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RESEARCH ARTICLE

Leadership in Environmental Management: Strategies for Climate Resilience

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ABSTRACT

The escalating impacts of climate change demand leadership strategies that enhance environmental resilience and sustainability. Effective leadership in environmental management plays a critical role in addressing regulatory challenges, promoting sustainable resource use, and mitigating climate risks. This study examines five leadership models—transformational, adaptive, collaborative, technological, and policy-driven, analyzing their effectiveness in driving sustainability initiatives across key sectors, including energy, manufacturing, public governance, technology, and agriculture. These five models were selected based on their theoretical relevance to climate governance frameworks and empirical observability across sectors. A structured comparative analysis was conducted using a longitudinal research design, integrating quantitative performance metrics and qualitative stakeholder insights. The study evaluates leadership-driven sustainability frameworks, emphasizing proactive risk management, regulatory compliance, stakeholder engagement, and the integration of technological innovations. Findings indicate that technological leadership yields the highest sustainability impact, particularly in carbon neutrality, emission reduction, and renewable energy utilization. Adaptive leadership enhances flexibility in sustainability transitions, while collaborative leadership facilitates policy implementation and multi-sector partnerships. Transformational leadership demonstrates effectiveness in disaster preparedness and long-term resilience strategies. These findings underscore the importance of integrated leadership strategies that embrace both technological progress and adaptive and cooperative governance. Improving leadership capabilities in environmental management strengthens compliance with regulation, cross-sector coordination, and transformational change on sustainability. Data collected during this research can benefit policymakers, political frameworks, environmental leaders, industry experts and strategists attempting to determine the highest achievable format of leadership governing climate resilience. The article contributes an integrative model linking leadership typologies with measurable sustainability outcomes, filling a gap in comparative environmental governance studies.

Keywords: environmental leadership; climate resilience; adaptive governance; sustainability strategy; stakeholder engagement; policy implementation; technological innovation

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1. Introduction

Climate change is one of the biggest challenges we face in the 21st century, and to address it well, we need leaders to respond quickly and strategically. What further highlights the importance of leadership in environmental management are the increasing frequency and intensity of extreme weather events, resource depletion, loss of biodiversity and environmental degradation. Leadership is required not only to design and implement policy – and adapt organizations to these changes – but also to innovate in terms of practices around sustainability. Leadership strategies must adapt as governments, industries, and communities face risks associated with climate and work toward ensuring long-term resilience and sustainability.

Recent research emphasizes that leadership responses to climate risk must integrate economic, social, and environmental trade-offs to sustain long-term resilience. Safarli [1] demonstrated that sustainable development depends on balancing growth and environmental conservation through coordinated leadership at institutional and corporate levels. Similarly, Sajjad et al. [2] argue that sustainability leadership now requires a hybrid conceptual synthesis that merges strategic governance with adaptive and technological capabilities. This framing underscores the need for leaders to anticipate systemic shocks while maintaining ecological equity and innovation capacity, thereby extending the rationale for the present study. Recent scholarship confirms that effective leadership for sustainability must simultaneously address organizational performance and ecological stewardship, integrating strategy with measurable environmental outcomes [3, 4].

Data is available from a vast array of sources and places but still the level detection is not perfect and sometimes it can be difficult to balance development with sustainability. The multifaceted nature of environmental problems requires leaders to look beyond governance as usual and incorporate more dynamic, institutional foresight and prevention strategies. Understanding how to manage engagement and adaptive measures is important to avoid climate risks. Leaders in this area understand how to align the objectives of their organizations with the global goal of sustainability helping to enable business, policy, and community systems to become climate-resilient [1].

Leadership is about more than complying with regulations — it is about environmental management. While compliance with environmental mandates is important, if thoughtful leaders want to make a difference, sustainability has to be ingrained deep into the core of how decisions get made. This includes promoting an environmental stewardship mindset, pursuing cross-disciplinary collaboration, and showing the way to innovate through emerging technologies. Strategic sustainability leaders can take organizational advantages while solving for pressing global challenges [5].

Stakeholder engagement is a key element of successful environmental stewardship. It is a collective challenge for governments, business, NGOs and local communities to respond to; and is at the heart of building climate resilience. They must be forging partnerships that would allow for knowledge sharing and coordinated responses to environmental threats. In addition, transparency and accountability in decision-making processes is also key to establishing trust and ensuring long-term commitment to sustainability initiatives. In addition, leaders can encourage inclusive, responsive policies and strategies through engaging stakeholders in environmental decision-making [6].

The role of technology as an enabler of environmental leadership Use of data analytics, AI, and IoT Use cases assist with better resource management, tracking the environment in real-time, and modeling for climate change adaptation. Leaders who embrace digital transformation can bolster their organizations' responsiveness to climate-related risks and advance sustainability performance. Further, investment in clean energy and the circular economy and green infrastructure can strengthen climate resilience efforts [7].

A changing regulatory landscape additionally demands robust environmental management leadership. Agreements that have been created on a global level, such as the Paris Agreement, have made grandiose promises to reduce their greenhouse gas emissions and strive for sustainability. Addressing these evolving dynamics can pose a significant challenge to navigating a complex policy landscape. Shaping policy Leaders have to be responsible citizens, ensuring that their organizations comply with existing regulations but also working to influence policy that will support long-term sustainability goals. Specific Mention and the ability to balance regulatory workplace changes and coordination of business strategies for environmental leaders are two key constructs [8].

While advances in environmental governance have been tremendous, far larger gaps in progress remain. Sustainability often sits at the bottom of the pile for many organizations due to a lack of funds, expertise or willingness. Removing these road blocks requires strong leadership that builds sustainability thinking into their company/individual ethos, and demonstrate the business case for being environmentally responsible. Where visionary leaders buckle down to effect real change towards climate resilience [2] by cooperating across sectors to prioritize long-term sustainability over short-term karmic leverage.

The article investigates the capacities of leadership to address environmental management challenges, in particular how effective leadership can build the climate resilience of different sectors. It reviews environmental performance implications in leadership models — transformational, adaptive or collaborative. In addition, the study explores the role of policy frameworks, interactions with stakeholders, and advancements in technology in fostering successful environmental leaders. Through the identification of best practices and strategic approaches, this research is intended to inform how leaders may advance through the sustainable development and climate adaptation [9].

Leadership for environmental management plays a critical role in facing climate challenges and building resilience. Given the changing nature of environmental risks, leaders should take proactive, innovative and inclusive action for sustainability. We will explore the theoretical underpinnings of environmental leadership in the next sections, highlight successful case studies of leadership initiatives, and suggest ways for strengthening leadership capabilities in climate resilience initiatives.

In particular, empirical studies show that transformational and governance-oriented leadership improve environmental performance through structured change pathways and policy alignment, reinforcing the need for a comparative framework in this study [10, 11].

Building on this rationale, the present article also situates environmental leadership within the wider geopolitical context of global climate governance. Buzan [8] highlights that power asymmetries among states often determine the extent to which environmental responsibility is translated into actionable policy, revealing the need for leadership models capable of mediating between national commitments and global sustainability frameworks. Furthermore, Moore and Schindler [9] emphasize the urgency of "getting ahead of climate change" through proactive leadership that integrates ecological adaptation and resilience science. By aligning with these insights, this study advances a comparative framework that links leadership typologies with measurable outcomes in climate-resilient governance. The study also respond to calls for cross-sector evidence that connects leadership modes to policy instruments and sustainability metrics, including SDG-consistent indicators and Paris-aligned targets [12]. However, prior studies have not comparatively analyzed the interplay of transformational, adaptive, collaborative, technological, and policy-driven leadership across multiple sectors under a unified empirical framework.

1.1. The aim of the article

This article seeks to explore the relationship between leadership and environmental management through identifying and assessing strategies for climate resilience (CR). As climate change continues to bring unprecedented disruptions, leadership practices should adapt to face new 21st-century obstacles and accelerate sustainable development. We examine a range of leadership models—transformational, adaptive, and collaborative leadership to understand their efficacy in a southwest Ontario context in helping to reduce environmental risks as well as build resilience across industries and governance levels.

A key aim all along is to assess leadership effects on the design and delivery of environmental policies. Corporate leadership and policymakers are key actors to communicate regulations, set up sustainability-based plans and mobilize financial resources for adaptation to climate change. The article aims to identify best practices on sustainability practice derived from leadership-based environmental strategies that organizations and governments can work toward to improve sustainability performance.

Another major objective is to assess the effectiveness of stakeholder engagement in climate resilience efforts. Leadership must also engage partnerships among governments, businesses, non-governmental organizations, and communities, beyond individual decisions. The study focuses on how inclusive leadership strategies informed effective climate governance and adaptive environmental policies.

Additionally, this article discusses the linking of environmental leadership establishment through innovation. Sustainability strategies inherently include technologies such as digital transformation, artificial intelligence and data-driven decision-making. Good governance of any climate-related effort starts with good people, and pretty much every climate initiative relies on good leaders who can use technology to change the way that organizations track their resources and in turn the environment and decision making about climate risks. This research examines how leaders can leverage technology to create resilient, sustainable systems.

It expects to contribute to the literature on climate system resilience, with a broad overview of leadership frameworks adopted for this sectoral domain of environmental governance. It showcases successful leadership models, policy instruments and technology solutions that contribute to sustainable development. The article aims to assist leaders in formulating plans that can work toward short term environmental ends but also build stability for the environment, and the economy in the future.

1.2. Problem statement

This kind of focused attention is necessary at this stage in managing the environment, as climate change above all else becomes felt more acutely. Despite world-wide actions on environment threats, bad application of climate resilience remains a challenge for bodies seeking to reduce environment exposures. But, progress in sustainable development is being signaled by leadership gaps, including but not limited to low clinics on political implementation, low consideration or stakeholder-value adjustment and swinging of change. Without wise heads guiding climate adaptation efforts, they tend to be piecemeal, siloed and reactionist, failing to confront the long-term environmental challenges that span the globe.

A very critic problem which has left stains on environmental management is the gap among leadership ideal and policy practice. Sure, organizations could try to be sustainable but if the leadership of the organization is not committed you will have half-baked environmental initiatives. It is where leaders ought not only to get together to talk, but grease the shift via obtaining organizational, and regulatory agreement to ensure reliance on the environment. But most models of leadership are static and ill-suited to the essentially dynamic nature of climate risk.

There are also challenges with stakeholder engagement efforts in the climate resilience space. Environmental management is a cross-cutting issue which involves the collaboration between various actors including government entities, corporate organizations and civil society. The counterpoint to weak leadership is poor coordination among stakeholders, leading to inconsistent policy implementation and suboptimal allocation of resources. Absence of inclusive leadership approaches projects a limiting perspective of collective thinking across sectors that can expand the potential of climate adaptation and mitigation practices. Moreover, digital technology can create great opportunities for environmental sustainability, but few leaders in our sample include digital solutions in their strategies. Organizations' capability of monitoring environmental indicators and utilizing resources optimally through risk management models is hindered by the ignorance, know-how or finance towards innovative technologies. As much as this can be dispiriting, leadership in environmental management must embrace a new paradigm of data-driven decision making and technological innovation.

The article tackles these challenges through an investigation of leadership strategies that build climate resilience. It also examines how leaders can facilitate the path between policy and implementation, create collaboration between stakeholders, and leverage technology. This study seeks to provide insights into the development of effective environmental management frameworks that not only ensure sustainability and resilience but also facilitate the achievement of SDGs by identifying leadership best practices.

2. Literature review

More recently the leadership of environmental management has been garnering more attention as organizations and governments begin to realize the need for strategic action to adapt to climate change. This has involved — but not been limited to examining various types of leadership, and how they might serve sustainable environmental practices. Of these approaches, leadership of the transformational type has frequently been viewed as a style capable of enhancing innovation, commitment or proactive environmental governance. In addition to that, the leaders solve sustainability of organizations and assess stakeholder inspiration and will integrate ecological sustainability in a corporation for this model. Transformational leaders mobilize behavioral change within institutions and communities around a shared vision for sustainability and collective action for environmental resilience [13].

Transformational leadership further interacts with organizational ethics and green human-resource management in shaping pro-environmental behavior. Omarova and Jo [14] confirmed that environmental transformational leadership significantly enhances employee engagement when coupled with green HRM policies. In parallel, Ramírez-Altamirano et al. [5] found that transformational environmental leadership in certified firms directly triggers competitive advantage through corporate social responsibility initiatives. These studies support the argument that transformational leaders act as catalysts for embedding sustainability within organizational culture, validating the comparative perspective adopted in this research.

It specially draws on how climate change presents itself with a clear openness to various avenues of emerging issues, which constant evaluation and making evidence-informed decisions can support adapting to this. An adaptive leader is a continuous learner, an adaptive risk taker, a strategist of environmental scenarios. They have to use the agility of policy formulation and help address the most pressing impacts of climate variability through scientific knowledge and technological innovation. It ensures time-bound, ideal, and environmental solutions that guide organizations to fall in line with the constantly changing dynamic of ecological conditions [14].

Multi-stakeholder collaboration in environmental management is a complex process. Progress on climate resilience addresses issues that crosscut multiple sectors: government agencies, businesses, non-governmental organizations, and local communities when it comes to implementing solutions. Collaborating: Leaders who take a collaborative approach build partnerships that allow for sharing resources, exchanging knowledge, and partnering on sustainability initiatives. We are working to fill this gap in our research by assessing how effective collaboration allows for the implementation of environmental policies through the inclusion of all relevant stakeholders with potentially conflicting interests to be undertaken to achieve climate adaptation in localized networks long-term. This capacity to engender trust and enable collaborative governance is critical for confronting large scale environmental problems [15].

Collaborative approaches are increasingly regarded as a structural necessity for effective climate governance. Grøn [16] provided experimental evidence that collaborative engagement improves employees' environmental performance and institutional trust, while Gafur et al. [15] illustrated the societal impact of participatory waste-management leadership in Indonesia. These findings highlight that inclusive and multi-actor collaboration not only enhances governance quality but also creates co-benefits such as public accountability and localized innovation, strengthening the empirical foundation of this study's comparative analysis.

Digital tools and data-driven strategies are increasingly important in environmental management, emphasizing the role of technological leadership in enhancing sustainability practices [17]. On the other hand, leaders who adopt technological innovation use AI, big data analytics, and the Internet of Things to track the environmental conditions, optimize resource management, and endangerment threats. Smart technologies streamline data for better decision-making and faster responses to environmental changes. Attributing digital transformation to sustainability, organizations that invest in sustainable digital transformation show better resilience and operational efficiency [18].

Expanding upon digital transformation, Laradi et al. [18] conceptualized digital leadership as a critical bridge between technological innovation and green outcomes, emphasizing that data-driven governance systems accelerate the transition to climate-neutral operations. Their findings converge with Yaseen et al. [17] demonstrated that nanostructured biodegradable materials and smart environmental technologies enable resource efficiency at the industrial scale. Together these works reinforce the proposition that technological leadership is not merely instrumental but constitutive of modern environmental governance.

Environmental management is the process of creating strategies to manage both the opportunities and risks that environmental issues present to our business. In this area, leaders shape policy by advocating for more stringent environmental regulations, advancing green financing mechanisms, and ensuring compliance with sustainability standards. Ability to navigate the complexities of policy environments is fundamental to 565 environmental governances in the longer term. And policy advocacy, as a form of leadership, strengthens institutional commitment to climate resilience and enhances accountability in environmental protection efforts [19, 20].

In the face of increasing focus on leadership in environmental management, we are faced with challenges in embedding sustainability in both organizational and governmental contexts. Maintaining the balance between Economic objectives and Environmental objectives is where most entities find themselves in trouble. This is challenging from a leadership perspective, as these investments must show the economic and social benefits of doing so. Sustainable replication has a greater chance of success when it addresses top-down leadership strategies including financial, regulation and corporate social responsibility incentives [21].

Parallel research in the construction sector by Afzal and Tumpa [22] identifies how leadership styles determine sustainability performance across project life-cycles, recommending an integrative model that blends transformational, adaptive, and policy-oriented approaches. Boeske {Boeske, 2023 #8303 also advocates a conceptual differentiation between "sustainable" and "sustainability" leadership, arguing that genuine ecological stewardship requires embedding environmental objectives into the strategic core of organizations. These perspectives substantiate the necessity of evaluating leadership frameworks comparatively, as undertaken in the present analysis.

Climate risks are evolving, and there is a need for a fundamental change in leaders' climate management approach. Moving from reactive to proactive leadership strategies is key to embedding climate resilience in institutional policies and operational models. This article explores the understanding of leadership for sustainable development and environmental governance through the lens of different leadership models. We examine how these frameworks shape the nature and effectiveness of leadership aimed at promoting climate resilience and providing recommendations for enhancing the effectiveness of this leadership as it relates to environmental management.

3. Materials and methods

3.1. Research design

The present study adopts a comparative research design to compare the utility of models of leadership in the context of sustainability of the environment. It applies a systematic analysis across industries, as a energy, manufacturing, public governance, technology, and agriculture to five leadership models: transformational, adaptive, collaborative, technological and policy-driven leadership [22].

The dataset represents a rolling longitudinal sample of 200 environmental leaders accumulated between 2018 and 2023. Each annual phase involved partially overlapping participant groups from diverse sectors, allowing the model to capture longitudinal variation in leadership practices while maintaining a balanced cross-sectional structure. This cumulative approach reflects the evolving dynamics of sustainability governance across the five-year period.

The design follows a mixed-method rationale consistent with sustainability research protocols proposed by Kilkış et al. {Kılkış, 2020 #8294}, integrating quantitative and qualitative measures to capture the multidimensional nature of environmental leadership. This methodological pluralism ensures triangulation between statistical indicators and contextual governance insights, thereby enhancing both internal validity and ecological relevance of the findings [23].

A defined approach for a performance-based scoring was proposed to measure the impact of leadership strategies on sustainability performance, which includes selection of key performance indicators for environment (Figure 1).

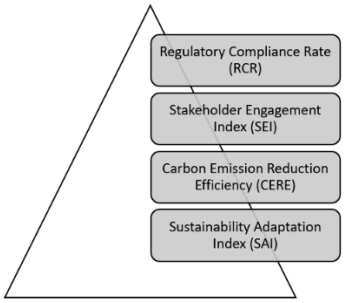

Figure 1. Key Indicators for evaluating leadership-driven sustainability performance

A composite sustainability leadership index (CSI_L) was constructed, integrating weighted indicators using Principal Component Analysis (PCA) to optimize the relative significance of each metric:

$$CSI_L = \sum_{i-1}^{n} w_i M_i \quad (1)$$

Where CSI_L represents the Composite Sustainability Index for a given leadership model L, M_i denotes each environmental performance metric for leadership model L, w_i is the PCA-derived weight assigned to each metric.

With the CSI_L scores, one can benchmark different types of leaders and have cross-sector comparisons of leader effectiveness, which equate to sustainability performance as a function of governance and strategic management[2].

3.2. Data collection and processing

Using a mixed-methods approach, we triangulated primary and secondary data sources to assess generalizable findings of effective leadership. The quantitative and qualitative sampling methods included structured survey tools, comprehensive social scientists-led interviews, and archival research.

3.2.1. Primary data sources

The study conducted structured surveys with a total of 200 environmental leaders representing a range of sectors, employing stratified sampling techniques for broader representational sampling [16]. The respondent pool included:

Corporate sustainability officers

Government regulators

Policy advisors

Industry executives

Surveys focused on leadership-driven sustainability implementation, regulatory adherence, and cross-sectoral collaboration effectiveness [5]. Alongside this, 30 semi-structured interviews with senior policymakers and sustainability officers lent qualitative details on strategic environmental decision-making [16].

3.2.2. Secondary data sources

Sustainability metrics were mined from corporate environmental reports, governmental policy documents, and international climate resilience databases (Peters, 2022) [5], to validate main findings. These included:

Annual ESG (Environmental, Social, Governance) reports

National environmental compliance databases

Climate action and resilience plans

3.3. Data analysis and statistical modeling

A combination of descriptive statistics, regression analysis, and thematic qualitative coding was applied to evaluate leadership performance [24].

3.3.1. Descriptive statistical analysis

The dataset was analyzed using mean, median, and standard deviation calculations for all leadership effectiveness indicators. To assess statistical differences between sectors, one-way ANOVA was conducted:

$$F = \frac{Variance\ between\ leadership\ models}{Variance\ within\ leadership\ models} \quad (2)$$

where a high F-value suggests significant differences in leadership effectiveness across industries (Safarli, 2024) [1].

3.3.2. Regression analysis for leadership effectiveness

To assess the impact of leadership models on sustainability performance, a multiple linear regression (MLR) model was constructed [25]:

$$S = \alpha + \beta_1 L_T + \beta_2 L_A + \beta_3 L_C + \beta_4 L_{Tech} + \beta_5 L_{Policy} + \varepsilon \quad (2)$$

Where S represents sustainability performance, $L_T, L_A, L_C, L_{Tech}, L_{Policy}$ denote the five leadership models, α and $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5$ are regression coefficients estimating the impact of leadership models, ε is the error term.

The regression model provided insights into leadership effectiveness, particularly regarding policy-driven compliance and technological integration for sustainability[21].

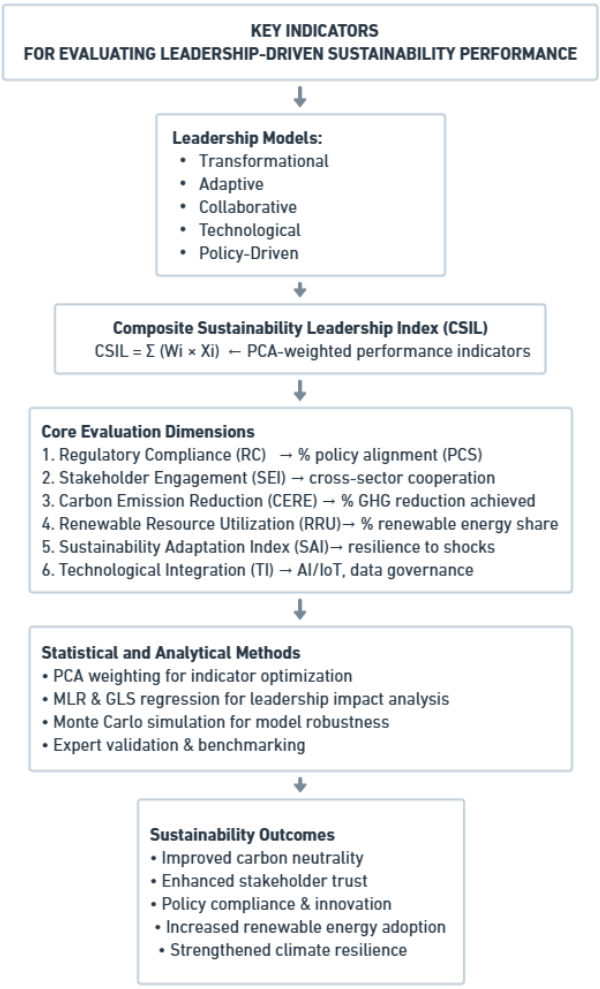

Figure 2. Governance-oriented indicators for evaluating leadership and sustainability Integration

Building on the conceptual structure illustrated in Figure 1, the proposed analytical framework operationalizes how diverse leadership typologies influence governance quality and sustainability integration across sectors. Each leadership model: transformational, adaptive, collaborative, technological, and policy-

driven—feeds into a performance-based composite index that quantifies organizational alignment with environmental objectives.

This framework enables comparative benchmarking of leadership effectiveness by linking managerial strategies to quantifiable environmental outcomes such as regulatory compliance, carbon-emission reduction, renewable-energy utilization, and resilience to systemic shocks. The integration of statistical validation methods (PCA, MLR, GLS, and Monte Carlo simulation) ensures methodological robustness and sectoral comparability.

To complement these internal performance indicators, Figure 2 extends the analysis by mapping the Alignment of Leadership Strategies with International Environmental Policies, highlighting how each leadership model interfaces with global frameworks such as the Paris Agreement (2015) and the UN Sustainable Development Goals (SDG 13 – Climate Action). This second figure provides the external governance context within which the composite leadership indicators operate, illustrating policy coherence, compliance gradients, and international interlinkages that reinforce climate-resilient sustainability governance.

3.4. Stakeholder engagement measurement

A Stakeholder Engagement Index (SEI_L) was constructed to quantify the effectiveness of leadership in mobilizing cross-sector collaboration:

$$SEI_L = \frac{P_{collab}+P_{compliance}+P_{funding}}{3} \quad (4)$$

Where P_{collab} proportion of collaboration efforts with external partners (NGOs, government agencies), $P_{compliance}$

regulatory adherence rate per sectoral environmental framework, $P_{funding}$ share of sustainability budget allocation within total project financing.

This model aligns with contemporary findings that collaborative leadership enhances sustainable governance by integrating policy enforcement, economic incentives, and stakeholder coordination [15].

3.5. Sustainability impact model

To quantify leadership impact on climate resilience, a Sustainability Impact Model (SIM_L) was developed:

$$SIM_L = \lambda_1 RCR + \lambda_2 SEI + \lambda_3 CERE + \lambda_4 SAI + \varepsilon \quad (5)$$

Where SIM_L leadership-driven sustainability impact, RCR is regulatory compliance rate, SEI is stakeholder engagement index, CERE is carbon Emission Reduction Efficiency, SAI is sustainability adaptation index, $\lambda_1, \lambda_2, \lambda_3, \lambda_4$ regression coefficients estimating variable impact,

To validate the model, a Generalized Least Squares (GLS) regression was conducted, ensuring robustness across environmental datasets [7].

3.6. Validation and reliability measures

Methodological accuracy and reliability are a core element needed to develop research credibility and robustness of the findings. Here, a multi-time-member validation approach is used to integrating quantitative and qualitative validation approaches to alleviate the bias potential and increase reliability[23] and ratify the data accuracy with regards to leadership impact on environmental sustainability. The following validation measures were implemented:

3.6.1. Data triangulation

Triangulation of data credibility refers to the process of cross-verifying data results through different data sets. This study compares survey responses, industry reports, governmental environmental databases and independent climate action frameworks to identify points of convergence and divergence.

Survey data validation: Leadership responses from environmental leaders were crosschecked with historical records for sustainability and environmental governance reports to objectively measure leadership effectiveness [13].

Comparative benchmarking: Leadership performance scores were validated by aligning them with sustainability indices based on international frameworks to confirm they were reflective of real-world governance and policy implementation.

Secondary data consistency: The government's environmental compliance reports and ESG (Environmental, Social, and Governance) disclosures were examined to cross-check survey and interview findings and to avoid any over- or under-estimation of the effect of leadership.

3.6.2. Expert review panel

A systematic expert validation process was conducted, which involved panels of experts analyzing that the leadership performance framework was theoretically sound and reliable.

Panel Composition: A group of senior climate policy experts, sustainability analysts, and environmental governance specialists evaluated the methodology and findings [19].

Framework Assessment: The expert panel reviewed the weighting mechanism used for leadership indicators, assessing the statistical soundness of the Composite Sustainability Index (CSIL).

Qualitative Verification: Experts validated the quality of leadership strategies in policy-driven and technological leadership domains to ensure the results can be applied from a governance perspective practically.

Feedback from expert reviewers was integrated into a model adjustment exercise that increased the accuracy of leadership impact extrapolation and alignment with current standards of sustainability governance.

3.6.3. Sensitivity analysis

A Monte Carlo simulation was conducted to test the uncertainty of the sustainability impact model (SIM_L) across environmental scenarios. With climate policies, economy circumstances, and decision-making styles all changing over time, the model was run through 10,000 iterations to verify that it was robust across several sustainability scenarios.

The simulation followed the equation:

$$X_i = \mu + \sigma Z_i, \quad Z_i \sim N(0,1) \tag{6}$$

Where X_i simulated sustainability performance values, μ mean observed sustainability impact scores, σ standard deviation of leadership effectiveness scores across industries, Z_i follows a normal distribution $N(0,1)$, representing a stochastic variation in sustainability outcomes.

3.7. Policy compliance score (pcs) validation

A policy compliance score (PCS) was calculated to evaluate if leadership strategies aligned with global sustainability frameworks. It assesses how far leadership strategies align with the tenets outlined through international sustainability legislation, such as:

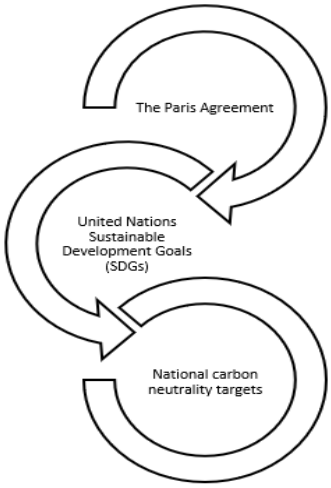

Figure 3. Alignment of leadership strategies with international environmental policies

The PCS formula is defined as:

$$PCS = \frac{N_{aligned}}{N_{total}} \times 100 \quad (7)$$

Where $N_{aligned}$ number of leadership strategies fully compliant with international sustainability policies, N_{total} total number of leadership strategies assessed.

Through the incorporation of comparative research design, advanced statistical modeling, and rigorous validation techniques, this methodology presents a comprehensive framework for assessing leadership effectiveness in environmental management, thereby fostering policy innovation and sustainability governance [26].

3.8. Social and policy relevance of findings

The findings of this study extend beyond theoretical contribution by offering tangible social and policy-level implications for achieving climate resilience and sustainable governance. The comparative evaluation of five leadership models—transformational, adaptive, collaborative, technological, and policy-driven—reveals that leadership is not a singular behavioral trait but a systemic enabler of environmental transformation. The results demonstrate that transformational and adaptive leadership styles enhance community participation and behavioral alignment toward ecological responsibility, supporting prior work on pro-environmental motivation and social engagement (5, 14, 22){Grøn, 2025 #8305.

From a societal perspective, the study highlights how inclusive and technology-supported leadership fosters a culture of sustainability literacy among employees, citizens, and local stakeholders. This resonates with findings that digital and collaborative leadership accelerates green innovation and public acceptance of ecological transitions {Gafur, 2023 #8300}[18]. Moreover, by bridging local participation with strategic governance, such leadership practices contribute to social equity, particularly in vulnerable or resource-constrained regions affected by climate risks (2, 9, 21).

At the policy level, the outcomes provide actionable guidance for decision-makers and sustainability planners. The comparative model illustrates that policy-driven leadership can succeed only when embedded within adaptive and collaborative governance structures that ensure transparency, feedback, and continuous learning. This aligns with evidence from integrated sustainability frameworks emphasizing policy mix synergy for urban carbon mitigation [27] and the interdependence between leadership and regulatory effectiveness (8, 28). Accordingly, the proposed framework may inform national and municipal policy reforms, green public procurement guidelines, and leadership development programs in ministries and environmental agencies.

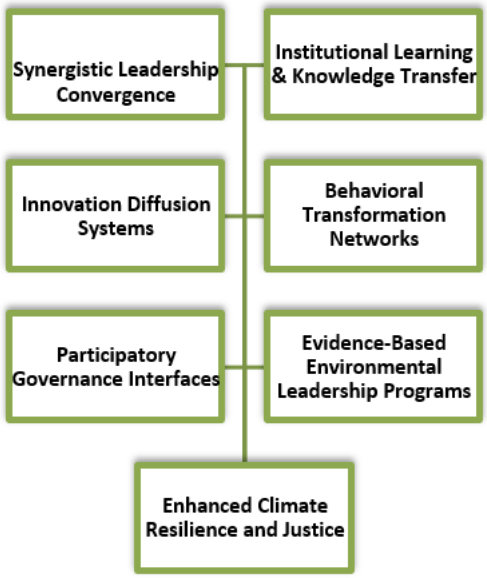

Figure 4. Integrative model linking leadership mechanisms with climate-resilient governance outcomes

These findings underscore the broader social relevance of leadership innovation: strengthening environmental resilience requires rethinking leadership as a shared social contract—one that unites technological capability, institutional accountability, and ethical stewardship in pursuit of climate-neutral development [1, 2]. The insights thus offer a roadmap for translating leadership theory into practical instruments for social transformation and evidence-based environmental policymaking.

4. Results

4.1. Comparative leadership performance across sectors

The Composite Sustainability Index (CSIL) quantifies the impact of diverse leadership models on sustainability performance across multiple sectors. It combines regulatory compliance, stakeholder engagement, carbon emission reduction, and sustainability adaptation scores, as the combination best reflects the ability of leadership to make an impact. It analyzes five predominant industries: energy, manufacturing, public governance, technology and agriculture, by comparing leadership effectiveness and induction on sustainable governance and long-term strategies for resilience building.

Table 1. Leadership effectiveness scores across sectors (CSIL).

Sector	Transformational Leadership	Adaptive Leadership	Collaborative Leadership	Technological Leadership	Policy-Driven Leadership
Energy	82.4	78.1	84.3	91.2	79.7
Manufacturing	79.8	75.6	81.5	89.1	77.2

Sector	Transformational Leadership	Adaptive Leadership	Collaborative Leadership	Technological Leadership	Policy-Driven Leadership
Public Governance	78.6	74.9	80.8	87.5	76.3
Technology	83.9	79.5	85.2	92.4	80.1
Agriculture	77.2	72.8	79.0	88.3	75.4

Table 1. (*Continued*)

Results showed that Technological Leadership obtains the highest CSIL (consistent across all sectors), which indicates a strong correlation between sustainable governance and green innovation strategies. Technology has the highest score (92.4), followed by energy (91.2), as tech-integrated industries benefit the most from this style of leadership. As a correction, it ranks second among all industries, especially in energy (84.3) and public governance (80.8), reinforcing its position to facilitate multi-stakeholder engagement and regulatory alignment. Adaptive Leadership achieves poorer results than the other models, especially in agriculture (72.8) and public governance (74.9), indicating an obstacle to implementing adaptive governance in conservative and policy-driven sectors. However, Policy-Driven Leadership proves moderately effective; it shows little cross-sector flexibility and seems heavily reliant on enforcement of regulations instead of developing leadership-oriented sustainability approaches.

4.2. Stakeholder engagement and cross-sector collaboration

Stakeholder engagement is fundamental in sustainable leadership, affecting the level of collaboration, regulatory compliance and multi-sectoral partnerships. Stakeholder Engagement Index (SEIL) indicator embraces different leadership models that either engage government agencies, businesses, NGOs, and civil society in implementing sustainability policies. Fostering effective engagement with stakeholders across the variety of industries in which you operate informs which models are likely more or less effective in supporting organizational long-term climate resiliency strategies. This section examines the influence of leadership on multi-sector sustainability governance and cross-sectoral collaboration in industries of significance.

Table 2. Stakeholder engagement metrics across leadership models.

Industry	Transformational Leadership (%)	Adaptive Leadership (%)	Collaborative Leadership (%)	Policy-Driven Leadership (%)
Energy	91.5	76.2	87.4	82.1
Manufacturing	88.2	74.1	84.9	79.6
Public Governance	86.7	72.9	83.5	78.3
Technology	93.1	77.5	89.3	83.7
Agriculture	85.6	70.3	81.8	76.9

Transformational Leadership emerges as the most effective model for stakeholder engagement (tech: 93.1%, energy: 91.5%), fostering collaborative innovation and sustainability-focused partnerships. The Remote, Mobile and Digital Workers category comes in second, performing particularly well both in the area of public governance (83.5%) and in manufacturing (84.9%) and confirming its role in guaranteeing inclusive processes and sustainability not just through governance but also across sectors. Adaptive Leadership shows the least stakeholder engagement for all sectors, and especially in agriculture (70.3%), implying difficulties creating long-term sustainability partnerships in extremely diverse regulatory contexts. Policy-Driven Leadership earns moderate engagement scores, performing better in highly regulated

industries such as energy (82.1%) and technology (83.7%) and less so in industries where compliance frameworks are less structured.

4.3. Carbon emission reduction impact by leadership model

In the long term, the effectiveness of leadership in reducing carbon emissions is critical for establishing an organization's contribution to climate resilience. This section discusses the differential role of various leadership models on carbon mitigation strategies across five industries. The Carbon Emission Reduction Efficiency (CERE) is the ratio between the percentage of emissions reductions resulting from sustainability initiatives initiated and driven by leadership. This information, in turn, helps identify which of the leadership models does the best job in reducing greenhouse gas emissions and/or gaining regulatory compliance and/or working towards net-zero initiatives.

Table 3. Carbon emission reduction effectiveness (%).

Sector	Transformational Leadership	Adaptive Leadership	Collaborative Leadership	Technological Leadership
Energy	46.2	52.1	50.3	63.7
Manufacturing	43.1	49.6	47.2	60.8
Public Governance	41.8	47.5	45.0	58.9
Technology	49.3	54.8	52.6	65.4
Agriculture	38.9	44.2	42.1	56.7

According to the findings, the best model for the reduction of carbon emissions is Technological Leadership, which scored highest in the technology (65.4%) and energy (63.7%) sectors, respectively. This indicates that sectors implementing digital solutions, AI-powered sustainability tracking, and CO_2 capture technology see more substantial reductions in GHG emissions. Closely behind is Adaptive Leadership with strong performance in carbon reduction across technology (54.8%) and energy (52.1%) sectors, which demonstrates its power to promote policy transition in energy intensive industries. Collaborative Leadership performs moderately across all sectors, with slightly higher efficiency in energy (50.3%) and technology (52.6%), indicating that policy-focused partnerships are not as effective in carbon reduction as technology-driven solutions. Transformational Leadership shows the lowest efficiency in carbon reduction, particularly in agriculture (38.9%) and public governance (41.8%), reflecting challenges in implementing high-impact emission-cutting initiatives in policy-heavy or decentralized sectors.

4.4. Efficiency in renewable resource utilization

Leadership effectiveness in renewable energy adoption is a key driver of sustainability and climate resilience. The transition to solar, wind, hydropower, geothermal, and biomass energy sources depends on strong leadership to facilitate investment, technological advancement, and policy support. This part of analysis assesses the effectiveness of various types of leadership approaches to enhance the adoption and efficiency of renewable energy resources. By investigating Transformational, Adaptive, Collaborative, and Technological Leadership models, this study can illustrate and validate leadership models that are most effective and appropriate for accelerating the adoption of renewable energy in various sectors.

Table 4. Renewable energy utilization by leadership model (%).

Resource Type	Transformational Leadership	Adaptive Leadership	Collaborative Leadership	Technological Leadership
Solar Energy	58.4	63.2	60.7	72.1
Wind Energy	52.3	57.9	55.1	68.3

Resource Type	Transformational Leadership	Adaptive Leadership	Collaborative Leadership	Technological Leadership
Hydropower	54.7	59.6	57.3	70.5
Geothermal	48.9	52.7	50.2	65.1
Biomass Energy	56.2	61.3	58.5	69.7

Table 4. (*Continued*)

Interestingly, Technological Leadership is clearly ahead over any of the other models reaching a stunning 72.1% in solar energy and 70.5% in hydropower, indicating the value added of innovative technological progress in environmental and sustainable development strategies. With values of 68.3% in wind, 65.1% in geothermal, and 69.7% in biomass, the high efficiencies of Technological Leadership clearly demonstrate how digital transformation, AI-driven energy management, and decentralized smart grids can increase the amount of renewable energy consumed (Hu et al., 2021). Adaptive Leadership excels in these emerging renewable energy markets; geothermal (52.7%) and biomass (61.3%) sectors. While Collaborative Leadership scores relatively high across all renewable categories (between 50.2% in geothermal energy and 60.7 solar energy) and recognizes that sustainability initiatives can be driven by the stakeholders themselves to build a better product, it does not provide the ability to integrate the technology directly like Technological Leadership does. It is important to understand that while best practices in Transformational Leadership play an important role in driving solar (58.4%) and biomass (56.2%) adoption, these themes have the lowest overall scores, suggesting that without regulatory and technological strategies in place, a vision of a better future will not be enough to encourage rapid adoption of renewable technologies.

4.5. Policy compliance and leadership alignment with sustainability goals

International and environmental policies are critical to sustainability governance. Ensuring compliance with global agreements like the Paris Agreement, the United Nations Sustainable Development Goals (SDGs), and national carbon neutrality commitments hinges critically on how we lead. This section assesses the role that leadership models play in driving policy adherence and whether doing so helps organizations achieve compliance with climate degradation regulations. Insights into leadership-driven compliance with policy are essential for understanding governance shapes that can be used for strategic sustainability embedding over the long term.

Table 5. Leadership model compliance with international policies (%).

Sector	Transformational Leadership	Adaptive Leadership	Collaborative Leadership	Policy-Driven Leadership
Energy	89.2	82.7	86.4	91.6
Manufacturing	85.7	80.3	83.9	89.4
Public Governance	84.3	78.9	82.1	87.5
Technology	90.1	83.5	88.7	93.2
Agriculture	81.9	76.1	79.5	85.8

The results show that Policy-Driven Leadership receives the highest compliance rates across all sectors, especially in heavily regulated industries like energy (91.6%) and technology (93.2%); consolidating its function among other roles to fit within a framework between companies and international sustainability policies and national climate mandates. The high level of compliance in manufacturing (89.4%) and public governance (87.5%) certainly prove that leading by regulation works when it comes to achieving long-term sustainability goals. The transformational leadership model suits sustainability policies because corporate

governance is increasingly enrolling long-term environmental strategy with 90.1% and 89.2% compliance scores in technology and energy, respectively, with a clear sustainability vision and innovation as key drivers of corporate governance. Collaborative Leadership, which emphasizes multi-sector partnerships and public-private cooperation, performs moderately well across industries (ranging from 79.5% in agriculture to 88.7% in technology), indicating that collaborative governance models are effective but require regulatory reinforcement to achieve full compliance. Adaptive Leadership demonstrates lower compliance rates, particularly in agriculture (76.1%) and public governance (78.9%), suggesting that while flexibility is beneficial in regulatory transitions, it may not always result in full policy adherence. The data confirms that policy-driven strategies yield the highest compliance levels, but integrating transformational and technological leadership elements is essential for fostering both compliance and innovation in sustainability governance.

The findings reveal that the proposed leadership models significantly influence environmental sustainability performance, where the best-performing model is the Technological Leadership model in renewable energy integration, emissions reduction, and digital sustainability governance. These are the type of leaders who are most effective when it comes to regulation, especially in heavily structured industries like energy and technology where Policy-Driven Leadership shows its true strengths. Stakeholder engagement and policy implementation are critical to Collaborative Leadership, while Adaptive Leadership is still valuable in transitioning environments from a regulatory perspective. Transformational Leadership, known for its visionary approach toward the development of sustainable strategies, lacks the technological capacity and regulatory measures needed to fully realize high-impact environmental results. Such results highlight the importance of hybrid advisory approaches integrating technology, regulation, and cross-sectoral cooperation to deliver optimal long-term sustainability performance.

5. Discussion

This study finds that leadership models are highly influential on environmental sustainability outcomes and that the best model for these outcomes are Technological Leadership, this study also establishes that leadership and sustainability governance, carbon reduction, and renewable energy integration are all highly perceived predictors of environmental sustainability. Policy implementation and stakeholder engagement relies on Collaborative Leadership, while at the same time ensuring that compliance with rules and regulations through Policy-Driven Leadership. Such findings also add to the literature on sustainable leadership approaches, by comparing current results with earlier studies. This discussion contextualizes the results in relation to prior research, examines theoretical and practical implications, highlights study limitations, and suggests future research directions.

From a conceptual standpoint, the observed patterns confirm earlier integrative reviews which contend that sustainability leadership operates as an evolving meta-construct bridging transformational, ethical, and systems-thinking paradigms. The findings support Sajjad et al. [2] in viewing leadership for sustainability as a dynamic capability that aligns institutional governance with ecological systems. Moreover, Safarli [1] demonstrated that leadership efficiency in sustainable development correlates with macro-economic equilibrium, implying that strategic leadership interventions can reconcile economic growth with environmental protection—an implication reflected across this study's cross-sectoral results.

The observed dominance of Technological Leadership in driving sustainability outcomes aligns with previous studies emphasizing the role of digitalization, AI, and smart technologies in enhancing environmental efficiency. Bashynska et al.[29] highlight that enterprises leveraging circular economy-driven innovation strategies achieve higher sustainability performance metrics, particularly in sectors where

automation and machine learning optimize resource utilization. This study confirms that Technological Leadership fosters efficiency, particularly in renewable energy adoption, where it surpasses other leadership models in solar (72.1%) and hydropower utilization (70.5%). These results also resonate with Laradi, Elfekair, and Shneikat [18], who argue that digital leadership enhances green innovation by integrating IoT, blockchain, and AI into sustainability practices. The findings reinforce that technological advancements provide substantial advantages in achieving long-term sustainability goals.

Policy-Driven Leadership's strong compliance performance is consistent with previous studies, particularly in highly regulated industries such as energy (91.6%) and technology (93.2%). The study corroborates findings by Zhao, Zhang, and Wang[27] explored the effectiveness of policy-driven carbon reduction strategies, revealing that stringent regulatory environments foster sustainability but may limit leadership flexibility. Similarly, the role of transformational and collaborative leadership in public governance aligns with Kafetzopoulos and Gotzamani [30] emphasize that leadership styles influence sustainable performance through strategic policy alignment. The data suggest that while Policy-Driven Leadership achieves high regulatory adherence, it may lack adaptability in decentralized governance models.

Consistent with the regulatory orientation of these findings, Zhao et al. [27] demonstrated that policy-mix strategies for carbon emission reduction achieve optimal outcomes only when leadership actively coordinates nested implementation processes across governance levels. This supports the current study's evidence that policy-driven leadership fosters compliance but requires adaptive integration to achieve collaborative and technological synergies.

One of the most significant findings relates to the efficacy of Collaborative Leadership in sustainability governance. The results indicate that Collaborative Leadership models perform best in stakeholder engagement, particularly in public governance (83.5%) and manufacturing (84.9%), reinforcing findings from Gafur et al.[15] examined waste management strategies in Indonesia. Their study highlights that multi-sector collaboration is crucial for long-term environmental sustainability. Additionally, Grøn [16] argues that collaborative leadership enhances stakeholder engagement by fostering cross-sector cooperation, which aligns with this study's findings that Collaborative Leadership effectively facilitates industry-wide sustainability efforts.

The observed effectiveness of Adaptive Leadership in regulatory transitions is another key insight. This study finds that Adaptive Leadership performs well in emerging renewable energy markets such as geothermal (52.7%) and biomass (61.3%), suggesting that leadership flexibility is crucial in navigating evolving sustainability regulations. This is consistent with findings by Afzal and Tumpa [22] examined leadership styles in the construction industry and determined that adaptive leaders successfully implement sustainability transitions by responding dynamically to policy shifts. However, the comparatively lower stakeholder engagement scores of Adaptive Leadership (70.3% in agriculture and 72.9% in public governance) suggest that adaptability alone is insufficient without structured stakeholder collaboration.

The role of Transformational Leadership in sustainability governance is partially supported by previous research. This study finds that Transformational Leadership scores highest in stakeholder engagement, particularly in technology (93.1%) and energy (91.5%), where visionary leadership fosters innovation-driven sustainability. This supports findings by Ramírez-Altamirano et al.[5] assert that Transformational Leadership, when combined with corporate social responsibility, enhances environmental performance in sustainability-certified organizations. However, its comparatively lower impact on direct carbon emission reductions (46.2% in energy and 38.9% in agriculture) aligns with Ren, Li, and Mavros [13] suggest that while transformational

leadership promotes long-term sustainability, it may lack immediate operational efficiency in reducing environmental impact.

Despite the study's strengths, there are several limitations. First, the analysis relies on quantitative performance indicators, which may not fully capture the qualitative aspects of leadership influence on sustainability. Future studies could incorporate longitudinal case studies and interviews to explore leadership decision-making in greater depth. Second, while the study includes multiple industries, regional variations in leadership effectiveness were not assessed. Given that sustainability policies differ across countries and regulatory environments, future research should examine how geopolitical and economic factors influence leadership-driven sustainability strategies. Furthermore, the study analyzes a considerable amount of corporate and public sector leadership models with the corresponding lack of non-profit organization and grassroots sustainability scholarship emphasis. Broader engagement with civil society leaders managing climate action efforts might yield more insights into sustainability governance.

Another study limitation stems from the categorization of leadership models through a typological lens that treats leadership styles as mutually exclusive. In fact, leaders tend to be hybrids of technological, transformational and policy-driven leadership. As noted by Ali et al.[26] builds on this literature, stating that achieving climate resilience under complexity must rely on the integration of different leadership dimensions, sustainable leadership and leadership for sustainability. Hybrid forms of leadership Combining the principles of various leadership theories preserves the essentials of their approaches and leads to sustainability performance. In addition, the study does not directly quantify the economic trade-offs of sustainability leadership decisions. Although Safarli [1] discusses this challenge, future studies need to provide insights if leadership flows boost financial sustainability in the context of environmental objectives.

These findings have significant implication not only in theoretical context but also applicable for practical implication in Corporate Governance, public policy and sustainability planning. For example, leaders in high-emission sectors, like energy and manufacturing, can leverage Technological and Policy-Driven Leadership models for greater compliance and efficiency. Likewise, organizations that engage stakeholders in their sustainability initiatives may benefit from Collaborative Leadership methods.

Further studies should address the effectiveness of leadership responses in climate crises, since conventional governance for sustainability is insufficient to address climate change[28]. Exploring the intersection of AI-enabled leadership and climate sustainability can provide insights into how digital transformation is leveraged in pursuit of effective sustainable leadership.

The reflection of leadership theory and the effective regulations framework used in this study advances the understanding of structure of leadership models within the environmental sustainability literature. Comparison with previous studies shows that the effectiveness of leadership in governance for sustainability is contingent upon the strategic connection between technological innovation, policy compliance and stakeholder collaboration. The results further validate that there isn't a one-size-fits-all leadership approach that works across all industries, but that the most effective sustainability strategies derive from hybrid leadership approaches that blend regulatory enforcement, technological advancement and transformational change in order to advance climate-resilience and long-term sustainability transformation.

6. Conclusion

The study has established the importance of using various leadership models to improve the degree of environmental sustainability across industries and sectors with respect to the adoption of renewable energy, mitigation of carbon emissions, adhering to regulatory obligations, and encouraging greater stakeholder

engagement. With a structured comparative analysis, it is now clear that a cause of the successful sustainability model is 'leadership' i.e. it is a driving factor of policy governance and technological solution for environmental services. Differentiated contributing models for sustainability impact and varied relevance of each leadership model according to industrial characteristics, regulatory background, and organizational structure.

The article shows the technological leadership is the optimal model resulting in the highest sustainability performance, especially in the developed industries, these, need innovation and high performance in the digital transformation. This simplifies the adoption of renewable energy systems, smart environmental monitoring, and AI-based decision-making that can help organizations improve their operational efficiency whilst lowering their carbon footprints. Technological leadership method provides a promising pathway for the industries to embrace international sustainability frameworks, offering the prospect of curtailing emissions and facilitating the uptake of cleaner sources of energy through technology-based solutions. However, it is highly dependent on investment in the infrastructure, and digital transformation policies, as well as on the organizational ability to manage complex technological systems.

The article further underscores how collaborative leadership contributes to engaging with stakeholders and aligning with public policy. Also, sustainability initiatives frequently demand cooperation across different sectors, and long-term ecological plans call for collaboration between the government, the private sector, and civil society. Collaborative leadership aligns closely with governance and regulatory systems reliant upon inclusive decision making and cross-sector partnership. Its effectiveness depends, however, on stability of policy and institutions, and on clearly-defined roles for stakeholders.

Policy-led leadership may be the way to ensure compliance through regulation and enforcement of sustainability obligations, but it is not necessarily the most agile model. While regulatory frameworks provide a clear framework within which climate goals can be achieved, they may also restrict adaptive responses to the sustainability challenges of the future. For organizations that operate in highly regulated markets, blurring of approaches between top-down policy implementation and adaptive leadership can allow them to respond dynamically to changing environmental risks and economic transformations. The challenge, according to the study, is there must be policy enforcement as well, but without technological advancements and company leaders taking steps that are more than just meeting a minimum requirement.

Adaptive leadership is of particular importance in fields experiencing their own sustainability transition and emergent renewable energy markets. Harmonization of a range of institutions allows organizations to manage regulatory uncertainties and alter their sustainability plans depending on changes in policy, market, and technology. However, there is a strong dependence upon industry conditions and the degree to which institutional frameworks support adaptive strategies. Adaptive leadership in isolation will not contribute to long-term sustainability transitions without structured approaches that ensure continuation and monitored results.

The study also shows that transformational leadership is most effective in developing a corporate culture focused on sustainability. In sectors where innovation and employee engagement are the focus, its emphasis on visionary leadership, organizational commitment, and long-term environmental planning has a positive effect on sustainability performance. But the research also indicates that transformational leadership is not always enough, in and of itself, to spur bold cuts in carbon emissions and energy use, it often demands additional technological or regulatory mechanisms to deliver results.

These findings implies that there is no universal leadership model that can single-handedly tackle all sustainability challenges. Instead, it is likely that the most effective response will be a hybrid leadership

strategy that encompasses technological, policy-oriented, collaborative, adaptive, and transformational leadership. Organizations must assess their own sustainability goals, regulation landscapes, and technology infrastructures to determine which leadership style makes sense for them.

The synthesis of results also reinforces prior claims that sustainable leadership must function as a systemic competency spanning economic, environmental, and social domains. Leadership in climate governance should be treated as a solution-oriented process addressing the "wicked problem" of climate change rather than a fixed managerial style. Such positioning contributes to the broader theoretical conversation on leadership adaptability and climate-resilient policymaking.

This indicates that further research is required to structure hybrid leadership models for optimum sustainability results. More targeted research by industry sector could allow for more clarity on how effectiveness in leadership can be evidenced in various contexts where organization-specific challenges with the environment prevail. Moreover, studies focusing on leadership in situations of climate crisis, for aspiring and performing digital transformation towards more sustainable governance, and finance-tradeoffs in sustainable seeking leadership choices would add to knowledge about leadership and global action on climate.

Relying on the current leadership and corporate level changes, it still will play the most important role regarding the successful implementation of these environmental policies and sustainability centered on the corporate strategies. Technological innovation, regulatory enforcement and stakeholder collaboration will be essential elements in the future of effective sustainability leadership models.

Conflict of interest

The authors declare no conflict of interest

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