



## Strategic Environmental Management and Green Technology Research and Development in Vocational Institutions Supporting the Clean Tech Industry

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### Abstract

This study examined the relationship between strategic environmental management and green technology research and development in vocational institutions supporting the clean-tech industry. It focused on strategic environmental management in terms of environmental goals, leadership commitment, and regulatory alignment, and on green technology research and development in terms of program quality, technology development, and innovation implementation. The study used a descriptive-correlational research design, with weighted mean, ranking, reliability analysis, and Spearman's rho used to analyze the data. Findings indicated that strategic environmental management was implemented at an "Agree" level, with regulatory alignment receiving the highest assessment, followed by leadership commitment and environmental goals. Green technology research and development was evaluated at a moderate level, with technology development ranking highest, followed by program quality and innovation implementation. The correlation results showed strong, positive, and statistically significant associations between all dimensions of strategic environmental management and green technology research and development, with p-values below .001. These findings suggest that stronger environmental goals, leadership commitment, and regulatory alignment are closely associated with higher levels of institutional green R&D capacity. The study implies that vocational institutions can strengthen clean-tech support by embedding environmental goals into planning, improving green R&D investment governance, and enhancing implementation systems for sustainable technology deployment.

**Keywords:** *strategic environmental management; green technology research and development; vocational institutions; clean-tech industry; regulatory alignment; green innovation*

### 1. Introduction

The intensification of climate change has compelled institutions across sectors to reconsider how their strategies, operations, and innovation systems contribute to environmental sustainability. In China, this pressure is especially significant because national development priorities increasingly emphasize green innovation, clean-technology advancement, carbon peaking by 2030, and carbon neutrality by 2060 (American Chamber of Commerce in China, 2023; International Energy Agency, 2022). These policy directions place green technology research and development (GT-R&D) at the center of institutional and industrial transformation. They also highlight the need for strategic environmental management (SEM), particularly as organizations are expected to align environmental priorities with leadership systems, regulatory expectations, resource allocation, and innovation outcomes.

Strategic environmental management refers to the systematic integration of environmental considerations into organizational planning, decision-making, and performance systems. Rather than treating environmental management as a compliance function alone, SEM positions sustainability as a strategic concern linked to institutional goals, leadership commitment, and regulatory responsiveness. Environmental goals provide direction by defining measurable sustainability priorities. Leadership commitment reflects the extent to which institutional leaders allocate resources, communicate sustainability values, and develop the organizational capabilities required for green innovation. Regulatory alignment concerns the ability of institutions to respond to environmental policies, standards, and compliance mechanisms in ways that support long-term strategic development. Recent studies suggest that organizations with clearer environmental objectives, stronger leadership commitment, and more coherent sustainability governance are better positioned to generate green innovation and improve environmental performance (Ledia et al., 2024).

Green technology research and development represents the innovation-oriented outcome of sustainability strategy. It includes the institutional processes through which environmentally sustainable technologies are funded, developed, tested, and implemented. In this study, GT-R&D is examined in terms of program quality, technology development, and innovation implementation. Program quality reflects the extent to which green R&D is supported by structured funding, milestone-based planning, institutional priorities, and performance tracking. Technology development pertains to the progression of green innovations from initial concepts toward prototypes, pilots, and demonstration activities. Innovation implementation concerns the translation of developed technologies into operational, deployable, and scalable applications. The effectiveness of GT-R&D is therefore not limited to invention; it also depends on whether institutions can sustain investment, manage development processes, and implement innovations in real-world settings.

Despite the growing attention given to SEM and GT-R&D, their relationship remains insufficiently examined in higher education and vocational education contexts. Much of the existing literature on SEM focuses on corporate and industrial organizations, while much of the literature on GT-R&D concentrates on enterprise innovation, green patents, clean-energy systems, and industrial transformation. Higher education institutions have increasingly adopted sustainability commitments, but reviews suggest that many institutions still struggle to translate such commitments into measurable innovation outcomes, often resulting in fragmented initiatives, symbolic compliance, or limited technological outputs (Abello-Romero et al., 2024; Times Higher Education, 2024). This gap becomes more pronounced in vocational and technical institutions, which are expected to contribute to applied research, industry partnerships, technical skills development, and clean-technology diffusion, yet remain less frequently examined than traditional universities. Comparable evidence from Philippine higher education shows that sustainability integration may remain fragmented when digital, curricular, and governance initiatives are not embedded within a whole-institution strategy, reinforcing the need to connect environmental goals with institutional systems (Atento, 2025).

This issue is particularly relevant in the Chinese vocational education context. Recent reforms in China's vocational education system emphasize applied research, industry-education integration, and alignment with emerging sectors, including the clean-technology industry (Ministry of Education of the People's Republic of China, 2024). Vocational institutions are therefore positioned not only as teaching institutions but also as applied innovation partners that can contribute to regional and national sustainability goals. However, their capacity to support clean-tech development depends on whether their environmental strategies are clearly defined, supported by leadership, aligned with regulation, and connected to actual R&D practices. Without such alignment, green innovation may remain confined to isolated projects rather than becoming a sustained institutional capability.

Fujian Forestry Vocational and Technical College provides a relevant setting for examining this relationship because it operates at the intersection of vocational education, environmental concern, applied research, and industry engagement. As vocational institutions are increasingly expected to support clean-technology development, it becomes necessary to assess whether strategic environmental management practices are meaningfully associated with green technology R&D capacity. Understanding this relationship can provide both scholarly and practical value. Scholarly, it contributes to the limited empirical discussion linking SEM and GT-R&D in vocational institutions. Practically, it can guide institutional leaders in strengthening environmental planning, green R&D investment, technology development systems, and innovation implementation mechanisms.

This study aimed to examine strategic environmental management and green technology research and development within Fujian Forestry Vocational and Technical College in relation to its support for the clean-technology industry. Specifically, it sought to determine the implementation of strategic environmental management in terms of environmental goals, leadership commitment, and regulatory alignment; evaluate the level of green technology research and development in terms of program quality, technology development, and innovation implementation; test the significant relationship between strategic environmental management and green technology research and development; and propose an action plan to enhance green technology R&D through effective strategic environmental management practices.

## **2. Review of Related Literature**

The review is organized into four themes: strategic environmental management as a driver of green innovation; environmental goals, leadership commitment, and regulatory alignment; green technology research and development in applied and vocational institutions; and program quality, technology development, and innovation implementation.

### ***2.1 Strategic Environmental Management as a Driver of Green Innovation***

Strategic environmental management has shifted from a narrow compliance function to a broader strategic system that connects environmental priorities with governance, resource allocation, innovation, and institutional performance. In

this view, SEM is not limited to meeting regulatory obligations; it also functions as a management framework through which organizations define sustainability priorities, mobilize leadership, structure decision-making, and guide innovation activities. Studies in corporate and institutional settings indicate that organizations that integrate environmental concerns into board-level governance, sustainability committees, operational processes, and project portfolios are more likely to generate green products, cleaner processes, and stronger innovation outcomes (Ahmad Javeed et al., 2022; Liu, 2024).

This strategic orientation is particularly relevant in China, where green innovation is closely tied to national development priorities. China's carbon peaking and carbon neutrality goals have elevated clean-energy innovation, applied R&D, and technology demonstration as policy imperatives (American Chamber of Commerce in China, 2023; International Energy Agency, 2022). Under this policy environment, SEM becomes mission-oriented because institutions must align internal environmental strategies with broader national and regional sustainability programs. Green investment also appears to strengthen innovation outcomes when it reduces financing constraints and supports substantive R&D activities rather than symbolic environmental reporting (Zhang et al., 2024). However, evidence on provincial R&D investment suggests that green innovation outcomes may depend on regional absorptive capacity, technological readiness, and institutional capability, indicating that SEM must be calibrated to context rather than implemented as a uniform template (Fan & Teo, 2022).

In higher education and vocational institutions, SEM also requires stakeholder engagement, curriculum alignment, applied research systems, and industry partnerships. Sustainability-oriented higher education studies suggest that institutions are more effective when environmental management is linked to transformative learning, stakeholder participation, and measurable institutional change (Leal Filho et al., 2025). For vocational institutions, this point is especially important because their role is not only to teach sustainability concepts but also to support applied green technology development through laboratories, training systems, and industry collaboration.

## ***2.2 Environmental Goals, Leadership Commitment, and Regulatory Alignment***

The SEM construct is commonly operationalized through environmental goals, leadership commitment, and regulatory alignment. Environmental goals provide the strategic direction for sustainability action. They clarify what the institution intends to achieve, how progress will be measured, and how environmental priorities will guide planning and innovation. Effective goals should be ambitious but realistic, translated into milestones, and supported by measurable indicators. Goal-setting studies emphasize that environmental objectives are more likely to shape organizational behavior when they are linked to stakeholder participation, transparent monitoring, and periodic adjustment (Isaacs et al., 2023). In innovation settings, environmental goals also provide cognitive and strategic anchors that connect sustainability intent with laboratory-level experimentation, green creativity, and applied R&D activity (Alnaim et al., 2022).

Leadership commitment is the second major dimension of SEM. Green transformational leadership has been associated with stronger environmental performance, especially when it is supported by green dynamic capabilities, or the ability to sense opportunities, mobilize resources, and reconfigure institutional systems for green innovation (Ledia et al., 2024). Leadership commitment operates through both formal and informal mechanisms. Formally, leaders influence budgets, research priorities, partnerships, HR systems, training, and recognition. Informally, they shape green organizational climate and encourage voluntary pro-environmental behavior among faculty, researchers, students, and laboratory staff (Liu & Yu, 2023). Evidence also suggests that green human resource management and green innovation are more effective when leadership aligns incentives, capability development, and sustainability-oriented governance systems (Niazi et al., 2023).

Regulatory alignment serves as the third dimension of SEM. In China, environmental regulation has generally been found to stimulate green innovation, although the strength of this effect varies by policy instrument, region, and industry (Ren & Chen, 2023). Regulatory alignment therefore involves more than passive compliance. It includes monitoring environmental policy changes, embedding compliance into project governance, using incentives and subsidies, and aligning R&D projects with national science and technology missions. Studies on China's green economy suggest that environmental regulation can influence green innovation both directly and indirectly through corporate technological innovation (Wang et al., 2024). Industrial policy, including programs such as Made in China 2025, also appears to support green innovation through subsidies, tax incentives, and corporate responsibility channels (Xu, 2022). For vocational institutions, regulatory alignment can guide laboratory protocols, research ethics, waste management, safety standards, and partnership arrangements with industry actors.

### *2.3 Green Technology Research and Development in Applied and Vocational Institutions*

Green technology research and development is the operational mechanism through which sustainability priorities are converted into technical outputs, prototypes, processes, and deployable solutions. GT-R&D is therefore not simply a research activity; it is a bridge between environmental strategy and practical clean-tech contribution. In the literature, GT-R&D is associated with green products, low-carbon processes, cleaner production systems, patents, technology transfer, and reduced environmental impacts (Harsono et al., 2024; Liu, 2024). The International Energy Agency (2022) also positions clean-energy innovation as a key mechanism for meeting long-term decarbonization goals, particularly when R&D is connected to demonstration, deployment, and diffusion.

In China, GT-R&D is shaped by national carbon goals, industrial transformation, and mission-oriented technology policy. The policy environment encourages organizations to identify priority technologies, develop innovation roadmaps, and connect applied R&D to regional and national sustainability targets (American Chamber of Commerce in China, 2023; International Energy Agency, 2022). This is relevant to vocational institutions because they are increasingly expected to contribute not only to skills formation but also to industry-education integration and applied innovation. The Ministry of Education of the People's Republic of China (2024) emphasizes reform in the modern vocational education system, including stronger links among education, industry, and applied research. Such reforms create an institutional basis for vocational colleges to support clean-tech development through laboratories, technical training, collaborative projects, and industry-oriented innovation. In the Chinese higher vocational context, craftsmanship spirit and professional values have also been linked with learning motivation, suggesting that applied innovation capacity is partly shaped by the skill-development culture and professional value formation cultivated among learners (Yan, 2026).

However, higher education institutions often face difficulty converting sustainability commitments into measurable technology outputs. Reviews on sustainability reporting and higher education indicate that universities may adopt sustainability language and reporting systems without always achieving substantive innovation outcomes (Abello-Romero et al., 2024; Times Higher Education, 2024). This concern is more pronounced in vocational institutions because applied R&D often requires stable funding, technical infrastructure, industry partners, project governance, and regulatory readiness. Without these supports, green innovation may remain fragmented or project-based rather than becoming an institutional capability. Systems-level work in higher education leadership similarly indicates that curriculum-practice alignment, resource capacity, quality assurance, and leadership governance interact as institutional conditions for program effectiveness (Bermido et al., 2025).

### *2.4 Program Quality, Technology Development, and Innovation Implementation*

The effectiveness of GT-R&D depends on program quality, technology development, and innovation implementation. Program quality concerns how green R&D is financed, prioritized, monitored, and governed. The literature suggests that investment is a central driver of green innovation, but investment alone is insufficient if it is not tied to institutional strengths, regional needs, technology readiness, and measurable milestones (Fan & Teo, 2022; Zhang et al., 2024). Green R&D programs require not only research funds but also enabling capabilities such as intellectual property management, compliance systems, pilot-testing capacity, and technology-transfer mechanisms. Studies on green finance and innovation also indicate that explicit targets and measurable R&D indicators can improve the ability of institutions to attract and sustain green investment (Kwilinski et al., 2025). In a parallel organizational setting, integrated capability, governance, and organizational alignment have been proposed as necessary conditions for translating technical systems into decision quality and dual outcomes, a logic comparable to the translation of SEM into structured GT-R&D routines (Atento et al., 2025).

Technology development refers to the movement of ideas from conceptual design to prototype, pilot testing, and demonstration. In green innovation, this process is usually long, uncertain, and cross-functional. Recent management literature argues that green innovation implementation and development require long-term pacing, disciplined project governance, and coordination among technical, operational, environmental, and financial actors (Qin et al., 2026). Technology roadmaps, stage-gate systems, risk assessment, and technology readiness targets are important because they reduce ambiguity and help institutions determine whether a project should proceed, be revised, or be discontinued. In applied educational institutions, technology development also benefits from stakeholder co-creation, especially when industry partners, local governments, and communities participate in testing and evaluation (Leal Filho et al., 2025). Strategy-oriented work on value innovation likewise suggests that sustainability features become stronger differentiators when integrated into a coherent transformation model rather than treated as isolated add-ons (Teodosio et al., 2025).

Innovation implementation is the final and often weakest part of GT-R&D. It refers to the actual deployment, adoption, and sustained use of green technologies. Implementation requires regulatory planning, safety protocols, waste management, reporting systems, user engagement, leadership reinforcement, and feedback loops. Literature on green innovation notes that leadership, culture, and organizational capability are critical during implementation because deployment often depends on cross-unit cooperation and voluntary adoption behaviors (Ledia et al., 2024; Liu & Yu, 2023). Regulatory alignment also becomes essential at this stage because permitting, compliance, and safety requirements can either accelerate or delay deployment. For vocational institutions, implementation capacity determines whether green technology remains a laboratory output or becomes a practical solution that supports the clean-tech industry.

### ***2.5 Synthesis and Literature Gap***

The reviewed literature shows that strategic environmental management and green technology research and development are conceptually connected. SEM provides the strategic conditions for green innovation through environmental goals, leadership commitment, and regulatory alignment, while GT-R&D represents the operational pathway through which these strategic conditions are translated into program quality, technology development, and innovation implementation (Ahmad Javeed et al., 2022; Ledia et al., 2024; Ren & Chen, 2023). China's policy environment further strengthens this connection because national carbon goals, environmental regulations, green finance, and vocational education reforms all encourage institutions to align sustainability management with applied innovation (International Energy Agency, 2022; Ministry of Education of the People's Republic of China, 2024).

However, existing research remains concentrated on firms, industrial sectors, universities, and macro-level policy systems. Less attention has been given to vocational institutions, despite their growing role in applied research, technical training, and industry-education integration. The literature also shows that sustainability commitments do not automatically translate into innovation outcomes; institutions may possess environmental goals and regulatory awareness but still struggle with R&D investment quality, structured technology development, and implementation capacity (Abello-Romero et al., 2024; Leal Filho et al., 2025). This study responds to that gap by examining how SEM dimensions are associated with GT-R&D dimensions within a vocational institution supporting the clean-tech industry.

## **3. Methodology**

### ***3.1 Research Design***

This study used a descriptive-correlational survey design to examine strategic environmental management and green technology research and development in a vocational institution context. The descriptive component was used to determine the assessed level of strategic environmental management and green technology research and development, while the correlational component was used to test the association between the two major variables. The design was appropriate because the study measured existing institutional conditions without manipulating the variables.

### ***3.2 Respondents and Sampling***

The respondents were drawn from Fujian Forestry Vocational and Technical College. The source manuscript identifies a population of 19,179 full-time vocational students across different program clusters, including forestry technology, economic management, and art and design. Using the RAOsoft sample-size calculator with a 95% confidence level, 50% response distribution, and the stated population size, the required sample was computed at 377 respondents. A proportionate stratified sampling approach was used to ensure representation across program clusters. This procedure was intended to reflect the distribution of students within the institution and provide adequate coverage of the respondent population.

### ***3.3 Research Instrument***

The study used a researcher-made questionnaire developed to measure strategic environmental management and green technology research and development. The instrument was constructed from the literature on sustainability governance, environmental management, green innovation, and institutional R&D performance. A self-developed questionnaire was used because no single standardized instrument fully captured both strategic environmental management and green technology R&D in the institutional context.

The questionnaire measured strategic environmental management through three dimensions: environmental goals, leadership commitment, and regulatory alignment. Green technology research and development was measured through

program quality, technology development, and innovation implementation. All items used a four-point Likert scale. For strategic environmental management, responses ranged from Strongly Disagree to Strongly Agree. For green technology R&D, responses ranged from Very Low Level to High Level. The instrument underwent expert validation by specialists in sustainability, environmental management, research methodology, and language or communication. It was also pilot tested to assess clarity, comprehensibility, and preliminary reliability before full data collection.

**Table 1.** Reliability of the Research Instrument

Variable / Dimension	Cronbach's Alpha	Number of Items	Interpretation
Strategic Environmental Management			
Environmental Goals	0.931	6	Excellent
Leadership Commitment	0.957	6	Excellent
Regulatory Alignment	0.907	6	Excellent
Green Technology R&D			
Program Quality	0.858	6	Good
Technology Development	0.919	6	Excellent
Innovation Implementation	0.896	6	Good

The reliability results indicate that all dimensions of the instrument demonstrated good to excellent internal consistency. The strategic environmental management dimensions obtained Cronbach's alpha values from 0.907 to 0.957, while the green technology R&D dimensions obtained values from 0.858 to 0.919. These values support the internal consistency of the instrument for the study's descriptive and correlational analysis.

### 3.4 Data Gathering Procedure

Data were gathered through a structured questionnaire administered using Google Forms. Respondents were informed of the purpose of the study, the nature of their participation, and the voluntary character of their involvement. The questionnaire was distributed to the target respondents after institutional permission was sought. Responses were collected, screened, encoded, and prepared for statistical analysis.

### 3.5 Data Analysis

Weighted mean and rank were used to determine the assessed implementation of strategic environmental management in terms of environmental goals, leadership commitment, and regulatory alignment. The same descriptive procedures were used to evaluate the level of green technology R&D in terms of program quality, technology development, and innovation implementation. The Shapiro-Wilk test was used to assess normality. Since the p-values were below .05, the data were treated as non-normally distributed. Spearman's rho was used to test the significant relationship between strategic environmental management and green technology research and development. Analyses were conducted using SPSS version 28.

### 3.6 Ethical Considerations

The study observed informed consent, voluntary participation, confidentiality, and anonymity. Respondents were informed that participation was voluntary and that they could withdraw from the study without penalty. Personal identifying information was not required in the questionnaire, and the collected data were used only for research purposes. Consent was also sought from the institution before the questionnaire was administered.

## 4. Results and Discussion

### 4.1 Implementation of Strategic Environmental Management

Strategic environmental management was assessed in terms of environmental goals, leadership commitment, and regulatory alignment. As shown in Table 2, the overall composite mean was 2.70, interpreted as Agree. This indicates that respondents generally perceived SEM practices as present in the institution, although not yet at a highly institutionalized or advanced level. The results suggest that the institution has established environmental management practices, but these may still require stronger integration into daily decision-making, research planning, and innovation systems.

**Table 2.** Implementation of Strategic Environmental Management

Dimension	Composite Mean	Verbal Interpretation	Rank
Environmental Goals	2.69	Agree	3
Leadership Commitment	2.70	Agree	2
Regulatory Alignment	2.71	Agree	1
Overall Composite Mean	2.70	Agree	

Regulatory alignment obtained the highest composite mean of 2.71. This suggests that respondents perceived the institution as relatively stronger in responding to environmental regulations, policy instruments, compliance expectations, and regional collaboration requirements. This is consistent with the policy-intensive character of clean-technology development in China, where environmental regulations and national sustainability missions often provide direction for institutional innovation priorities.

Leadership commitment ranked second, with a composite mean of 2.70. This indicates that institutional leaders were perceived as supportive of environmental priorities and green innovation, particularly through formal systems such as policy alignment, capability-building, and stakeholder engagement. However, the lower item-level result on fostering a green organizational climate suggests that leadership support may be more visible in formal governance mechanisms than in everyday culture and voluntary pro-environmental behavior.

Environmental goals ranked lowest, with a composite mean of 2.69. Although still interpreted as Agree, this result suggests that environmental goals may not yet function as strong operational anchors for resource allocation, laboratory-level creativity, and day-to-day decision-making. This is important because strategic goals must be translated into budget priorities, laboratory practices, project indicators, and innovation targets to become fully effective.

#### 4.2 Level of Green Technology Research and Development

Green technology research and development was assessed in terms of program quality, technology development, and innovation implementation. As shown in Table 3, the overall composite mean was 2.69, interpreted as Moderate Level. This indicates that GT-R&D practices were present but still developing in terms of maturity, coherence, and implementation capacity.

**Table 3.** Level of Green Technology Research and Development

Dimension	Composite Mean	Verbal Interpretation	Rank
Program Quality	2.69	Moderate Level	2
Technology Development	2.71	Moderate Level	1
Innovation Implementation	2.68	Moderate Level	3
Overall Composite Mean	2.69	Moderate Level	

Technology development obtained the highest composite mean of 2.71. This suggests that the institution was perceived as relatively stronger in the technical and developmental aspects of GT-R&D, particularly in maintaining knowledge-management routines, aligning projects with clean-tech roadmaps, and specifying technology development targets. However, since the result remained at a moderate level, technology development efforts may still lack full standardization, scalability, and structured progression from proof-of-concept to pilot and demonstration stages.

Program quality ranked second, with a composite mean of 2.69. This indicates that green R&D activities were supported by some degree of investment planning, milestone-based funding, and impact tracking. However, the results also suggest weaknesses in prioritizing R&D investments based on institutional strengths and regional needs. This is a critical concern because green R&D programs are most effective when funding decisions are tied to institutional competencies, local industry demands, and clear implementation pathways.

Innovation implementation ranked lowest, with a composite mean of 2.68. This identifies implementation as the weakest area of GT-R&D. Although the institution appeared to recognize the importance of managing implementation as a designed and cross-functional process, lower ratings on permitting, safety, waste, reporting, and measurable deployment outputs suggest that developed technologies may face difficulty moving from research activity to sustained adoption. This finding is consistent with the common innovation-pipeline problem in which upstream development capacity is stronger than downstream implementation capacity.

### 4.3 Relationship Between Strategic Environmental Management and Green Technology Research and Development

Spearman's rho was used to test the relationship between SEM and GT-R&D. Table 4 shows that all correlations were positive, strong, and statistically significant at the .01 level, with p-values below .001. These results indicate that higher assessments of strategic environmental management were associated with higher levels of green technology research and development across all measured dimensions.

**Table 4.** Relationship Between Strategic Environmental Management and Green Technology Research and Development

SEM Dimension	GT-R&D Dimension	rho-value	p-value	Interpretation
Environmental Goals	Program Quality	0.931**	< .001	Highly Significant
Environmental Goals	Technology Development	0.966**	< .001	Highly Significant
Environmental Goals	Innovation Implementation	0.871**	< .001	Highly Significant
Leadership Commitment	Program Quality	0.951**	< .001	Highly Significant
Leadership Commitment	Technology Development	0.978**	< .001	Highly Significant
Leadership Commitment	Innovation Implementation	0.857**	< .001	Highly Significant
Regulatory Alignment	Program Quality	0.933**	< .001	Highly Significant
Regulatory Alignment	Technology Development	0.973**	< .001	Highly Significant
Regulatory Alignment	Innovation Implementation	0.858**	< .001	Highly Significant

Note. \*\*Correlation is significant at the 0.01 level.

The strongest relationship was observed between leadership commitment and technology development ( $\rho = 0.978$ ,  $p < .001$ ). This suggests that leadership support is closely associated with the technical progression of GT-R&D activities. In institutional settings, leadership commitment may influence technology development by shaping priorities, allocating resources, supporting interdisciplinary collaboration, and legitimizing long-term innovation work.

Regulatory alignment also showed a very strong relationship with technology development ( $\rho = 0.973$ ,  $p < .001$ ). This indicates that institutions that align research activities with environmental regulations, policy instruments, and national science and technology priorities tend to report stronger technology development. This finding is consistent with the idea that regulatory clarity can reduce uncertainty and guide cleaner technology design.

Environmental goals were also strongly associated with technology development ( $\rho = 0.966$ ,  $p < .001$ ), program quality ( $\rho = 0.931$ ,  $p < .001$ ), and innovation implementation ( $\rho = 0.871$ ,  $p < .001$ ). These results suggest that environmental goals provide strategic direction for the full GT-R&D process, from program planning to technical development and implementation.

It is important to interpret these findings as associations rather than causal effects. Since the study used a descriptive-correlational design, the results do not establish that SEM causes GT-R&D improvement. Rather, they show that stronger SEM dimensions are significantly and positively related to stronger GT-R&D dimensions.

### 4.4 Proposed Action Plan to Enhance Green Technology R&D

Based on the weakest areas identified in the results, the proposed action plan focuses on strengthening environmental goal internalization, laboratory-level innovation translation, green organizational climate, beyond-compliance project design, and alignment with national clean-tech missions. The action plan is retained in compact form because it directly responds to the fourth objective of the study.

**Table 5.** Proposed Action Plan to Enhance Green Technology R&D through Strategic Environmental Management

Key Result Area	Objective	Strategies	Target	Persons Responsible
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Key Result Area	Objective	Strategies	Target	Persons Responsible
Environmental targets guiding resource allocation and day-to-day decisions	Embed environmental targets into budgeting and operational decisions	Integrate environmental targets into annual R&D budgeting and procurement policies; introduce green budget tagging.	Environmental targets reflected in all R&D budget plans and annual operating plans.	College President; Finance Director; Research Director; Sustainability Office
Translation of green innovation strategy into laboratory-level innovation	Strengthen the link between institutional strategy and laboratory-level GT-R&D	Develop lab-specific GT-R&D roadmaps; create seed grants and awards for green prototypes and pilots.	All research laboratories adopt green innovation roadmaps within one academic year.	Vice President for Research; Laboratory Heads; Technology Transfer Office
Green organizational climate	Cultivate voluntary pro-environmental research behavior	Implement recognition programs; institutionalize green champions or sustainability stewards.	At least one green champion per department and annual recognition of green research efforts.	Human Resource Office; College Leadership; Department Chairs
Beyond-compliance GT-R&D design	Shift from minimum compliance to proactive environmental design	Adopt beyond-compliance design guidelines; conduct early environmental impact and lifecycle assessments.	All new GT-R&D projects assessed against enhanced environmental criteria.	Research Ethics Committee; Project Leaders; Environmental Compliance Officer
Alignment with national science and technology missions	Strengthen mission-oriented GT-R&D and access clean-tech programs	Map GT-R&D priorities against national and regional clean-tech roadmaps; require mission-alignment statements in proposals.	All GT-R&D proposals demonstrate alignment with national clean-tech missions.	Research Planning Office; External Relations Office; Project Proponents

#### 4.5 Discussion

The findings show that strategic environmental management was generally present, but its implementation remained moderate in depth. Regulatory alignment ranked highest among the SEM dimensions, suggesting that external policy and compliance pressures may be stronger drivers of institutional behavior than internally generated environmental goals. This pattern is consistent with the broader literature on China's green innovation environment, where environmental regulation, industrial policy, and national sustainability missions often shape institutional and organizational priorities (Ren & Chen, 2023; Wang et al., 2024; Xu, 2022). In this study, regulatory alignment appears to provide structure and direction for GT-R&D, particularly in relation to technology development.

Leadership commitment also emerged as an important SEM dimension. Its strong association with all GT-R&D dimensions, especially technology development, suggests that leadership may be central to translating environmental strategy into innovation activity. This supports prior literature indicating that green leadership contributes to environmental performance through capability-building, organizational climate, resource mobilization, and green innovation systems (Ledia et al., 2024; Liu & Yu, 2023). However, the item-level weakness related to green organizational climate indicates that formal leadership systems may not yet be fully translated into shared values, voluntary behavior, and laboratory-level innovation culture.

Environmental goals received the lowest SEM assessment, although still within the Agree range. This suggests that the institution has environmental goals, but these may not yet be deeply embedded into daily decisions, laboratory practices, and resource allocation. The implication is that goals may remain partly aspirational unless translated into

project-level indicators, budget priorities, technology roadmaps, and performance measures. This aligns with the literature emphasizing that environmental goals become strategically meaningful only when they are measurable, periodically reviewed, and linked to innovation systems (Isaacs et al., 2023; Alnaim et al., 2022).

For GT-R&D, technology development ranked highest, followed by program quality and innovation implementation. This pattern suggests that the institution may be more capable of generating or developing green technology ideas than of organizing these efforts into mature programs and implementing them at scale. The result reflects a common challenge in sustainability-oriented innovation: technical development may progress, but implementation may lag because of weak deployment systems, insufficient regulatory planning, limited field-testing partnerships, or inadequate adoption incentives. This is consistent with literature emphasizing that green innovation requires not only invention but also long-cycle implementation, stakeholder co-creation, and governance structures that support movement from prototype to deployment (Qin et al., 2026; Leal Filho et al., 2025).

The correlation findings strengthen the central argument of the study. All SEM dimensions were strongly and significantly associated with all GT-R&D dimensions. This indicates that environmental goals, leadership commitment, and regulatory alignment are not isolated institutional practices but are closely related to the quality, development, and implementation of green technology R&D. The strongest relationships were observed in technology development, suggesting that SEM may be particularly important in helping institutions organize, direct, and sustain the technical work of green innovation.

The study therefore contributes to the literature by showing how SEM and GT-R&D are linked in a vocational institution context. While prior studies have largely focused on firms, industries, and traditional universities, this study highlights the importance of vocational institutions as applied innovation actors in the clean-tech ecosystem. The findings suggest that vocational institutions can strengthen their clean-tech role by moving from compliance-oriented environmental management toward a more integrated model in which environmental goals, leadership systems, regulatory alignment, R&D investment, technology development, and implementation planning reinforce one another.

## **5. Conclusions, Recommendations, and Implications**

### **5.1 Conclusions**

The study concludes that strategic environmental management is implemented at an acceptable but still developing level within the vocational institution. Among its dimensions, regulatory alignment emerged as the strongest area, followed by leadership commitment and environmental goals. This suggests that the institution is more responsive to external policy and regulatory expectations than to the deeper internalization of environmental goals in everyday planning, budgeting, and laboratory-level innovation practices.

Green technology research and development is present at a moderate level. Technology development was assessed more strongly than program quality and innovation implementation, indicating that the institution has some capability in developing green technology initiatives but still faces limitations in strategic R&D investment, prioritization, implementation planning, and deployment. This suggests that the institution's green innovation capacity is still stronger at the development stage than at the implementation and scaling stage.

The findings further conclude that strategic environmental management and green technology research and development are strongly and significantly associated. Environmental goals, leadership commitment, and regulatory alignment were all positively related to program quality, technology development, and innovation implementation. However, because the study used a descriptive-correlational design, the relationship should be interpreted as association rather than causation.

Finally, the proposed action plan is justified by the findings because the weakest areas point to the need for stronger environmental goal internalization, leadership-supported green culture, beyond-compliance project design, and mission-oriented alignment of GT-R&D with national and regional clean-tech priorities.

### **5.2 Recommendations**

The College President, Sustainability Office, Planning Office, and Finance Office may strengthen the integration of environmental goals into annual operational plans, R&D budgeting, procurement systems, and laboratory performance indicators. This would help ensure that environmental goals are not only stated at the policy level but also embedded in daily institutional decision-making.

The Vice President for Research, Research and Development Office, Finance Office, and laboratory heads may improve the quality of GT-R&D programs by adopting milestone-based funding, green budget tagging, project-level technology roadmaps, and clearer prioritization criteria based on institutional strengths and regional clean-tech needs.

The institutional leadership may strengthen green organizational climate by developing recognition systems, green champions, sustainability stewards, and incentives for faculty, researchers, students, and laboratory personnel who contribute to green innovation. This recommendation responds to the finding that formal leadership commitment is present but must be translated more strongly into shared culture and voluntary pro-environmental behavior.

The Research Management Committee, Environmental Compliance Officer, and project leaders may adopt beyond-compliance design standards for GT-R&D projects. Environmental impact review, lifecycle assessment, safety planning, waste management, and reporting requirements should be integrated early in project proposal and implementation stages rather than treated as downstream compliance concerns.

The External Relations Office and Research Planning Office may strengthen partnerships with industry, government, and regional clean-tech actors. GT-R&D proposals should explicitly demonstrate alignment with national and regional clean-tech roadmaps to improve eligibility for funding, collaboration, field trials, and deployment opportunities.

Future researchers may conduct longitudinal, comparative, or mixed-method studies to examine how strategic environmental management practices influence green technology innovation over time and across different vocational institutions, regions, or industry-linked educational settings.

### 5.3 Implications of the Study

Theoretically, the study contributes to the literature by linking strategic environmental management and green technology research and development in the vocational education context. Much of the existing discussion focuses on corporations, industries, and traditional universities; this study extends the discussion to vocational institutions that are increasingly expected to support applied innovation and clean-tech development.

Institutionally, the findings imply that vocational colleges cannot rely on regulatory compliance alone. While regulatory alignment appears to be the strongest SEM dimension, deeper innovation capacity requires environmental goals to be embedded into budgeting, laboratory activity, research governance, and performance monitoring.

Managerially, the study suggests that leadership commitment must move beyond formal policy support. Leaders need to build green capabilities, create incentives, support cross-functional coordination, and cultivate a green organizational climate that encourages voluntary participation in sustainability-oriented research and implementation.

Practically, the findings point to innovation implementation as a key bottleneck. Vocational institutions may be able to develop green technology ideas and prototypes, but these efforts will have limited impact unless they are supported by implementation planning, field-testing partnerships, regulatory readiness, and measurable deployment outputs.

From a policy and clean-tech perspective, the study implies that vocational institutions can serve as important applied innovation partners in regional sustainability systems. Their contribution to the clean-tech industry will be stronger if institutional SEM practices are aligned with national missions, regional industry needs, and structured GT-R&D pathways.

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