale solar, wind, and battery energy storage systems: Integrating performance analytics with investor EBITDA targets. International Journal of Scientific Research and Modern Technology, 3(11), 141–155.

[31]. Ilesanmi, M. O., Anim-Sampong, S. D., and Enyejo, J. O. (2023). Cross-sector asset management: Applying real-estate portfolio optimization models to renewable-energy infrastructure. International Journal of Scientific Research and Modern Technology, 2(10).

[32]. Anim-Sampong, S. D., Ilesanmi, M. O., and Yetunde Adetutu, O. O. (2022). Bridging the gap between technical asset management and executive strategy in renewable energy: A framework for portfolio managers as policy and investment influencers. International Journal of Scientific Research in Mechanical and Materials Engineering, 6(5).

[33]. Oyekan, M., Jinadu, S. O., and Enyejo, J. O. (2025). The role of strategic asset management in accelerating the energy transition. International Journal of Innovative Science and Research Technology, 10(9).

[34]. Oyekan, M., Jinadu, S. O., and Enyejo, J. O. (2023). Harnessing data analytics to maximize renewable-energy asset performance. International Journal of Scientific Research and Modern Technology, 2(8), 64–80.

[35]. Ilesanmi, M. O., Raphael, F. O., Oyekan, M., and Enyejo, L. A. (2024). Dynamic reporting frameworks for enhancing investor confidence in renewable-infrastructure portfolios. International Journal of Scientific Research in Science, Engineering and Technology, 11(6), 526–549.

[36]. Ijiga, O. M., Anim-Sampong, S. D., and Ilesanmi, M. O. (2022). Land-use optimization for utility-scale solar and wind projects: Integrating estate management and technology-driven site analytics. International Journal of Scientific Research in Science, Engineering and Technology, 9(6), 505–510.

[37]. Ilesanmi, M. O., Bamigwojo, O. V., Jinadu, S. O., Oyekan, M., and Ijiga, O. M. (2023). Mitigating regulatory and market risks in U.S. renewable-energy portfolios: A portfolio asset manager's perspective. International Journal of Scientific Research in Science and Technology, 10(6), 878–906.

[38]. Ilesanmi, M. O., Okoh, O. F., and Ijiga, O. M. (2025). Financial risk modeling for hybrid renewable-energy portfolios under evolving U.S. regulatory and tax-equity structures. International Journal of Innovative Science and Research Technology, 10(10).

[39]. Oyekan, M., Igba, E., and Jinadu, S. O. (2024). Building resilient renewable infrastructure in an era of climate and market volatility. International Journal of Scientific Research in Humanities and Social Sciences, 1(1).

[40]. Awolola, O. J., Azonuche, T. I., Enyejo, J. O., Ononiwu, M., and Ayoola, V. B. (2026). Integrating digital project controls and risk-mitigation frameworks to improve decision-making in complex civil-engineering projects. International Journal of Innovative Science and Research Technology, 11(1), 2869–2886.

[41]. Akunna, N. L., and Ijiga, O. M. (2025). A predictive analytics model for early detection of budget overruns in large-scale projects using integrated financial and operational data. International Journal of Scientific Research and Modern Technology, 4(12), 190–208.

[42]. Akunna, N. L., and Ijiga, O. M. (2025). An artificial-intelligence-driven framework for predicting project-delivery risks using enterprise resource-planning data in large multinational projects. World Journal of Advanced Multidisciplinary Research, 2(6), 7–25.

[43]. Jalloh, A. M. S., Akingbade, R., and Enyejo, J. O. (2026). A risk-adjusted capital-monitoring algorithm for infrastructure project accounts with comparative evaluation against traditional variance-analysis techniques. International Journal of Innovative Science and Research Technology, 11(3), 1792–1807.

[44]. Jalloh, A. M. S., Akingbade, R., and Enyejo, J. O. (2026). Data-driven financial-performance monitoring in utility-sector projects using Power BI and SQL-based analytics for executive-level decision support. International Journal of Recent Research in Commerce Economics and Management, 13(1), 13–33.

[45]. Nwokocha, C. R., and Peter-Anyebe, A. C. (2025). Enhancing health-data governance through Agile Scrum practices and sprint metrics for effective stakeholder collaboration and delivery. International Journal of Scientific Research and Modern Technology, 4(11), 179–195..

[46]. Kwarteng, R. A., Idoko, I. P., and Azonuche, T. I. (2023). Applying Agile and Project Management Professional-aligned practices to technology change management in resource-constrained institutions. International Journal of Scientific Research in Science and Technology, 10(5), 784–810.

[47]. Akindote, O., Igba, E., Awotiwon, B. O., and Otakwu, A. (2024). Blockchain integration in critical systems: Enhancing transparency, efficiency, and real-time data security in agile project management. International Journal of Scientific Research and Modern Technology, 3(11).
[48]. Enyejo, J. O., Fajana, O. P., Jok, I. S., Ihejirika, C. J., Awotiwon, B. O., and Olola, T. M. (2024). Digital-twin technology, predictive analytics, and sustainable project management in global supply chains for risk mitigation, optimization, and carbon-footprint reduction. International Journal of Innovative Science and Research Technology, 9(11).
[49]. Okoh, O. F., Ukpoju, E. A., Otakwu, A., Ayoola, V. B., and Enyejo, L. A. (2024). Construction management: Some issues in the construction project. Engineering Heritage Journal, 8(1), 42–50.
[50]. Bashiru, O., Ochem, C., Enyejo, L. A., Manuel, H. N. N., and Adeoye, T. O. (2024). The crucial role of renewable energy in achieving the Sustainable Development Goals for cleaner energy. Global Journal of Engineering and Technology Advances, 19(3), 11–36.
[51]. Idoko, I. P., Ijiga, O. M., Akoh, O., Agbo, D. O., Ugbane, S. I., and Umama, E. E. (2024). Empowering sustainable power generation: The vital role of power electronics in California's renewable-energy transformation. World Journal of Advanced Engineering Technology and Sciences, 11(1), 274–293.
[52]. Idoko, I. P., Ijiga, O. M., Harry, K. D., Ezebuka, C. C., Ukatu, I. E., and Peace, A. E. (2024). Renewable-energy policies: A comparative analysis of Nigeria and the United States of America.
[53]. Ibokette, A. I., Ogundare, T. O., Akindele, J. S., Anyebe, A. P., and Okeke, R. O. (2024). Decarbonization strategies in the U.S. maritime industry with a focus on overcoming regulatory and operational challenges in implementing zero-emission vessel technologies. International Journal of Innovative Science and Research Technology, 9(11).
[54]. Idoko, I. P., Akindele, J. S., Imarenakhue, W. U., and Bashiru, O. (2024). Exploring the role of bioenergy in achieving sustainable waste utilization and promoting low-carbon transition strategies. International Journal of Scientific Research in Science and Technology..
[55]. Aikins, S. A., Avevor, J., and Enyejo, L. A. (2024). Optimizing thermal management in hydrogen fuel cells for smart heating, ventilation, and air-conditioning systems and sustainable building-energy solutions. International Journal of Scientific Research and Modern Technology, 3(4).
[56]. Jinadu, S. O., Akinleye, K. E., Onwusi, C. N., Okoh, O. F., and Ijiga, O. M. (2024). Advancing atmospheric carbon-dioxide capture integration with oil-reservoir injection for sustainable domestic hydrocarbon-production expansion. International Journal of Scientific Research and Modern Technology, 3(6), 123–136.
[57]. Ilesanmi, M. O., Raphael, F. O., Oyekan, M., Jinadu, S. O., and Ijiga, O. M. (2025). Hydrogen-integrated wind farms: Applying real-time electrolyzer optimization and turbine-curtailment minimization strategies. South Asia Journal of Multidisciplinary Studies, 1(10).
[58]. Oladoye, S. O., Bamigwojo, O. V., Ogboji, A. J., and Ijiga, O. M. (2023). Techno-economic evaluation of hybrid solar-diesel microgrids for underserved communities using simulation-based load forecasting. Engineering Science and Technology Journal, 4.
[59]. Oladoye, S. O., Bamigwojo, O. V., James, A. O., and Ijiga, O. M. (2022). Grid integration and reliability analysis of electric-vehicle charging infrastructure in weak distribution networks. International Journal of Scientific Research in Science and Technology, 9(3), 881–902.