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# From Symbolic to Systemic Sustainability in Higher Education: A Readiness-Gated Framework for Governance, Monitoring, and Institutional Change

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**Abstract**

Universities' sustainability commitments frequently outpace their systemic implementation. This paper addresses that gap by proposing the Sustainability Integration Framework (SIF), a mechanism-based, readiness-gated model for verifiable progression from symbolic adoption to institutionalized practice. Using a design science research approach, the study integrates institutional theory, resource-based theory, and responsible leadership to explain how external pressures, leadership interpretation, and internal capabilities shape sustainability integration. The framework is operationalized through a six-component institutional architecture, an Input–Process–Output logic model with auditable indicators, and a five-domain Readiness and Maturity Index (RMI). A six-stage mechanism—pressure, interpretation, resource reconfiguration, routinization, feedback closure, and coupling or decoupling—is supported by PDCA-gated progression, with Institutional Equity and data/AI Governance as cross-cutting levers. A dual-rater protocol, reliability thresholds, and an External Composite Readiness Index support transparent, comparable assessment across institutions. A single-rater demonstration at the American University of Beirut returns a domain profile of three defined domains (Leadership and Governance, Curriculum and Pedagogy, Operations) and two ad hoc domains (Strategy, Metrics and Data), summarized as an indicative RMI of 1.60 at the lower edge of the Intermediate stratum, indicating substantial external visibility alongside partial internal embedding. The contribution is a design proposal in the design science sense: an integrated theorized mechanism and an evidence-gated maturity model aligned with leading sustainability standards, intended to give administrators a replicable, audit-ready pathway for coordinating governance, curriculum, operations, and data systems once validated. The RMI and IPO tools remain conceptual artifacts. The demonstration establishes operability, with reliability, sensitivity, and generalizability reserved for a staged validation program comprising inter-rater reliability testing, a single-institution pilot, and multi-site and longitudinal testing.

**Keywords:** sustainability integration; higher education; sustainability governance; institutional theory; responsible leadership; resource-based theory; data/AI governance; environmental performance monitoring; maturity model

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## 1. Introduction

Over the past three decades, higher education institutions (HEI) around the world, have adopted the sustainability discourse. However, they continue to have trouble embedding this into their institutional practices [1]. Many HEIs reflect symbolic adoption of sustainability through measures that demonstrate legitimacy but are decoupled from governance and pedagogy [2,3]. This gap prevents HEIs from driving sustainable development [4].

HEIs are multi-level systems that reflect broader socio-technical transitions [5]. They rely heavily on frameworks such as STARS, UI GreenMetric, AISHE, ISO 14001 [6], and PRME [7]. Even though these tools enhance transparency and benchmarking, they largely emphasize what to measure rather than how to change [8,9]. Without a change mechanism or readiness logic, HEIs risk decoupled diffusion, which is an accumulation of sustainability labels and projects without structural or cultural embedding [10,11].

The paper addresses the gap by proposing a Sustainability Integration Framework (SIF). The SIF is a readiness gated, mechanism-based model that is meant to translate sustainability from symbolic compliance to systemic integration. It conceptualizes institutional transformation as a sequenced process which integrates institutional theory [3], resource-based theory [12] and responsible leadership [13]. As a group, the former explain why institutions respond to external pressures for legitimacy, how they reconfigure internal capabilities, and who exercises leadership agency to mobilize change.

Accordingly, the study asks: How can HEIs progress from symbolic to systemic sustainability through a readiness-gated, theorized mechanism that remains interoperable with existing frameworks?

This research employs a Design Science Research (DSR) methodology [14] in the construction of a SIF as a conceptual construct with support from two operational tools: the Readiness and Maturity Index (RMI) and the Input–Process–Output (IPO) model [15]; together, they enable sustainability to be integrated as a measurable and improvable system rather than an aspirational ideal.

The study is positioned within the broader sustainability–environment–technology nexus by showing how HEIs can connect institutional governance with environmental performance and digital monitoring systems. Rather than treating sustainability as a set of isolated commitments, the SIF links decision-making, curriculum reform, operational indicators, and data governance into a unified institutional architecture. This makes the framework relevant not only to higher education sustainability, but also to wider debates on sustainable management, evidence-based monitoring, and technology-enabled accountability.

This study extends ongoing debates on decoupling → recoupling by embedding leadership mediation and feedback governance within a readiness-gated mechanism. It reframes sustainability integration as a verifiable organizational process rather than an aspirational discourse. The paper is a design proposal in the design science sense: it contributes a theorized mechanism, a measurement architecture, and a demonstration of operability, and it specifies rather than reports the evaluation that would validate them (Sections 3–5, 7.4 and 9).

The contribution is delimited as follows. Theoretically, the paper extends the decoupling literature [10,16,17] by specifying the conditions under which policy–practice decoupling in HEI sustainability is expected to give way to coupling: leadership interpretation (P1), routinization (P2), legitimacy and equity feedback (P3), feedback closure (P4), and academic–operational linkage (P5). It integrates three literatures that have developed largely in parallel in higher-education research—institutional pressures and sustainability reporting [2,18,19], dynamic capabilities and the university's third mission [20,21], and sustainability leadership [22,23,24]—into one temporally ordered account. It challenges

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an assumption shared by existing assessment tools [11], namely that the dimensions of sustainability integration can be assessed as parallel and independent. The SIF treats them as sequence-dependent and makes readiness in upstream domains a condition for progression in downstream ones. The measurement architecture (RMI and IPO) is included because a readiness-gated claim is empty without a specification of what readiness is and how a gate is adjudicated. Its validation is not part of this paper. Operational detail is confined to Appendices A–H so that the main text carries the argument.

The paper proceeds as follows. Section 2 reviews existing frameworks and identifies the gaps. Section 3 sets out the three theoretical lenses, the six-stage mechanism, and the tensions among the lenses. Section 4 describes the six SIF components and the two cross-cutting levers. Section 5 derives five propositions, covering interpretation through coupling, each with its theoretical basis. Sections 6 and 7 specify the measurement architecture (IPO and RMI), map the components to the measurement domains (Table 1), and report the single-institution demonstration. Sections 8 and 9 address interoperability and the staged validation design (Section 9.2). Sections 10–12 discuss implications, limitations, and conclusions.

**Table 1.** Correspondence between the six SIF components and the five RMI domains, with elements assessed outside the RMI mean.

| SIF Component | RMI Domain Scored | Also Reflected in (RMI) | Assessed Outside the RMI Mean |
|---|---|---|---|
| Strategic Leadership and Governance Alignment (SLGA) | Leadership and Governance | Strategy (planning, resource allocation) | — |
| Curriculum and Pedagogical Innovation (CPI) | Curriculum and Pedagogy | — | — |
| Research and Knowledge Mobilization (RKM) | — (no dedicated domain) | Strategy; Metrics and Data (enabling conditions) | IPO process and output indicators: RKM-PROC1/2, RKM-OUT1/2 (Appendix D) |
| Institutional Policies and Accountability Mechanisms (IPAM) | Metrics and Data | Strategy (policy instruments); Leadership and Governance (governance routines, SLGA/IPAM-PROC1) | — |
| Stakeholder Engagement and Social Responsibility (SESR) | — (not scored) | Leadership and Governance; Strategy (internal participation structures, dual-coded) | SESR Gate Index (SGI) = mean of SESR-OUT1 and SESR-OUT2, 0–1 scale; progression gate only (Section 7.2) |
| Operational Sustainability and Resource Management (OSRM) | Operations | — | — |
| Cross-cutting levers: Institutional Equity; Data/AI Governance | — (threshold conditions, Section 4.2) | Data/AI Governance indicators sit within Metrics and Data | Equity outcomes via IPO indicators EQ-OUT1/2 (Appendix D) |

*Note.* Each domain score is the mean of its indicators (Appendix D). The overall RMI is the mean of the five domain scores. The SGI and the IPO-only indicators are reported alongside the RMI and are excluded from the mean. Theoretical anchors and IPO constructs for each component are given in Appendix F.

## 2. Systems-Oriented Literature Review and Gap

### *2.1. Existing HEI Sustainability Frameworks: Breadth Without Mechanism*

In this section, we review the scope, strengths, and gaps of major HEI sustainability frameworks and their comparative coverage. HEIs lean on these frameworks to structure and signal sustainability performance [18,25]. STARS enhances comparability across academics, engagement, operations, and administration, but often rewards documentation more than capability development [19,26]. UI GreenMetric supplies global environmental indicators with limited coverage of governance and pedagogy [27,28]. AISHE offers a staged self-assessment (five levels) yet lacks evidence-gated, PDCA-linked progression from policy to embedded practice [11,29]. ISO 14001 embeds auditable PDCA routines but focuses on operational compliance [6,30]. PRME introduces an ethics/transparency lens but is normative and non-sequential [31,32]; see Appendix A (Table A1). Across frameworks, three limitations persist: (i) emphasis on compliance evidence over capability building; (ii) weak interoperability; and (iii) no mechanism linking adoption to embedded practice [33]. SIF integrates their strengths—STARS' transparency, UI GreenMetric's benchmarking, AISHE's staging, ISO 14001's continuous improvement, and PRME's ethics—and supplies the missing readiness-gated, theorized sequencing. Section 7.2 sets out how the SIF's evidence gates differ from the documentation-based credits criticized here.

### *2.2. Barriers and Enablers Identified in Prior Reviews*

Syntheses of higher-education sustainability research, including recent systematic reviews [11,34,35], consistently identify persistent barriers that impede the shift from symbolic to substantive practice. Fragmented governance and curricular inertia remain the core obstacles. HEI sustainability often stalls when mandates sit in mid-level units without authority or budgets while disciplinary silos block cross faculty work [1,36,37]. Resource scarcity, short funding cycles, and entrenched norms all negatively affect accountability [38]. The literature identifies enabling conditions: visible senior commitment, participatory governance, transparent metrics, and collaboration. These levers are most effective when implemented in a specific sequence: first, leadership and accountability, then data and governance systems, and finally pedagogical reform [25,34]. Current frameworks rarely encode this readiness logic, treating dimensions as parallel rather than interdependent [11].

### *2.3. Corporate and Continuous-Improvement Analogues*

Corporate sustainability and quality systems offer staged capability analogues. CMMI's levels and ISO's PDCA cycle institutionalize feedback and governance that lock learning before scale [39,40,41]. For HEIs, progress should be readiness gated and evidence based, verified by leadership commitment, data maturity, and integration capacity. Most current frameworks do not enforce this logic.

### *2.4. Gap Statement and Research Need*

Despite numerous sustainability frameworks, HEIs remain fragmented in translating sustainability goals into systemic practice. Four interdependent gaps persist. (1) Existing tools describe states, governance, operations, and curriculum, without specifying the change pathways linking external pressures, leadership interpretation, and capability reconfiguration, leaving transitions anecdotal and non-replicable [42]. (2) Readiness gates and maturity logic are absent. While AISHE and ISO 14001 offer staged structures, they lack validated progression criteria [43]. (3) Reporting systems rarely employ data or AI-supported analytics. Nor do they disaggregate indicators by equity dimensions, constraining continuous learning [44]. (4) Divergent metrics and ontologies undermine

comparability and meta-analysis [45]. To address these gaps, this study proposes the Sustainability Integration Framework (SIF) and its RMI, a standards-agnostic, mechanism-based architecture enabling sequenced, auditable transformation across diverse institutional contexts.

## 3. Theoretical Foundations and Meta-Framework

Sustainability Integration in HEIs unfolds the interacting mechanisms of institutional pressure, capability development, and leadership agency. The SIF draws on three theoretical pillars that complement each other: Institutional Theory (IT), Resource-Based Theory (RBT) and Responsible Leadership (RL). Each of them explains how each of the symbolic commitments leads to systemic transformation. Their integration supports a temporally ordered meta-framework that provides the basis for the theorized mechanism of SIF [46].

### *3.1. Institutional Theory: Legitimacy and Decoupling*

IT supplies an external perspective on how HEIs respond to coercive, normative, and mimetic pressures from governments, accrediting agencies, and peers [3], which can contribute to diffusion and lead to decoupling of formal commitments and enacted practices [10]. Decoupling in this sense has two forms that the SIF treats differently: policy–practice decoupling, in which adopted commitments are not implemented, and means–ends decoupling, in which practices are implemented but disconnected from outcomes [16,17]. The evidence gates discussed in Section 7.2 are designed to detect the first, and the outcome indicators of Appendix D the second. HEIs may establish sustainability policies and/or certifications to enhance their reputation while failing to embed sustainability into their governance or curricula. Within the SIF, IT explains the trigger phase of transformation, where external expectations stimulate internal responses that may be initially symbolic yet create opportunities for transformative change.

### *3.2. Resource-Based Theory: Dynamic Capabilities*

RBT offers the internal logic of transformation as it explains how organizations convert resources into dynamic capabilities that maintain long-term performance. Resources in HEIs include leadership commitment, expertise of personnel, stakeholder networks, and digital data systems. The capacity to integrate, build, and reconfigure resources in response to changing environments is the defining feature of a dynamic capability [21], and in universities it has been shown to underpin the third mission [20]. Transformation takes place as these tangible and intangible resources are mobilized, recombined, and routinized to create adaptive capabilities which refer to organizational capacity to sense, seize, and reconfigure assets [47].

Within the SIF, RBT anchors the process phase that outlines the mechanisms by which universities convert their strategic intent to actual practices such as carbon accounting, sustainability literacy audits, and cross faculty cooperation. These routines form the micro-foundations of the RMI with higher maturity representing progressively institutionalized behaviors. However, RBT alone does not explain who orchestrates and integrates these transformations across boundaries, which necessitates a leadership-centric lens.

### *3.3. Responsible Leadership: Agency and Boundary Spanning*

Responsible Leadership (RL) bridges external legitimacy with internal capability by introducing agency and moral orientation [13]. RL interprets institutional pressures through ethical reasoning, linking sustainability outcomes to organizational identity and stakeholder expectations.

Responsible leaders act as boundary spanners connecting internal actors (faculty, administration, students) with external actors (community, government, industry) [48]. Their sense-making transforms coercive pressures into voluntary, value-driven commitment, a determining factor to whether sustainability remains symbolic or becomes systemic; RL is theorized as the mediator in this chain at the IT–RBT interface [49].

### *3.4. Integrated Temporal Mechanism and Micro-Foundations*

The IT–RBT–RL triad is presented as a temporally ordered, multi-level mechanism linking external legitimacy pressures, leadership sense-making, and internal capability transformation. The mechanism unfolds through six stages that trace the full arc from initial pressure to systemic embedding.

- **Pressure (External Pressures)**—External legitimacy pressures (coercive, normative, and mimetic) initiate institutional responses. Regulatory mandates, accreditation requirements, ranking systems, and peer imitation generate exogenous forces that push HEIs toward sustainability alignment, though initial responses are frequently symbolic [50].
- **Interpretation (Leadership Mediation)**—Responsible leaders interpret and translate these pressures into coherent strategies that align sustainability goals with institutional values and stakeholder expectations. This sense-making converts compliance pressure into values-based commitment and determines the scope that subsequent stages can achieve [22].
- **Reconfiguration (Internal Capabilities)**: HEIs mobilize and reconfigure knowledge, partnerships, and systems, through RBT, to integrate sustainability across governance, curriculum, and operations, shifting from symbolic compliance to systemic integration [46].
- **Routinization.** Governance and measurement systems move from ad-hoc initiatives to standardized organizational routines, following the sequence of habitualization, objectification, and sedimentation through which practices become taken for granted [51]. Routines are the carriers of both stability and change [52]. Sustainability KPIs, audit protocols, and reporting cycles become embedded in institutional practice, reinforcing the connection between resource reconfiguration and desired outcomes [53]**.**
- **Feedback Closure** processes generate corrective action and institutional learning. PDCA cycles ensure that monitoring data drives adjustments to governance, curriculum, and operations, preventing premature scaling and sustaining progress over time**.**
- **Coupling/Decoupling.** At this stage, sustainability either becomes structurally integrated across academic and operational subsystems through shared metrics, coordinated governance, and joint routines, or it remains fragmented and symbolically adopted. Successful coupling increases external legitimacy and internal trust through stakeholder engagement and transparent reporting, producing a self-reinforcing maturity trajectory along the RMI continuum [54]. Where coupling fails, formal commitments persist while core processes remain unchanged—a condition of institutional decoupling [10].

This integrated system connects macro-level legitimacy pressures (IT), meso-level resource dynamics (RBT), and micro-level leadership agency (RL), positioning sustainability integration as a readiness-gated process. The six-stage sequence provides the theoretical scaffolding for the theorized mechanism detailed in Section 5 and the empirical operationalization in Sections 6 and 7. Its temporally ordered structure produces propositions that can be empirically assessed through the RMI and IPO instruments.

### *3.5. Tensions Between the Three Lenses and Their Design Implications*

The sequence in Section 3.4 indicates which logic is most salient at each stage, not that the others are inactive, and the three lenses do not sit together without friction. Institutional Theory's legitimacy-seeking logic rewards visible conformity, which can be satisfied by adopting policies, labels, and reports without implementing them. Resource-Based Theory's capability-building logic rewards internal routines that are costly, slow to develop, and often invisible to external audiences. Decoupling arises precisely where the first logic can be satisfied at lower cost than the second [10]. Responsible Leadership is positioned as the mediating lens not because it dissolves this tension but because leaders decide, under resource constraints, which logic to serve, choosing among strategic responses to institutional pressure that range from acquiescence to manipulation [55]. Where legitimacy is prioritized, the mechanism predicts symbolic adoption and, at Stage 6, decoupling. Where capability is prioritized, it predicts systemic integration. A second tension runs between isomorphism and idiosyncrasy. Institutional pressures and the external standards that carry them push institutions toward homogeneous forms, whereas capabilities in the resource-based view are path-dependent and institution-specific. The SIF accommodates this by holding the mechanism, the PDCA logic, and the evidence gates invariant while leaving indicator selection, pacing, and data granularity adaptive (Section 10, "Contextual and Equity Dimensions"). The separation of the SGI from the RMI (Section 7.1) is the measurement expression of the first tension: external legitimacy is recorded, but it is not allowed to stand in for internal capability.

## 4. Conceptual Framework: The Sustainability Integration Framework (SIF)

The SIF offers a mechanism-based, readiness-gated architecture that transforms sustainability commitment in HEIs from symbolic compliance into systemic integration. The SIF combines Institutional Theory (IT) with Resource-Based Theory (RBT), and Responsible Leadership (RL) to provide a framework that bridges descriptive and design-oriented perspectives to support evidence-based transformation across different dimensions such as governance, teaching, research, operations, and stakeholder engagement.

Within this model, institutional change emerges through interdependent subsystems that coevolve and therefore cannot be viewed as independent initiatives [56].

These subsystems are designed to be standard-agnostic yet interoperable. Each has its own purpose, yet they reinforce others via a set of structured feedback loops. The SIF aligns with frameworks such as AASHE STARS, PRME, AISHE, ISO 14001, UI GreenMetric, ensuring comparability (Appendix A). Institutional Equity and Data/AI Governance are two cross-cutting levers that support this model to ensure that progress is fair and evidence-based when applied to all institutions, regardless of type or geography.

### *4.1. Core Components of the SIF*

The SIF comprises six interconnected components, each addressing a distinct cluster of challenges rooted in one or more of its theoretical foundations. Their correspondence with the five RMI measurement domains is set out in Table 1 and discussed in Section 7.1.

1. **Strategic Leadership and Governance Alignment (SLGA)**: The SLGA is the SIF's control center. It translates the vision of the institution into policy and decision-making. Informed by Responsible Leadership Theory, it tackles sustainability as a strategic and governance priority where it aligns organizational mission, structures, and accountability mechanisms with societal and environmental priorities. These mechanisms include formal sustainability boards, executive mandates with sustainability KPIs, and performance-linked evaluations [57].

2. **Curriculum and Pedagogical Innovation (CPI)**: CPI establishes a connection between education and sustainability and utilizes experiential and competency-based methods in the classroom (Education for Sustainable Development) to support student learning (CPI is essentially an application of ESD to both curriculum and pedagogy). CPI addresses the rigidity of traditional curricula and the disciplinary siloed nature of the curriculum through supporting faculty development and designing inter-disciplinary courses [58,59] such that sustainability is established as the "norm" in pedagogy, which includes both systems' thinking and adaptive learning.
3. **Research and Knowledge Mobilization (RKM):** RKM bridges the research–practice gap to ensure a tangible societal impact. Drawing on Resource-Based Theory, it connects academic research with policy and practice, expanding the role of higher education institutions (HEIs) from centers of knowledge creation to hubs of sustainable innovation. RKM enhances institutional capability by encouraging cross-disciplinary collaboration, industry partnerships, and diversified funding [60].
4. **Institutional Policies and Accountability Mechanisms (IPAM):** IPAM uses continuous feedback and verification mechanisms to transform sustainability commitments into measurable results, building on PDCA cycles and ISO 14001. It provides a framework for governance and data infrastructure to facilitate transparency in measuring organizational performance. IPAM utilizes KPIs for sustainability, audit protocols, and progress in alignment with institutional theory's concepts of legitimacy and accountability [61,62].
5. **Stakeholder Engagement and Social Responsibility (SESR)**: Grounded in Responsible Leadership, SESR promotes inclusive participation among all internal and external stakeholders (students, faculty members, community members and industry partners). It fosters trust, co-creates knowledge, and aligns academic activities and initiatives with societal priorities and the UN SDGs [63,64]. This makes SESR the basis for the social legitimacy and public accountability of HEIs.
6. **Operational Sustainability and Resource Management (OSRM)**: HEIs use the OSRM based on Resource Based Theory (RBT) for the integration of sustainable practices in everyday activities such as resource consumption; energy; water; procurement; waste; and carbon footprint management. The OSRM enables HEIs to have a structured process for achieving operational efficiency and environmental performance based on the improvement cycles that are defined within ISO 14001 and CMMI [65] principles. The OSRM allows for sustainability to be executed through tangible and auditable processes. See Appendix B, Table A2 for the crosswalk to external frameworks.

### *4.2. Cross-Cutting Levers*

Two cross-cutting levers make SIF executable. Institutional equity is operationalized as capacity parity across faculties, campuses, and regions, with explicit thresholds that must be met before progression, for example minimum budget per student for sustainability initiatives, facility readiness scores, faculty release time for ESD, and access to core data systems. The focus is on correcting structural gaps and replicating effective practices across institutional archetypes, particularly where Global North and Global South disparities persist [66]. Data and AI Governance provide the metrics that confirm the gate movement through each stage of the SIF. A standardized data pipeline and AI analytics provide measurable standards to verify whether there are adequate readiness criteria to measure completeness, quality, and improvement [67], thereby integrating PDCA cycles into routine decision making. Together, the levers create uniform entry requirements for all six SIF components by providing compliance tracking and triggering corrective action should a unit fail to meet the requirements. The levers also establish minimum thresholds for

progression along the RMI, ensuring that capability equity and data readiness are prerequisites for advancement. Thus, Data/AI Governance functions as the technological infrastructure of the SIF, enabling sustainability data to be collected, validated, compared, and translated into corrective action across governance, curriculum, and operations.

The Data/AI Governance lever rests on an assumption that should be stated and bounded: that digital monitoring improves sustainability performance by shortening the loop between measurement and decision. The evidence for this is conditional rather than general. Firm-level work on digital technology adoption and corporate carbon performance asks whether adoption helps or undermines carbon outcomes and treats the answer as contingent on how the technology is coupled to operations, with opportunities and paradoxes coexisting [68]. An analysis of how a shift from growth-oriented to sustainability-oriented development goals reshapes urban land supply shows that a declared change in goals is carried into allocation practice only through the instruments that implement it [69]. Both bear on the symbolic-to-systemic claim: A dashboard is as symbolic as a policy if it is not connected to decision rights. The SIF therefore scores the lever on data completeness, quality, and use in corrective action (Appendix D), not on technology adoption as such, and it anticipates three failure modes: data systems acquired without the governance to act on them, data quality below the gate thresholds, and unequal access to data infrastructure across units, which is why the lever is paired with the equity lever and why progression requires documented closure rather than the existence of a reporting system [67].

### *4.3. Adaptation and Contextualization*

The SIF has been designed to be adaptable to different governance structures, resource levels, and institutional scale. For example, public HEIs tend to emphasize compliance, accountability, and policy alignment, whereas private HEIs often leverage organizational agility to pursue innovation and cross-sector collaborations that advance sustainable development (OSRM, RKM, IPAM, SESR). The SIF also adapts to resource constrained environments, especially those found in the Global South, by first establishing an infrastructure for data and building capacity before deploying the full SIF system. Additionally, the SIF's adaptability to the scale of institutions allows for small or specialized HEIs to develop "modular" paths that start with specific initiatives (CPI, SESR) and build toward being a fully functional system of sustainability over time as they become more prepared to do so. Thus, the SIF provides a flexible and evidence-based architecture to support institutions in developing their own sustainability integration that is appropriate to their unique context.

## 5. Theorized Mechanism and Propositions

The SIF, as an institutional mechanism, can guide HEIs to transition from symbolic to systemic sustainability through a path-dependent process which involves six sequential stages: pressures, leadership interpretation, resource reconfiguration, governance routines, and feedback closure and coupling (Figure 1).

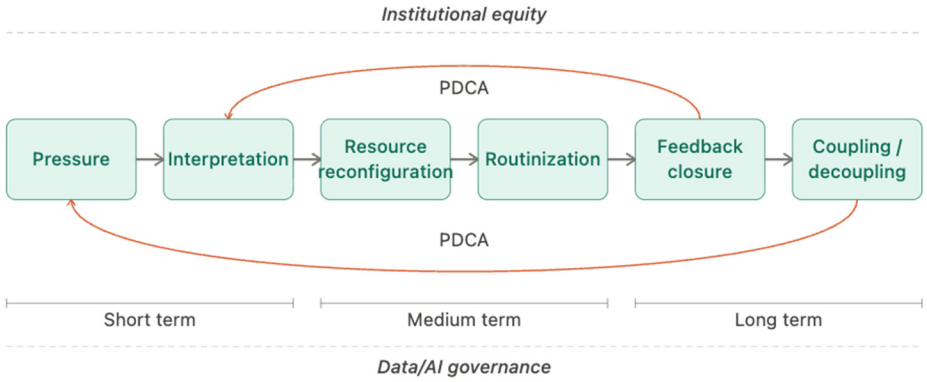



**Figure 1.** Theorized pathway: transition from symbolic to systemic integration.

### *5.1. Mechanistic Pathway: From Pressure to Coupling*

**Stage 1—Pressure:** The initial stages of sustainability integration are triggered by normative, coercive, and mimetic pressures from accreditation bodies, rankings, policies, and peers. Even though these exogenous forces push HEIs to align with sustainability norms, early responses are often symbolic and focused on rhetoric and reporting instead of transformation [56].

**Stage 2—Interpretation:** Responsible leadership uses ethical/strategic sense-making to align sustainability with mission and identity, thus switching compliance pressure into values-based commitment [23,70].

**Stage 3—Resource Reconfiguration:** At this stage, HEIs will start to reorganize both their tangible and intangible resources to provide an environment for adaptive capabilities to be developed among cross-faculty teams to establish effective data systems, enhance sustainability literacy, and ultimately to foster long-term institutionalization [20].

**Stage 4—Routinization:** This is when governance and measurement systems move from being ad hoc initiatives to becoming standardized organizational routines that institutionalize sustainability and therefore reinforce the connection between the reconfiguration of resources at Stage 3 and the desired outcomes [53].

**Stage 5—Feedback Closure:** Finally, legitimacy feedback occurs at Stage 5 to allow HEIs to increase external legitimacy and internal trust through stakeholder engagement and transparent reporting. Universities also strengthen their institutional credibility, maintain leadership, and secure funding by developing partnerships and practicing responsible disclosure [54]. In addition, feedback loops and PDCA cycles ensure the progress is sustained so that the institutional learning continues and premature scaling does not occur [71,72].

**Stage 6—Coupling/Decoupling**: Coupling is when sustainability becomes part of all aspects of an institution, including teaching, research, and operations, indicating a deep structural embedding. The redesign of curricula (CPI) and the transformation of operations (OSRM) represent higher levels of readiness and maturity within the RMI [73].

### *5.2. Testable Propositions*

The theorized mechanism recasts transition theory as a leadership-mediated model of institutional change [71,72].

The SIF has testable propositions that connect the three theoretical elements of the SIF (institutional pressures, responsible leadership, and routinization) to observable outcomes within HEIs. The following propositions are presented as theoretically derived and empirically testable rather than as established findings. Each specifies a relationship grounded in the mechanism above, with operational indicators and tests set out in Appendix C (Table A3) and the validation design in Section 9. The basis for each proposition

in the institutional, organizational-change, and higher-education leadership literatures is stated beneath it. The five propositions are the minimum set that covers the mechanism, one per stage from interpretation to coupling.

**Proposition 1 (P1)** (Mediation)**.** *Sustainability pressures drive organizational change only when leaders interpret them and translate them into aligned governance arrangements and resource commitments.*

Basis: P1 rests on the strategic-response tradition in institutional theory, which holds that organizations do not respond to pressure uniformly but through acquiescence, compromise, avoidance, defiance, or manipulation, depending on how leaders read the pressure and on their dependence on its source [55]. The higher-education change literature finds that mandates succeed only when they are translated through sense-making at several organizational levels [24]. The sustainability-leadership evidence indicates that leadership interpretation is the proximate determinant of whether commitments are enacted [22,23]. Another finding states that sustainability policy mediates the relation between leadership and practice in HEIs [74]. The mediation form follows: Pressure is necessary but not sufficient, and the interpretation stage determines the type of response.

**Proposition 2 (P2)** (Moderation)**.** *Sustainability moves beyond symbolic commitment when it becomes embedded in monitoring systems, accountability structures, and everyday routines.*

Basis: P2 rests on the distinction between policy–practice and means–ends decoupling [17] and on the account of institutionalization as habitualization, objectification, and sedimentation [51], in which routines carry both stability and change [52]. In higher education, the absence of monitoring and accountability structures is the most consistently reported barrier between commitment and practice [1,36,37]. Data-driven governance has been shown to be the mechanism by which commitments become routine [53]. The moderation form follows: Reconfigured resources produce outcomes to the extent that routines connect them to accountability.

**Proposition 3 (P3)** (Direct/moderating effect)**.** *Equity, inclusion, and legitimacy shape the durability of sustainability integration by influencing trust, participation, and institutional accountability.*

Basis: P3 rests on the legitimacy foundations of institutional theory, in which conformity secures resources and support [3,16]; on the whole-institution literature, which finds that participation and perceived fairness across units sustain engagement [36,46,56]; and on the evidence that uneven resourcing across faculties and regions reproduces symbolic adoption in under-resourced units [66]. The direct and moderating form follows: Equity and legitimacy both contribute to durability and condition the effect of the other stages.

**Proposition 4 (P4)** (Longitudinal feedback effect)**.** *Progress toward systemic integration depends on feedback processes that trigger corrective action and support institutional learning.*

Basis: P4 is the continuous-improvement proposition. PDCA logic [15] and maturity-model staging [39] hold that capability consolidates through repeated cycles of measurement and corrective action, and the evidence on sustaining improvement programs shows that programs without closed feedback decay [75]. In the transitions literature, learning cycles are what distinguish managed transitions from drift [71,72]. The longitudinal form follows: The effect is cumulative and cannot be observed cross-sectionally.

**Proposition 5 (P5)** (Interaction effect)**.** *Systemic integration emerges when academic and operational domains are structurally linked through shared metrics, aligned governance, and coordinated routines.*

Basis: P5 rests on the following arguments: radical organizational change requires reconnecting interpretive schemes with structures across subsystems rather than within one [76]; the dynamic-capabilities view that integration across functions is itself a capability [21]; academic and operational cultures must be reconciled for whole-institution sustainability governance [77]; and living-lab arrangements are where that reconciliation has been observed [54]. The interaction form follows: Academic and operational integration are jointly, not additively, predictive.

Together, the five propositions give HEIs and policymakers an auditable route for aligning funding and accreditation with verified systemic integration. The statements above are canonical. Table A3 (Appendix C) reproduces them verbatim and adds, for each, the relationship type, the constructs involved, and the operational expectation to be tested. Appendix G maps each to the indicator dictionary of Appendix D.

## 6. The Input–Process–Output (IPO) Logic Model

The IPO model comprises three distinct phases—inputs, processes, and outputs—each described by a set of measurable criteria that support continuous improvement, performance evaluation, and replication. An overview of the model is shown in Figure 2, and the constructs are detailed in Appendix D (Table A4).

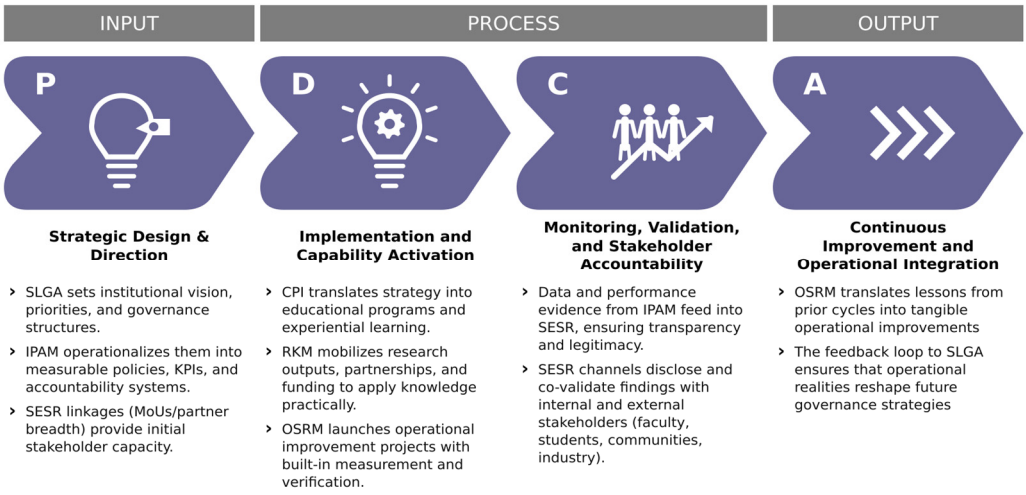



**Figure 2.** Input–Process–Output (IPO) logic model. **P = Plan; D = Do; C = Check; A = Act.**

### *6.1. Inputs: Leadership Commitments, Policies, and Resources*

Inputs represent the institutional conditions and capacity for sustainability integration. They are generally represented by the SLGA, IPAM, and SESR components of the SIF (Appendix D, Table A5).

### *6.2. Processes: Governance Routines, Curriculum Redesign, Research Mobilization, and Operations*

Processes correspond to the "Do" and "Check" phases of the PDCA cycle, transforming institutional inputs into structured actions. They primarily reflect the SLGA, CPI, RKM, OSRM, and IPAM components of the SIF (Appendix D, Table A6).

### *6.3. Outputs and Outcomes*

Outputs represent the "Act" stage of the PDCA cycle and capture measurable improvements in performance and/or value creation for each of the CPI, RKM, SESR, and OSRM components of the SIF. (Indicators and detailed definitions are provided in Appendix D (Table A7).) Internal SESR structures (e.g., participation councils, partnership MoUs) are dual coded within the RMI's Leadership and Strategy domains and in the IPO's process indicators, ensuring traceable continuity from institutional readiness to societal engagement outcomes.

### *6.4. SESR Gate Index (SGI) and Feedback into the RMI*

To preserve visibility while keeping SESR outside the RMI scoring, SESR outputs are summarized as a single SESR Gate Index (SGI) and used solely as a progression threshold (Section 7.2). In subsequent cycles, IPO outputs, particularly SESR and operational metrics, feed back into the Leadership and Strategy domains of the RMI, ensuring that performance evidence translates into structural learning and capability recalibration (Appendix F; Appendix E.5).

## 7. Readiness and Maturity Index (RMI)

The RMI operationalizes the SIF by translating qualitative institutional change into measurable, evidence-based progression. It operates as a diagnostic and benchmarking tool to evaluate how HEIs move from symbolic to systemic sustainability integration. The RMI has its roots in the Capability Maturity Model Integration [39] and the concept of continuous improvement described in [15]. It offers a structured and auditable path for institutional advancement. Although the term "Readiness and Maturity Index" may appear occasionally in other domains, to our knowledge the concept of a Readiness and Maturity Index has never been theorized or operationalized in the context of higher education and sustainability development. Prior uses include the Smart and Sustainable Supply Chain Readiness and Maturity Model (S3RM) by Demir et al. [78] in industrial contexts, Petit et al.'s, [79] Resilience Measurement Index for infrastructure systems, and Anderson and Felici's [80] Requirements Maturity Index in software engineering. These models, while methodologically valuable, remain sector-bound and lack theoretical integration across institutional change dimensions. The present study introduces the RMI as a novel construct that synthesizes institutional theory, responsible leadership, and resource-based perspectives to quantify sustainability integration through five interdependent domains, leadership and governance, strategy, curriculum and pedagogy, metrics and data, and operations, supported by PDCA-linked gating, evidence anchoring, and quantitative reliability validation.

### *7.1. Domains*

The RMI provides the quantitative architecture through which the theorized mechanism in Section 5 can be empirically tested. It is organized into five interdependent domains reflecting the systemic architecture of HEIs: Leadership and Governance (executive commitment, accountability, mission alignment) [81,82]; Strategy (planning, resource allocation, policy instruments) [83,84]; Curriculum and Pedagogy (sustainability competencies, interdisciplinary provision, experiential learning) [85]; Metrics and Data (indicator quality, data-governance routines, analytics) [86]; and Operations (infrastructure, procurement, resource management) [65].

Each domain is assessed via multiple indicators (Appendix D, Tables A4–A7; Appendix F), scored on a 0–4 scale. The domain score is the mean of its indicators, and it feeds the overall RMI (see Section 7.3 for scoring mechanics). While the SIF comprises six

components, the RMI intentionally operationalizes only these five internal domains. The remaining component, Stakeholder Engagement and Social Responsibility (SESR), functions as an external bridging mechanism rather than a scored domain. SESR outcomes are captured via the IPO model's outputs (see Section 6) and summarized as SGI on a 0–1 scale. SGI is reported alongside the RMI and used only as a progression gate (see Section 7.2). Internal participation elements relevant to SESR (e.g., faculty/student engagement) are represented within the Leadership and Governance and Strategy domains to maintain continuity between readiness and impact. A one-line crosswalk linking propositions P1–P5 to specific IPO/RMI indicators is provided in Appendix G.

Table 1 makes the correspondence between the six SIF components and the five RMI domains explicit. The SIF describes the institutional architecture that must change. The RMI measures how far that change has been embedded in systems the institution controls internally. Four components map directly onto a scored domain: SLGA onto Leadership and Governance, CPI onto Curriculum and Pedagogy, IPAM onto Metrics and Data, and OSRM onto Operations. The Strategy domain has no single-component owner. It scores the planning, resource-allocation, and policy instruments through which SLGA and IPAM commitments are given effect, and it is also where the internal participation structures of SESR and the resourcing of RKM are read. Two elements are deliberately assessed outside the RMI mean. RKM has no dedicated domain. Its enabling conditions are read within Strategy and Metrics and Data, while its mobilization activity and impact are tracked through the IPO process and output indicators (RKM-PROC1/2; RKM-OUT1/2, Appendix D). SESR is summarized as the SGI and applied as a progression gate rather than scored as a domain, because stakeholder engagement and legitimacy are the external outcomes of the mechanism (Stages 5–6, Section 5) rather than internal readiness conditions. Including them in the readiness mean would allow external visibility to inflate internal maturity, which is precisely the symbolic–systemic confound the framework is designed to expose. The full alignment, including theoretical anchors and IPO constructs, is given in Appendix F.

### *7.2. Scoring Levels and PDCA-Linked Gate Rules*

Multiple indicators are used to evaluate each of the domains using a 0–4 scale. These domain scores are then averaged to provide an overall Maturity Rating. The use of gradations for tracking progress and identifying gaps aligns with the best practice in maturity modeling, and each score will be tied to the PDCA Cycle to ensure continuous improvement [75,86].

At Level 0 (Absent), there is no evidence that the organization has formally engaged in sustainability (pre-plan); Level 1 (Ad Hoc), corresponds to isolated pilot activities and informal practices reflecting an early "Do" stage; Level 2 (Defined), represents formalized policies/processes with some initial/limited data validation aligning with the Check stage; Level 3 (Managed) signifies a systematic implementation with measurable results and recorded corrective actions, thus corresponding to the Act stage; Level 4 (Optimized) denotes a fully institutionalized state where continuous improvement is embedded into governance and the feedback loop is consistently closed. Progression between levels is gated, meaning advancement requires verifiable documentation of closed PDCA loops, such as audit findings, review minutes, or corrective-action records. This mechanism prevents premature scaling and safeguards audit integrity, ensuring that sustainability maturity is substantiated by evidence rather than rhetoric. Domains cannot skip levels. Progression is adjudicated at most once per 12 months.

SESR Gate (SGI): An organization needs to achieve a minimum SGI score of 0.60 to reach Level ≥3; a minimum SGI of 0.75 to reach Level 4.

The two SGI thresholds were established with input from experts who have experience with sustainability management systems and will be validated through empirical research during pilot studies. See Appendix D (Table A7) for further details.

Evidence gates versus documentation-based compliance: The gates above require documentation, and Section 2.1 criticizes STARS for rewarding documentation; the two are not the same test. STARS-type credits score the existence of a policy, plan, or report. The SIF gates score evidence that a loop has closed: a finding, the corrective action assigned to it, and verified closure within a defined service level (PDCA close-rate, IPAM-PROC1; M and V compliance, OSRM-PROC2). A document that records a commitment satisfies the first. Only a document that records a changed routine satisfies the second. Three further features limit the scope for satisfying the gates symbolically. Progression cannot skip levels and is adjudicated at most once every 12 months, so documentation cannot substitute for time in practice. The gate to Levels 3 and 4 also depends on the SGI, an outcome measure computed from engagement coverage and public transparency rather than from internal paperwork. Unverifiable evidence scores 0 under dual-rater adjudication (Section 7.3). We do not claim that this removes the risk. Any evidence-based system can be worked to the letter, and a corrective-action register can be populated without the underlying practice changing. The gates are a necessary rather than a sufficient defense against decoupling. The sufficient test is whether documented closures are followed by movement in the outcome indicators (Appendix D, Table A7), which is what Stage 4 of the validation roadmap (Section 9.2) examines.

### *7.3. Evidence Anchoring and Scoring Mechanics*

Evidence-based assessments are a critical aspect of RMI's commitment to transparency and accountability through use of quantifiable data. All indicators are supported by verifiable documentation (such as performance dashboards, policy documents, or publicly accessible websites) which include the date, source, and name of the department responsible for that document. Two independent raters evaluate each indicator based on both the strength and quality of evidence supporting the assessment. If the two raters disagree on an evaluation, they engage in a structured adjudication with a documented rationale. The two-stage rater process improves inter-rater reliability and meets the standards of methodological transparency and replicability [81,85].

**Scoring:**

- Indicator scores (0–4) are averaged to a domain score where the overall RMI is the mean of the five domain scores.
- Readiness strata: Early (0–1.49), Intermediate (1.50–2.49), Advanced (≥2.50).
- Reliability targets. ICC ≥ 0.70 for domain (continuous) scores, Cohen's $\kappa \geq 0.60$ for categorical judgments, and Cronbach's $\alpha \geq 0.70$ for any composite indices; report with 95% confidence intervals. Data-quality/ETL checks are described in Appendix H. See Appendix D.

Aggregation assumptions. Three choices in the scoring mechanics require justification. First, equal weighting across domains is a deliberate default for a diagnostic instrument whose primary output is the domain profile rather than the index. The two-step aggregation, indicators to domain mean and domain means to RMI, gives each domain equal weight regardless of how many indicators it carries, so a domain with more indicators gains reliability, not influence. Differential weights would require evidence of the domains' relative contribution to systemic integration, which Stages 3 and 4 of the validation roadmap (Section 9.2) are designed to produce. Until then, any weighting would be as arbitrary as equal weights and less transparent. Second, the 0–4 scale is ordinal, and averaging treats it as interval. The RMI therefore reports the profile of domain levels as the

primary result and the mean as a summary, accompanied by the median and the minimum domain level. The minimum corresponds to a weakest-link reading, consistent with the rule that domains cannot skip levels. Third, the stratum cut-points are not free parameters: 1.50 and 2.50 are the rounding boundaries between the level anchors, so Intermediate denotes a profile that is on average closer to Defined than to Ad Hoc, and Advanced a profile closer to Managed than to Defined. Section 7.4 reports a sensitivity analysis under alternative aggregation rules, and Stage 3 of the roadmap in Section 9.2 tests whether the strata discriminate between institutions.

To anchor self-assessment to publicly verifiable benchmarks, the RMI incorporates an External Composite Readiness index that normalizes scores from major sustainability frameworks (STARS, UI GreenMetric, PRME, ISO 14001, and AISHE) onto the common 0–4 scale; its formula, weighting, and normalization procedures are specified in Appendix B.

### *7.4. Illustrative Application: The American University of Beirut*

To show that the RMI can be scored from available evidence, this section reports a single-institution demonstration. It is a demonstration activity of the design science process (Section 9.1), not an evaluation. The American University of Beirut (AUB) is a useful case because its sustainability activity is substantial but unevenly distributed across the five domains. Scoring combines public evidence, including annual sustainability reports, UI GreenMetric submissions, and facilities records, with the institution's governance and reporting records, and was conducted by a single rater. The exercise departs from the protocol in Section 7.3 in three respects, stated here so that the result is read at its proper weight. There was one rater rather than two, and no adjudication. The rater is the first author, who holds an administrative position at the institution, so the assessment is an insider assessment. Furthermore, the evidence is reported as a summary rationale per domain rather than as indicator-level evidence files with dates and owners. Stage 1 of the validation roadmap (Section 9.2) is designed to remove the first two departures through independent dual-rater re-scoring. The third is addressed by the indicator-level data template (File S1). Table 2 reports the result.

**Table 2.** Indicative RMI application to the American University of Beirut (Stage 0 demonstration; single rater; summary evidence).

| RMI Domain | Score (0–4) | Level | Evidence and Rationale |
|---|---|---|---|
| Leadership and Governance | 2 | Defined | AUB established a Sustainability Committee in 2004 with a documented mandate. Sustainability KPIs support performance monitoring and external reporting but are not tied to senior-leadership evaluation. Sustainability is present in strategic initiatives rather than as an explicit core pillar of the formal mission. The responsible unit's mandate is being revised. |
| Strategy | 1 | Ad Hoc | Sustainability remains initiative-based, without a consolidated, board-approved institutional strategy. A new strategy is under development following the revision of the responsible unit's mandate. |
| Curriculum and Pedagogy | 2 | Defined | ESD provision is formalized at program level in some faculties, through approved courses and programs with sustainability learning outcomes listed in the academic catalog, which meets the Defined criterion of formalized processes with limited validation. No institution-wide sustainability competency framework exists, which is what prevents a Managed rating. |

| | | | |
|---|---|---|---|
| Metrics and Data | 1 | Ad Hoc | AUB has no centralized sustainability dashboard or formal institution-wide data-governance procedures. The Safety and Sustainability Unit collects data from departments and centers for institutional and external reporting, leaving the process distributed and manually compiled. |
| Operations | 2 | Defined | Data on waste, water, energy, transport, and related areas are collected for reporting and used to support improvement initiatives. These activities are not managed through a formal corrective-action tracking and closure process. |
| SESR gate (SGI, 0–1) | ≈ 0.78 | Gate | Formal participation councils, partnership MoUs, and public reporting; clears both the 0.60 (Level ≥3) and 0.75 (Level 4) thresholds. |
| **Overall RMI** | **1.60** | Intermediate | Mean of the five domain scores: (2 + 1 + 2 + 1 + 2)/5 = 1.60. The SGI is reported separately and is not included in the calculation. |

*Note.* Scores are indicative, single-rater, and based on summary rationale rather than indicator-level evidence files. Section 7.4 states the departures from protocol and reports a sensitivity analysis. Domain levels follow the 0–4 scale: Absent, Ad Hoc, Defined, Managed, and Optimized. Overall readiness strata are Early (0–1.49), Intermediate (1.50–2.49), and Advanced (≥2.50). Because no AUB domain exceeds Level 2, the SGI does not currently limit the domain scores. *Bold identifies the overall RMI summary row; it does not indicate statistical significance.*

Read through the mechanism described in Section 5, the profile in Table 2 locates AUB at a specific point on the pathway. The early stages have clearly been passed. External pressure has been interpreted into institutional structure, with a Sustainability Committee holding a documented mandate since 2004, annual sustainability reports, and UI GreenMetric submissions. Resource reconfiguration (Stage 3) is visible but partial: Operational data on energy, water, waste, and transport are collected and used to support improvement initiatives, and ESD content is present in some faculties and programs. What the assessment reveals is that routinization (Stage 4) has not yet occurred at the institutional level. Sustainability KPIs inform monitoring and external reporting but are not tied to senior-leadership evaluation. There is no consolidated, board-approved strategy. Data are compiled manually by the Safety and Sustainability Unit from departments and centers rather than through a centralized dashboard governed by institution-wide procedures. Operational improvements are not managed through a formal corrective-action tracking and closure process. Feedback closure (Stage 5), the evidentiary condition for Level 3, therefore cannot yet be demonstrated in any domain.

The constraints are unevenly distributed, and their location matters. The two Ad Hoc domains, Strategy and Metrics and Data, sit upstream of every gate in Section 7.2. Progression to the Managed level requires documented closed PDCA loops, which presuppose both targets to close against (Strategy) and the data governance needed to record closure (Metrics and Data). The Defined ratings in Leadership and Governance and Operations are therefore capped by weaknesses elsewhere rather than by their own practice. This pattern is consistent with the sequencing identified in Section 2.2, in which leadership and accountability precede data and governance systems, which in turn precede pedagogical reform. The practical reading is that AUB's next cycle should formalize strategy and data governance before investing in further domain-level activity. Under the 12-month adjudication rule, progression can be recorded only once those loops are documented.

The case also shows how the RMI separates external visibility from internal integration. AUB's SGI of approximately 0.78 clears both the Level 3 (0.60) and Level 4 (0.75) thresholds. Its participation councils, partnership MoUs, and public reporting are well developed. Its indicative RMI of 1.60 is Intermediate, though only 0.10 above the Early boundary (see the sensitivity analysis below). The divergence between the two measures

is the diagnostic result. The institution's engagement and disclosure infrastructure is more mature than the internal routines that would make sustainability systemic, the configuration that Institutional Theory describes as decoupling between formal commitment and enacted practice (Section 3.1). Because the SGI is reported alongside the RMI rather than included in it, this visibility cannot raise the readiness score. Had it been averaged in, the composite would have risen without any change in governance, strategy, or data practice. Conversely, the gate will not bind when AUB's domains reach Level 3, so the constraint on progression is wholly internal.

Sensitivity of the index: The domain profile, not the index, carries the diagnostic, and the index should be read with the aggregation assumptions of Section 7.3 in view. Under equal weighting, the mean is 1.60. The median domain level is 2 (Defined). The minimum is 1 (Ad Hoc), which a weakest-link rule would report as the institutional level. Doubling the weight of the two gate-critical domains (Leadership and Governance and Metrics and Data) gives 1.57. Doubling the weight of the two upstream domains (Leadership and Governance and Strategy) also gives 1.57. Under the stricter reading of the Curriculum and Pedagogy evidence (Ad Hoc rather than Defined), the mean falls to 1.40 and the stratum to Early. The stratum assignment is therefore boundary-sensitive, whereas the profile, two Ad Hoc domains upstream of the gates and three Defined domains capped by them, is stable under every rule considered. We report 1.60 as a one-decimal summary of that profile, not as a measurement with that precision.

The exercise establishes operability, not validity. The scores are indicative and single-rater. Reliability and generalizability remain subjects for the staged validation program set out in Section 9.1 (Table 3).

## 8. Interoperability with External Standards

SIF is standards-agnostic and orchestrates existing systems rather than competing with them. STARS informs academic and administrative process indicators; ISO 14001 underpins OSRM's PDCA-based operational improvement and auditability; PRME anchors leadership ethics and stakeholder transparency; UI GreenMetric contributes environmental performance metrics; AISHE contributes staged self-assessment; and SIF supplies the evidence-gated progression from symbolic to systemic integration. This alignment enables cross-referencing, harmonized reporting, and verifiable progression without redundancy (see Appendix B, Table A2, and Appendix E.4).

## 9. Methodological Stance and Validation Design

### *9.1. Methodological Stance*

The validation of the SIF adopts Design Science Research (DSR) along with Realist Evaluation to ensure that it has both conceptual rigor and contextual applicability. The DSR [14] provides the means to iteratively develop an SIF as a design artifact which addresses a practical gap, namely the absence of a readiness-gated mechanism-based framework for sustainability in HEIs. The Realist Evaluation [87], assesses the context–mechanism–outcome (C–M–O) relationships between the context in which SIF operates, the SIF mechanisms used, and their resultant outcomes to determine how/under what circumstances SIF mechanisms will function effectively in different institutional settings.

In the design science process of Peffers et al. [14], the present paper completes problem identification, definition of objectives, design and development, and a first demonstration (the single-rater application in Section 7.4). The evaluation activity is specified in Section 9.2 and Table 3 but has not been executed. The contribution is therefore a design proposal with a demonstrated artifact, not a validated instrument, and the claims in the Abstract, Introduction, and Conclusions are stated accordingly.

**Table 3.** Staged validation roadmap for the RMI and IPO instruments.

| Stage | Objective | Design and Sample | Pass Criterion (Gate to Next Stage) | Propositions |
|---|---|---|---|---|
| 0. Operability (complete) | Demonstrate that the RMI can be scored from available evidence | Single-rater application to one institution (Section 7.4), combining public evidence with governance and reporting records | Scored profile with an evidence trail for all five domains and the SGI | — (illustrative) |
| 1. Reliability and content validity | Establish that independent raters reach the same scores and that indicators and thresholds are judged valid | Dual-rater re-scoring of the Stage 0 case under the Section 7.3 protocol, with documented adjudication; expert-panel review of the indicator dictionary (Appendix E) and the SGI thresholds (Section 7.2) | ICC ≥ 0.70 for domain scores; Cohen's $\kappa \geq 0.60$ for level and stratum judgments; Cronbach's $\alpha \geq 0.70$ for composite indices, each with 95% CI; rubric revised and re-tested where criteria are not met | Instrument-level (all) |
| 2. Single-institution pilot (Tier 1) | Test internal coherence, data availability, and scoring reliability across units | Deep-dive pilot within one institution across selected faculties and operational units; 8–12 semi-structured interviews; process tracing of minutes and policy documents; ETL quality checks | Completeness, freshness, and audit error rate within target (error ≤ 5%); reliability thresholds held at unit level; indicators without a verifiable data source revised or removed | P1, P2, P3 |
| 3. Multi-site benchmarking (Tier 2) | Test cross-institutional discrimination and convergence with external benchmarks | Four to six HEIs across at least three governance archetypes (public, private, hybrid) and distinct readiness strata, scored from public sustainability reports, STARS submissions, and ISO 14001 audits; External Composite Readiness computed per Appendix B, "External Composite Readiness" | Reliability thresholds held across sites; RMI discriminates between readiness strata; Composite Readiness–RMI correlation in the expected range (r ≈ 0.7–0.9, Appendix E.7.5); C–M–O patterns consistent with the mechanism | P1, P3, P5 |
| 4. Longitudinal validation | Test sensitivity to change and the feedback propositions | Baseline ($T_1$) and endline ($T_2$) scoring at 12–18 months across the Stage 3 sites; difference-in-differences or interrupted time-series models with cluster-robust standard errors; realist coding of C–M–O patterns | Detectable, evidence-backed domain progression consistent with the gate rules; documented PDCA closures precede level changes; thresholds and SGI gates recalibrated where warranted | P2, P4, P5 |

*Note.* Stages are sequential; the pass criterion of each stage is the entry condition for the next. Reliability thresholds, data-quality targets, and analytical models are those specified in Section 7.3 and Appendix H; proposition codes refer to Section 5.2 and Appendix G.

Validation proceeds in two tiers (Stages 2 and 3 of Table 3): (1) A deep-dive pilot within a single institution, testing internal coherence, data availability, and RMI scoring reliability across selected faculties and operational units; and (2) Comparative benchmarking of four to six HEIs representing at least three governance archetypes (public, private, and hybrid) and distinct readiness strata, using publicly available sustainability reports, STARS submissions, and ISO 14001 audits. Temporal assessment across baseline ($T_1$) and endline ($T_2$) (12–18 months) enables evaluation of incremental progress. No primary institutional data was collected during this conceptual phase; full empirical testing will follow.

### *9.2. Validation Roadmap*

Validation proceeds through a convergent mixed-methods design that pairs RMI domain scoring with an IPO-derived KPI panel and mechanism probes, including semi-structured interviews and process tracing, analyzed for context–mechanism–outcome patterns against propositions P1–P5. Table 3 sets out the program as a staged sequence. Each stage has a defined objective, design, and pass criterion, and the pass criterion of one stage is the entry condition for the next, so that the validation program applies to the instruments the same readiness-gated logic the SIF applies to institutions. Stage 0, the single-rater application in Section 7.4, is complete and establishes operability. Stage 1 tests whether the instrument can be scored consistently before it is used comparatively: two independent raters re-score the AUB case under the protocol in Section 7.3, and an expert panel reviews the indicator dictionary (Appendix E) and the SGI thresholds (Section 7.2). Stages 2 and 3 correspond to the two tiers in Section 9.1 and test, respectively, internal coherence and data availability within one institution and cross-sectional discrimination across four to six institutions spanning three governance archetypes. Stage 4 adds the temporal dimension required to test the feedback propositions (P2, P4) and the sensitivity of the gate rules. Measurement instruments, analytical models, reliability thresholds, data-quality controls, and ethics procedures are specified in Appendix H.

## 10. Discussion and Implications (Systems and Cross-Sector)

Building on the previously described mechanism, the SIF represents a dynamic readiness-gated view of sustainability integration in HEIs. It reframes the organization from a linear compliance process to a feedback-driven process, thus extending socio-technical transition theory [71,72] by embedding leadership mediation and capability reconfiguration within a sequenced institutional logic.

Implementation of the SIF and RMI is possible in modular form for low to middle income or resource limited countries, thus enabling incremental implementation of the RMI that does not require a significant audit or data infrastructure.

Practically, RMI's evidence-gated model will enable this by preventing "moving" or "scaling" until an institution has demonstrated its preparedness through established governance practices, data management systems, and accountable leadership. The evidence-gated model prevents premature scaling and allows differentiated pacing based on institutional context.

The supporting data dashboard and IPO indicators provide transparency for all parties involved and facilitate evidence-based decision-making and ongoing improvements.

For journals and audiences concerned with sustainable futures, the SIF contributes by connecting institutional transformation to environmental accountability and technology-enabled monitoring. The framework shows how universities can move from fragmented sustainability activities to integrated systems in which governance decisions, operational performance, stakeholder participation, and data infrastructures reinforce one another. This is particularly relevant now, as HEIs are increasingly expected to demonstrate credible progress on emissions, resource efficiency, circular practices, and socially responsible development.

Planetarily and managerially, the SIF links RMI scores to curricular and operational outcomes. This enables leadership to allocate resources according to the organization's readiness, as opposed to simply relying on the declarative intentions of the organization.

The SIF–RMI model provides a connection between the operational metrics (e.g., carbon footprint, water use, waste generation) and the planetary boundaries (e.g., atmospheric CO2 concentrations), thus creating a bridge between managerial accountability and ecological limits.

At the policy level, the SIF–RMI model provides a combined policy framework for integrating funding and reporting mechanisms, and accreditation systems, with institutional readiness verified through credible data. As such, this framework can create system-wide coherence across governance layers.

Accreditation agencies can incorporate RMI indicators into their quality assurance processes and link performance-based funding to the maturity level of the institution.

Governments or funders may also utilize the readiness strata as eligibility criteria for sustainability grants. Public disclosure of maturity scores could improve the transparency of institutions and the stakeholders' confidence in institutions (like emerging ESG assurance models for corporations).

*Contextual and Equity Dimensions*

The SIF can be applied differently based on the governance systems in place, resource availability, and institutional maturity. Centralized systems are more likely to lead to faster early-stage readiness when leveraging top-down mandates. However, this may risk impeding bottom-up innovation. In decentralized systems, on the other hand, additional coordination mechanisms are required to ensure that all faculties/units work together toward a common goal. In resource-constrained environments (particularly in the global south), it would be necessary to develop capacity, digital infrastructure, and data governance before the full deployment of the SIF.

To accommodate such variance, the SIF differentiates between:

- Core elements: The theorized mechanism, PDCA logic, and RMI evidence gates that remain invariant across contexts, and
- Adaptive elements: Indicator selection, pacing, and data granularity that can be localized without compromising conceptual integrity.

This scalable design aligns with ISO 14001's continuous improvement and scalability principles and PRME's emphasis on contextual engagement and inclusivity. Accordingly, the SIF functions as a globally consistent yet locally adaptable framework ensuring equity, relevance, and operational feasibility across diverse institutional and regional ecosystems. Applied to the American University of Beirut (Section 7.4), the RMI returns an indicative score of 1.60 at the lower edge of the Intermediate stratum while identifying the absence of a board-approved strategy, of institution-wide data governance, and of a verified institution-wide curriculum competency framework as the specific constraints on further progression, illustrating the diagnostic precision the framework is designed to deliver.

## 11. Limitations and Future Research

This study presents a conceptual and methodological synthesis and the RMI and IPO offer verifiable constructs. However, their statistical reliability and sensitivity must be validated using longitudinal, multi-site studies. Potential construct validity threats, including common-method bias, halo effects, or self-reported dependency, will be examined through triangulation of evidence sources in future empirical validation. We have not conducted a formal scoping review of all readiness/maturity indices across all clear domains. Our claim to novelty arises instead from a conceptual extension to HEIs rather than from exclusivity. The single illustrative application of the RMI reported in Section 7.4 reinforces this point: it demonstrates operability rather than validity, since reliability and generalizability remain contingent on the multi-site testing described above. Two further limitations follow from Sections 7.3 and 7.4. The index treats an ordinal scale as interval under equal weighting, which is why the domain profile rather than the index is the primary output. The single demonstration was an insider assessment by the first author, which Stage 1 of the roadmap replaces with independent dual-rater scoring. A further

limitation is breadth. The framework is deliberately comprehensive, so the five propositions are stated at the level of the mechanism rather than as fine-grained hypotheses, and the instrument carries more indicators than any single study can validate. The paper's answer is sequencing rather than reduction: the propositions are the minimum set that covers the mechanism, one per stage, and the roadmap in Table 3 orders the validation work rather than attempting it here.

The staged roadmap in Section 9.2 (Table 3) sets out the sequence through which these limitations are to be addressed. Inter-rater reliability testing and expert review of the indicator dictionary first, a single-institution pilot of data availability and governance second, and multi-site and longitudinal testing third, with external audits of evidence trails throughout to minimize symbolic compliance. By working on these next steps, the SIF aims to institutionalize sustainability as an adaptive, evidence driven governance system capable of supporting systemic transformation across higher education and related sectors.

## 12. Conclusions

The SIF is a readiness-gated, mechanism-based model that moves HEIs from symbolic compliance to systemic sustainability. Integrating institutional theory, resource-based theory, and responsible leadership, it theorizes how external pressures, leadership sense-making, and capability reconfiguration embed sustainability across governance, pedagogy, research, and operations. With its companion RMI and IPO tools, SIF is designed to convert theory into measurable, auditable pathways for continuous improvement, comparable benchmarking, and policy-linked accountability, offering a practical roadmap for universities and other complex organizations. The framework is offered as a design proposal. Its mechanism is theorized rather than demonstrated, its instruments have been shown to be operable but not yet reliable or valid, and the staged program in Section 9.2 specifies the evidence that would change that status.

**Supplementary Materials:** The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su182111434/s1, File S1: SIF Data Template (Excel workbook: case list, readiness scoring, RMI coding, IPO indicators, and framework crosswalk).

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## Abbreviations

The following abbreviations are used in this manuscript:

| | |
|---|---|
| AISHE | Assessment Instrument for Sustainability in Higher Education |
| AUB | American University of Beirut |
| CMMI | Capability Maturity Model Integration |
| C–M–O | Context–mechanism–outcome |
| CPI | Curriculum and Pedagogical Innovation |
| DSR | Design Science Research |
| EMS | Environmental management system |
| ESD | Education for Sustainable Development |
| ETL | Extract–transform–load |
| FTE | Full-time equivalent |
| GRI | Global Reporting Initiative |
| HEI | Higher education institution |
| ICC | Intraclass correlation coefficient |
| IPAM | Institutional Policies and Accountability Mechanisms |
| IPO | Input–Process–Output |
| IT | Institutional Theory |
| KPI | Key performance indicator |
| MoU | Memorandum of understanding |
| OSRM | Operational Sustainability and Resource Management |
| PDCA | Plan–Do–Check–Act |
| PRME | Principles for Responsible Management Education |
| RBT | Resource-Based Theory |
| RKM | Research and Knowledge Mobilization |
| RL | Responsible Leadership |
| RMI | Readiness and Maturity Index |
| SASB | Sustainability Accounting Standards Board |
| SESR | Stakeholder Engagement and Social Responsibility |
| SGI | SESR Gate Index |
| SIF | Sustainability Integration Framework |
| SIP | Sharing Information on Progress (PRME report) |
| SLA | Service-level agreement |
| SLGA | Strategic Leadership and Governance Alignment |
| STARS | Sustainability Tracking, Assessment and Rating System |

## Appendix A. Comparative Overview of Major Sustainability Frameworks in Higher Education

**Table A1.** Comparative Overview of major Sustainability Frameworks in HE.

| Framework | Primary Scope and Structure | Strengths/Contributions | Limitations/Gaps Identified | Key References |
|---|---|---|---|---|
| **AASHE STARS** | Weighted scoring system across academics, engagement, operations, and administration | Enhances transparency, comparability, and public disclosure | Rewards documentation over improvement; lacks a progression logic | [19,26,88] |
| **UI GreenMetric** | Global ranking using quantitative indicators (energy, waste, transport, water) | Enables international benchmarking | Over-emphasizes environmental metrics; minimal governance or leadership focus | [27,28] |
| **AISHE** | Self-assessment across policy, education, research, operations, society; 5 maturity levels | Introduces staged development logic | Functions mainly as periodic audit; lacks linkage between stages | [11,29] |
| **ISO 14001** | Environmental management-system standard (PDCA cycle, audit verification) | Adds procedural rigor and third-party assurance | Narrow operational scope; limited pedagogical or cultural integration | [6,30] |
| **PRME** | Six-principle framework for responsible management education | Provides ethical and leadership orientation | No sequencing or cross-domain integration; primarily normative | [31,32] |

*Note:* These frameworks inform the architecture of the Sustainability Integration Framework (SIF) by supplying discrete strengths, transparency (STARS), benchmarking (UI GreenMetric), staged assessment (AISHE), continuous improvement (ISO 14001), and ethical orientation (PRME), which the SIF unifies within a mechanism-based, readiness-gated model for systemic transformation.

## Appendix B. Crosswalk of SIF Components with External Sustainability Frameworks

**Table A2.** Crosswalk of SIF components with external sustainability frameworks and how SIF operationalizes each for comparability and readiness assessment.

| SIF Component | Aligned External Framework(s) | Mapped Artifact(s) | How SIF Operationalizes/Enhances Use |
|---|---|---|---|
| Strategic Leadership and Governance Alignment (SLGA) | AISHE<br>PRME<br>STARS (Administration) | AISHE Policy and Organization domain<br>• PRME Principles 1–2<br>• STARS Governance credits | Embeds sustainability into executive structures and board accountability; establishes readiness gates for policy adoption and legitimacy consolidation. |
| Curriculum and Pedagogical Innovation (CPI) | STARS (Academics)<br>PRME<br>AISHE (Education) | STARS AC credits<br>PRME Principles 3–4<br>AISHE Education domain | Translates course-level metrics into process indicators; links curriculum integration with faculty training and outcome-based assessment. |
| Research and Knowledge Mobilization (RKM) | STARS (Research)<br>PRME<br>AISHE (Research) | STARS Research credits<br>PRME Principle 5<br>AISHE Research domain | Connects research indicators with knowledge-transfer outputs and cross-sector partnerships, strengthening translational impact. |

| | | | |
|---|---|---|---|
| Institutional Policies and Accountability Mechanisms (IPAM) | STARS (Admin and Planning)<br>AISHE (Policy)<br>GRI/SASB | STARS PA credits<br>AISHE Policy domain<br>GRI/SASB Disclosure standards | Converts policy commitments into routinized KPI families with audit cadence; enables inter-framework comparability and transparent data governance. |
| Stakeholder Engagement and Social Responsibility (SESR) | PRME<br>STARS (Engagement)<br>AISHE (Society) | PRME Principles 5–6<br>STARS EN credits<br>AISHE Society domain | Anchors participatory governance and co-production with stakeholders; ensures SDG alignment and local responsiveness. |
| Operational Sustainability and Resource Management (OSRM) | ISO 14001<br>UI GreenMetric<br>STARS (Operations)<br>AISHE (Operations) | ISO 14001 EMS clauses<br>UI GreenMetric environmental metrics<br>STARS OP credits<br>AISHE Operations domain | Applies PDCA-based continuous-improvement logic to resource management; normalizes environmental performance data for readiness assessment. |

*External Composite Readiness*

To support cross-framework comparability, the RMI incorporates an External Composite Readiness index that integrates normalized scores from major sustainability frameworks: STARS, UI GreenMetric, PRME, ISO 14001, and AISHE. Each framework is converted to a common 0 to 4 scale and averaged:

$$\textit{Composite Readiness} = \Sigma(\textit{normalized framework scores for STARS, UI GreenMetric, PRME, ISO 14001, AISHE}) \div n$$

Here, n is the number of frameworks with available data. Per-framework normalization to the 0 to 4 scale follows the indicator dictionary in Appendix E. The composite index anchors institutional self-assessment to publicly verifiable benchmarks, reinforcing the RMI's accountability function and enabling external validation without compromising standards agnosticism.

## Appendix C. Empirically Testable Propositions of the SIF

The mechanism yields several empirically testable propositions that capture the theorized direct, mediating, and moderating relationships among its core constructs:

**Table A3.** Empirically Testable Propositions of the Sustainability Integration Framework (SIF).

| Proposition | Type/Relationship | Core Variables or Constructs | Operational Expectation (Testable Form) |
|---|---|---|---|
| **P1. Sustainability pressures drive organizational change only when leaders interpret them and translate them into aligned governance arrangements and resource commitments.** | Mediation | *Institutional Pressures* → *Responsible Leadership* → *Resource Reconfiguration* | Responsible leadership sense-making mediates the relationship between institutional pressures and resource reconfiguration. Institutions where leaders interpret sustainability as a strategic and ethical imperative are more likely to mobilize resources effectively toward systemic integration. [74] |

| | | | |
|---|---|---|---|
| **P2. Sustainability moves beyond symbolic commitment when it becomes embedded in monitoring systems, accountability structures, and everyday routines.** | Moderation | *Resource Reconfiguration* × *Routinized Metrics* → *Sustainability Outcomes* | The presence of routinized metrics and governance structures (IPAM) strengthens the effect of resource reconfiguration on sustainability outcomes. KPI systems, audit routines, and transparent reporting accelerate readiness and reduce decoupling risks. [53] |
| **P3. Equity, inclusion, and legitimacy shape the durability of sustainability integration by influencing trust, participation, and institutional accountability.** | Direct/Moderating Effect | *Institutional Equity* → *Legitimacy Feedback* | Embedding institutional equity and capacity parity mechanisms enhances legitimacy and stakeholder trust. Balanced resource distribution increases perceived fairness and reinforces sustainability adoption [56]. |
| **P4. Progress toward systemic integration depends on feedback processes that trigger corrective action and support institutional learning.** | Longitudinal/Dynamic Effect | *PDCA Cycles* → *Cumulative Readiness Gains* | The sustainability mechanism strengthens over time as feedback loops institutionalize learning. HEIs that maintain PDCA-like cycles achieve measurable gains across short-, medium-, and long-term phases [56]. |
| **P5. Systemic integration emerges when academic and operational domains are structurally linked through shared metrics, aligned governance, and coordinated routines.** | Interaction Effect | *Academic Subsystems (CPI/RKM)* ↔ *Operational Subsystems (OSRM/IPAM)* | Strong interaction between academic (CPI/RKM) and operational (OSRM/IPAM) subsystems predicts systemic sustainability integration, higher institutional maturity, and reduced symbolic compliance [77]. |

## Appendix D. Operationalization of the SIF via the Input–Process–Output (IPO) Model

The IPO model translates the framework's theoretical underpinnings into empirical constructs that link leadership commitment, institutional practices, and sustainability outcomes. It is built on Deming's [15] Plan–Do–Check–Act (PDCA) cycle and aligned with the Global Reporting Initiative (GRI) [89] and the Sustainability Accounting Standards Board (SASB) [90] categories, providing a structure for quantifying the transformation from intention to impact with comparability and transparency across higher education institutions. The model comprises three phases—Inputs, Processes, and Outputs—each described by measurable criteria that support continuous improvement, performance evaluation, and replication. Tables A4–A7 define the constructs and indicators for each phase.

**Table A4.** Operationalization of the Sustainability Integration Framework (SIF) through the Input–Process–Output (IPO) model, defining key constructs and illustrative indicators aligned with GRI [89] and SASB [90] categories.

| Level | Construct | Definition | Illustrative Indicators (2–3 Examples per Construct) | Primary Data Source(s) |
|---|---|---|---|---|
| Inputs | Leadership Commitment | Extent to which executive and board-level actors embed sustainability in mission and accountability systems. | (1) % of senior leaders with sustainability KPIs in performance plans. (2) Existence of formal sustainability governance body or board subcommittee. (3) Sustainability included in institutional strategy or accreditation report. | HR systems; strategic plans; governance records. |
| | Policy Infrastructure | Institutional presence of formal sustainability policies and frameworks. | (1) # of sustainability policies in effect. (2) Policy alignment index = (# of policies referencing SDGs/total policies). (3) Annual sustainability report publication status (binary: 0/1). | Policy repositories; institutional websites. |
| | Resourcing and Budget Allocation | Proportion of budget and human resources dedicated to sustainability. | (1) Sustainability spending ratio = sustainability-related expenses/total budget. (2) # of sustainability staff (FTE). (3) Annual external sustainability grants secured (USD). | Finance systems; HR data; grant records. |
| | Stakeholder Linkages | Degree of partnership engagement across sectors and stakeholder groups. | (1) # of active sustainability partnerships (MOUs). (2) Stakeholder diversity index = (# sectors engaged/total potential sectors). (3) Frequency of stakeholder advisory forums per year. | Partnership databases; outreach logs. |
| Processes | Governance Routines | Regularized decision and review processes for sustainability oversight. | (1) # of sustainability governance meetings per year. (2) Audit closure rate = (# of audit items resolved/total items). (3) Policy review cadence (months). | Meeting minutes; internal audit reports. |
| | Curriculum Integration | Extent of sustainability embedding within formal curricula. | (1) % of degree programs with sustainability learning outcomes. (2) % of students enrolled in sustainability-tagged courses. (3) Curriculum refresh interval (years). | Academic affairs data; course catalogs. |
| | Research Mobilization | Degree to which sustainability research informs external practice and policy. | (1) % of sustainability papers with non-academic co-authors. (2) # of research-policy dialogues or workshops annually. (3) External research funding secured (USD). | Research office records; Scopus/Dimensions; funding agency reports. |
| | Operational Levers | Adoption of sustainability practices in infrastructure and operations. | (1) Energy intensity reduction (%) vs. baseline. (2) % of sustainable procurement contracts. (3) Waste diversion rate = (recycled + reused)/total waste. | Facilities data; procurement systems; sustainability reports. |
| Outputs/Outcomes | Sustainability Literacy | Evidence of sustainability competencies among graduates and staff. | (1) % of students demonstrating sustainability literacy (survey/test). (2) % of faculty completing sustainability training. (3) # of sustainability-related professional certifications earned. | Graduate surveys; HR learning systems. |

| | | | | |
|---|---|---|---|---|
| | Research and Policy/Industry Impact | Evidence that sustainability research influences external stakeholders. | (1) Policy citation ratio = (# of sustainability papers cited in policy docs/total sustainability papers). (2) # of industry partnerships yielding sustainability outputs. (3) Patent or prototype count related to sustainability innovations. | Policy repositories; research analytics; tech transfer office data. |
| | Operational Performance | Tangible environmental performance gains. | (1) GHG emissions reduction (%) = (baseline—current)/baseline × 100. (2) Water use reduction (%) vs. baseline. (3) Renewable energy share (%) of total use. | Facilities and environmental dashboards; ISO 14001 audits. |
| | Community and Institutional Equity Outcomes | Distributional fairness of sustainability impacts across academic units and regions. | (1) Equity of resource allocation = SD of sustainability budget share across faculties. (2) % of sustainability projects involving Global South partners. (3) # of community co-designed sustainability programs. | Financial systems; project databases; outreach records. |

Inputs represent the institutional conditions and capacity for sustainability integration, expressed mainly through the Strategic Leadership and Governance Alignment (SLGA), Institutional Policies and Accountability Mechanisms (IPAM), and Stakeholder Engagement and Social Responsibility (SESR) components. Table A5 specifies the input-level constructs and indicators.

**Table A5.** Input-level constructs, definitions, and indicators for leadership, policy, resourcing, and stakeholder engagement within the SIF.

| **Construct** | **Indicator (Code)** | **Definition** | **Formula/Scoring** | **Direction** | **Primary Data Sources and Frequency** |
|---|---|---|---|---|---|
| Leadership Commitment (SLGA) | Leadership KPI coverage (SLGA-INP1) | Extent to which senior leaders are performance-accountable for sustainability. | (%) senior leaders with at least one sustainability KPI in their annual review = (leaders with KPI ÷ total senior leaders) × 100. *Senior leaders* = president/VC, provost, VPs, deans (declare list in Appendix E). | Higher = better | Admin HR/performance systems; annual. |
| | Executive mandate and budget authority (SLGA-INP2) | Presence of a formal, institution-wide sustainability mandate with decision rights and a protected budget line. | 0/1 binary: score 1 if a charter/policy specifies (i) decision rights, (ii) accountable officer, (iii) named budget line for FY; else 0. Evidence: charter URL, org chart, budget ref. | Higher = better | Governance repository; budget book; annual. |
| Policy Infrastructure (IPAM) | Policy stack completeness (IPAM-INP1) | Coverage of core sustainability-related institutional policies. | (%) present = (count of required policies in force ÷ 5) × 100. Required: Sustainability policy, Climate/energy plan, Sustainable procurement, ESD/curriculum guideline, Data governance policy. | Higher = better | Policy repository; annual. |

| | | | | | |
|---|---|---|---|---|---|
| | Policy review discipline (IPAM-INP2) | Whether policies have owners and current review cycles. | (%) policies with named owner and last review ≤ 24 months and next review date posted. | Higher = better | Policy repository; review calendar; annual. |
| Resourcing and Budget Allocation (STR) | Sustainability budget ratio (STR-INP1) | Portion of total spend dedicated to sustainability initiatives/capabilities. | (%) = (sustainability OPEX + CAPEX ÷ total OPEX + CAPEX) × 100. *Declare inclusions/exclusions in App. E; exclude restricted/endowment spend unless deployable.* | Higher = better | Finance systems; budget ledgers; annual. |
| | Multi-year earmark coverage (STR-INP2) | Stability of funding for planned sustainability work. | (%) sustainability line items funded with ≥2-year earmarks = (items with ≥2-yr runway ÷ total sustainability items) × 100. | Higher = better | Finance systems; project portfolio; annual. |
| Stakeholder Linkages (SESR—input; outside RMI) | Partnership breadth index (SESR-INP1) | Diversity of external partners supporting sustainability. | 0–1 index = (# partner sectors engaged ÷ # sector categories listed in Appendix E). Sectors include: community/NGO, public, industry, schools, health, utilities, international orgs. | Higher = better | Partnership register; MoU database; annual. |
| | Co-creation MoU share (SESR-INP2) | Proportion of active MoUs that include co-creation/knowledge-transfer clauses. | (%) = (active MoUs with co-creation deliverables and term ≤ 24 months ÷ active MoUs) × 100. | Higher = better | Partnership register; legal/MoU store; annual. |

**Notes (auditing and comparability).** 1. Each indicator must have an evidence file (URL or doc ID) with date, owner, and method; unverifiable evidence scores 0 per Section 7.3. 2. Keep financial normalizers constant across years; disclose the sustainability spending taxonomy in Appendix E. 3. SESR inputs (SESR-INP1/2) are descriptive and do not affect RMI progression; SESR gating uses the SESR Gate Index (SGI) computed from Table A7 (SESR-OUT1/2) and applied per Section 7.2.

Processes correspond to the Do and Check phases of the PDCA cycle, converting inputs into structured action across the SLGA, Curriculum and Pedagogical Innovation (CPI), Research and Knowledge Mobilization (RKM), Operational Sustainability and Resource Management (OSRM), and IPAM components. Table A6 specifies the process-level constructs and indicators.

**Table A6.** Process-level constructs, definitions, and indicators for governance, curriculum, research, and operational sustainability.

| **Construct** | **Indicator (code)** | **Definition** | **Formula/Scoring** | **Direction** | **Primary Data Sources and Frequency** |
|---|---|---|---|---|---|
| Governance Routines (SLGA/IPAM) | Governance cadence with quorum (SLGA-PROC1) | Regularity and formality of sustainability oversight. | Count/year of institution-level sustainability boards/committees that met with quorum, published minutes, and issued action registers. | Higher = better | Board/committee calendars; minutes/action logs; annual. |

| | | | | | |
|---|---|---|---|---|---|
| | PDCA close-rate (IPAM-PROC1) | Closure discipline for corrective actions. | (%) closed within SLA = (closed PDCA actions within SLA ÷ total actions raised) × 100. (SLA defined in Appendix E.) | Higher = better | Internal audit tracker; CAPA logs; quarterly/annual. |
| Curriculum Integration Cadence (CPI) | Program ESD coverage (CPI-PROC1) | Extent of programs embedding assessed ESD learning outcomes. | (%) programs with approved ESD LOs and an assessment plan = (qualified programs ÷ total programs) × 100. | Higher = better | Curriculum database; QA approvals; annual. |
| | Curriculum refresh interval (CPI-PROC2) | Pace of updating sustainability content. | Median months between approved sustainability-related syllabus revisions per program (rolling 36-month window). | Lower = better | Academic affairs workflow; version history; annual. |
| Research Mobilization Protocols (RKM) | External co-authorship share (RKM-PROC1) | Co-production with policy/industry/civil partners. | (%) sustainability outputs with external stakeholder co-author = (co-authored outputs ÷ total sustainability outputs) × 100. | Higher = better | Scopus/Dimensions; CRIS; partner registry; annual. |
| | Research-to-practice workshops with products (RKM-PROC2) | Structured translation mechanisms. | Count/year of workshops that produce a public brief (methods, findings, next steps) within 30 days. | Higher = better | Research office logs; brief URLs; quarterly/annual. |
| Operational Levers (OSRM) | Sustainable procurement penetration (OSRM-PROC1) | Integration of sustainability in purchasing. | (%) addressable spend under contracts with explicit sustainability criteria (environmental and/or social) = (sustainable-criteria spend ÷ addressable spend) × 100. | Higher = better | Procurement systems; contract clauses; semiannual/annual. |
| | M and V compliance for ops projects (OSRM-PROC2) | Evidence that improvements are verified. | (%) completed sustainability ops projects with M and V report posted ≤ 60 days after completion = (projects with timely M and V ÷ projects completed) × 100. | Higher = better | Facilities PMO; M and V repository; quarterly/annual. |

**Notes (auditing and comparability).** 1. Each indicator must have an evidence file (URL or doc ID) with date, owner, and method; unverifiable items are scored 0 per Section 7.3. 2. Keep normalizers constant across years (e.g., program counts, addressable spend definitions); declare choices in Appendix E and the Supplementary Workbook (File S1). 3. *Qualified sustainability outputs* (RKM-PROC1) follow the scope definition in Appendix E (include reports, datasets, tools). 4. PDCA close-rate (IPAM-PROC1) is a gate-relevant process metric referenced in Section 7.2; use the same SLA used for audits across domains. 5. For small HEIs (≤3 faculties), compute CPI coverage at program/department level and allow a 24-month window for CPI-PROC2.

Outputs correspond to the Act phase of the PDCA cycle and capture measurable improvements in performance and value creation across the CPI, RKM, SESR, and OSRM components. Table A7 specifies the output and outcome constructs and indicators.

**Table A7.** Output and outcome constructs, definitions, and indicators for literacy, impact, performance, and equity within the SIF.

| Construct | Indicator (Code) | Definition | Formula/Scoring | Direction | Primary Data Sources and Frequency |
|---|---|---|---|---|---|
| Sustainability Literacy (CPI) | Graduate literacy attainment (CPI-OUT1) | Share of graduates demonstrating agreed ESD competencies. | (%) graduates ≥ benchmark = (graduates meeting standard ÷ assessed graduates) × 100. Benchmark = rubric in Appendix E. | Higher = better | Graduate exit assessments; program QA records; annual. |
| | Faculty ESD PD completion (CPI-OUT2) | Share of faculty completing ESD-focused PD aligned to program needs. | (%) PD completion = (faculty w/≥1 verified ESD PD in last 24 months ÷ total faculty) × 100. | Higher = better | HR/L and D systems; PD certificates; rolling 24-mo snapshot. |
| Research and Policy/Industry Impact (RKM) | Policy citation ratio (RKM-OUT1) | Extent to which HEI sustainability outputs inform policy. | Policy citation ratio = (# policy/strategy docs citing HEI sustainability outputs ÷ # HEI sustainability publications) × 100. | Higher = better | Policy repositories; library/altmetric logs; annual. |
| | Co-developed solutions adopted (RKM-OUT2) | Solutions created with external partners that moved to implementation. | Count adopted in year, evidenced by MoU/license/implementation note; report per SDG/theme. | Higher = better | Tech transfer system; partnership MoUs; annual. |
| Operational Performance (OSRM) | Scope 1 + 2 emissions intensity change (OSRM-OUT1) | Progress in carbon management normalized for scale. | Δ intensity YoY = [($tCO_2e/m^2$ or $tCO_2e/FTE)_t - (\cdot)_{t-1}]/(\cdot)_{t-1} \times 100$. | Lower (more negative) = better | Carbon inventory; facilities; annual GHG audit. |
| | Waste diversion rate (OSRM-OUT2) | Share of waste diverted from landfill. | Diversion = ((reused + recycled + composted) ÷ total waste) × 100. | Higher = better | Waste hauler records; sustainability reports; quarterly/annual. |
| Community and Institutional Equity Outcomes (Equity lever) | Equity parity index (EQ-OUT1) | Fairness of sustainability resourcing across faculties/units. | 0–1 index = (1−) Gini of per-student sustainability spend (coverage-adjusted; Appendix E). | Higher = better | Finance data; unit budgets; annual. |
| | Global South/underserved collaboration coverage (EQ-OUT2) | Extent of partnerships with Global South or underserved communities. | Coverage = (projects with qualifying partners ÷ total sustainability projects) × 100. | Higher = better | Project registry; partnership database; annual. |

| | | | | | |
|---|---|---|---|---|---|
| Stakeholder Engagement and Legitimacy (SESR—outputs; outside RMI) | SESR coverage (SESR-OUT1) | Breadth of co-created SESR activity across the institution. | 0–1 = faculties (or programs *) with ≥1 co-created initiative + public results note in past 12 months ÷ total faculties (or programs *). | Higher = better | SESR registry; public results notes (URL/date); annual. |
| | SESR transparency (SESR-OUT2) | Visibility and auditability of SESR evidence. | 0/0.5/1.0: 1.0 if methods + downloadable data + partner list + update ≤90 days; 0.5 if ≥3 elements or update ≤180 days; else 0.0. | Higher = better | Public SESR page/dashboard; quarterly check. |
| | SESR Gate Index (SGI) | Single engagement score used for readiness gates in Section 7.2. | SGI = average(SESR-OUT1, SESR-OUT2) on 0–1 scale. Gate: Level ≥ 3 in any RMI domain requires SGI ≥ 0.60; Level 4 requires SGI ≥ 0.75. | Higher = better | Computed from SESR-OUT1/2; see Sections 7.1–7.2. |

*Note.* The dual coding of internal SESR structures within the Leadership and Governance and Strategy domains is described in Section 6.3 and Table 1. * *Select either faculties or programs as the unit of analysis, declare that choice, and use the same unit in the numerator and denominator.*

## Appendix E. SIF Data Template and Indicator Dictionary

The Sustainability Integration Framework (SIF) translates institutional sustainability into measurable, readiness-based constructs. This appendix details the operational data architecture supporting the SIF and Readiness and Maturity Index (RMI), outlining construct definitions, indicator formulas, scaling logic, and framework crosswalks for replication.

### *Appendix E.1. Template Structure*

The Supplementary Excel Workbook (File S1) should include one master sheet with the following columns, ensuring traceable scoring, evidence anchoring, and audit readiness:

- Construct Level: Input | Process | Output/Outcome
- Construct Name: (e.g., Leadership Commitment)
- Indicator Code/Name: (e.g., SLGA-INP1)
- Definition/Formula Stub: Explicit formula, baselines, and normalizers
- Unit and Direction: %, ratio, count, currency | Higher = better/Lower = better
- RMI Domain: Leadership and Governance | Strategy | Curriculum and Pedagogy | Metrics and Data | Operations
- IPO Stage: Input | Process | Output/Outcome
- Frequency and Scaling: Quarterly | Annual | Rolling 24 mo | 0–4 maturity rubric
- Relevant Framework Links: GRI, SASB, ISO 14001 [6] and ISO 50001 [91], STARS, AISHE, PRME, UI GreenMetric
- Evidence Link and Owner: URL/Doc ID | Responsible office
- Method Summary/Last Updated/Completeness %/Freshness (days)
- Audit Error Rate %/ETL Notes/Version ID/Notes

Include a computed **"Gate Flag (Y/N)"** for PDCA closure or **SESR Gate Index (SGI)** thresholds to support RMI progression.

*Appendix E.2. Construct Families*

- Inputs: Leadership Commitment (e.g., sustainability in strategic plan); Policy Infrastructure; Resourcing and Budget Allocation; Stakeholder Linkages.
- Processes: Governance Routines (e.g., board meetings); Curriculum Integration; Research Mobilization; Operational Levers.
- Outputs/Outcomes: Sustainability Literacy; Research and Policy/Industry Impact; Operational Performance; Community and Equity Outcomes.

All constructs use percentages, ratios, counts, intensity metrics, or 0–1 indices to enable longitudinal and cross-institutional comparison.

*Appendix E.3. Scaling and Aggregation*

Maturity Scale (0–4):

0 = No evidence; 1 = Ad hoc actions; 2 = Defined processes with limited validation; 3 = Managed implementation with measurable results; 4 = Optimized PDCA closure and routine audits.

RMI Composite Score: RMI = (sum of the five domain scores)/n,

where n = 5 domains.

Indicator → Domain Average → Overall RMI; use the *Direction* field to maintain correct polarity (e.g., lower = better).

Maintain consistent baselines across reporting cycles for comparability.

Reliability tracking (Completeness %, Freshness days, Audit Error Rate %, Version ID) ensures reproducibility and audit readiness.

These indicators serve as quantitative anchors for Propositions P2 and P4, linking routinization and feedback loops to maturity progression.

*Appendix E.4. Framework Alignment*

Each indicator includes interoperability tags linking to major frameworks:

- GRI [89]: Governance, performance, and disclosure items.
- SASB [90]: Education-sector ESG standards.
- ISO 14001 [6] and ISO 50001 [91]: PDCA and monitoring/verification alignment.
- STARS, AISHE, PRME, UI GreenMetric: Higher-education benchmarking.

Map framework codes (e.g., *GRI 2-9*, *STARS OP*, *AISHE domains*) in the "Relevant Framework Links" column to support cross-walking and external validation.

*Appendix E.5. Application and Use*

- Baseline Assessment: Populate institutional data to diagnose domain readiness and priority gaps.
- Progress Tracking: Update at set intervals and visualize PDCA cycle closures over time.
- Benchmarking: Compare normalized composite scores across HEIs, noting data boundaries.
- RMI Calibration and Analysis: Use the dataset directly for reliability checks (ICC/$\kappa$/$\alpha$), SGI computation, and readiness-gate validation.
- Assurance and Transparency: Leverage Evidence Link, Owner, and Version fields to ensure auditability and open-science compliance; apply small-cell suppression per ethics policy.

The workbook (File S1) should include computed fields for Domain Scores, Overall RMI, and the SESR Gate Index (SGI), supporting the gate rules in Section 7.2 and the indicator families in Appendix D (Tables A4–A7).

The treatment of SESR outputs as a progression gate rather than a scored domain, and their feedback into the Leadership and Governance and Strategy domains in subsequent cycles, is specified in Section 6.4 and is not repeated here.

*Appendix E.6. External Framework Normalization and Composite Readiness Scoring*

To support the External Composite Readiness index described in Section 7.3, this section provides the normalization logic and worked example used in the supplementary Excel workbook (File S1, Sheet 2: "Readiness Scoring"). The composite metric integrates publicly verifiable framework data to provide an evidence-based proxy for institutional sustainability maturity.

Appendix E.6.1. Purpose

The Composite Readiness (0–4) indicator combines five major higher-education sustainability frameworks—STARS, UI GreenMetric, PRME, ISO 14001, and AISHE—into a single normalized index. Each framework contributes a score on a 0–4 scale, and the average across available frameworks yields an overall readiness value (Table A8).

Appendix E.6.2. Normalization Rules

**Table A8.** Normalization rules for converting external framework results to the common 0–4 scale.

| Framework | Original Scale | Normalization Rule | Notes |
|---|---|---|---|
| **AASHE STARS** | Bronze = 1, Silver = 2, Gold = 3, Platinum = 4 | Use numeric equivalent directly | Official AASHE tiering |
| **UI GreenMetric** | 0–10 000 points | Divide by 2 500 | Maps raw points → 0–4 |
| **PRME** | Count of SIP (Sharing Information on Progress) reports | 0 = none; 1 = 1–2; 2 = 3–4; 3 = 5+; 4 = "Advanced" recognition | Reflects leadership continuity |
| **ISO 14001** | Certification scope | 0 = none; 2 = partial (unit/faculty); 4 = full campus EMS | Based on certification record |
| **AISHE** | Levels 1–5 | (AISHE Level − 1) × 1.0 | Converts 1–5 → 0–4 |

Note. Bold identifies framework names; it does not indicate statistical significance.

Normalization and weighting formulas are implemented in the Supplementary Workbook (File S1) under each column header.

Appendix E.6.3. Composite Readiness Equation

Composite Readiness = (sum of available normalized framework scores)/n,

where n = number of frameworks with available data (missing values excluded). This yields a mean between 0 and 4.

Appendix E.6.4. Readiness Strata

Table A9 defines the three Composite Readiness strata.

**Table A9.** Composite Readiness strata.

| Composite Score | Stratum | Description |
|---|---|---|
| 0–1.49 | Early (Symbolic) | Isolated or rhetorical initiatives |
| 1.50–2.49 | Intermediate (Developing) | Structured programs, partial integration |
| ≥ 2.50 | Advanced (Systemic) | Institution-wide sustainability integration |

This three-tier scheme (Table A9) mirrors conventional maturity-model logic (e.g., CMMI levels 0–4) and RMI readiness strata (Section 7.3).

*Appendix E.7. Calculation and Reliability Notes*

This section consolidates the computation logic for two core performance measures, Composite Readiness (0–4) and the Average Domain Score (RMI), along with reliability metrics used to verify scoring consistency.

Appendix E.7.1. Purpose

This sheet operationalizes scoring formulas, thresholds, and reliability metrics to ensure replication, transparency, and statistical validation of the SIF's readiness architecture.

Appendix E.7.2. Composite Readiness (0–4)

**Purpose:** Provides an *external* benchmark for sustainability maturity using five frameworks (STARS, UI GreenMetric, PRME, ISO 14001, AISHE).

Normalization rules and readiness strata are specified once, in Tables A8 and A9 (Appendix E.6), and apply here without modification.

Appendix E.7.3. Average Domain Score (RMI)

- Purpose: Aggregates internal institutional performance across the five RMI domains: Leadership and Governance, Strategy, Curriculum and Pedagogy, Metrics and Data, Operations.
- Interpretation: Readiness strata as defined in Table A9 and Section 7.3; the rationale for the cut-points is given in Section 7.3 (aggregation assumptions).

Appendix E.7.4. Reliability Metrics

**Purpose:** Validate inter-rater and internal consistency of RMI scoring.

1. Cohen's Kappa (κ): agreement on categorical (Stratum) values
   - Formula: $\kappa = (P_o - P_e)/(1 - P_e)$; Targets ≥ 0.60
2. Cronbach's Alpha ($\alpha$): internal consistency across 5 RMI domains
   - Target ≥ 0.70 (acceptable for exploratory validation)
3. Intraclass Correlation Coefficient (ICC): agreement in domain scores
   - Target ≥ 0.70 (consistent with Section 7.3 and Appendix H)

These metrics can be computed in SPSS, R, or Python using standard reliability functions. These are proposed options for future validation; no software version is specified because these reliability analyses have not yet been conducted. The software and package versions will be reported when the analyses are implemented.

Appendix E.7.5. Alignment Between Composite and RMI Scores

- Optional Validity Check:
  Correlate "Composite Readiness" (File S1, Sheet 2) and "Average Domain Score" (File S1, Sheet 3) using Pearson r.
- Expected Result: $r \approx 0.7–0.9 \rightarrow$ strong alignment between external (framework-based) and internal (RMI-based) measures.
- Visualization Suggestion: Scatter plot (Composite Readiness vs. RMI Average) with regression line.

Cross-references: Sections 7.1 and 7.3 (RMI domains and Composite Readiness); Section 7.3 and Appendix H (reliability and data quality).
Formulas are pre-coded in the Supplementary Workbook (File S1, Sheets 2 and 3).

**Final note:**

This appendix provides a reproducible operational backbone linking the conceptual SIF model (Section 4), mechanism logic (Section 5), IPO process (Section 6), and empirical readiness measurement (Sections 7–9). It enables full transparency, replication, and longitudinal comparison across HEIs.

## Appendix F. Alignment of SIF Components with RMI Domains and IPO Constructs

Table A10 aligns the SIF components with their theoretical anchors, RMI domains, and IPO constructs.

**Table A10.** Alignment of SIF components with theoretical anchors, RMI domains (internal readiness), and IPO constructs, with typical measurement focus/indicators.

| SIF Component | Primary Theoretical Anchor | RMI Domain (Internal Readiness) | IPO Construct (Process/Output) | Measurement Focus/Typical Indicators |
|---|---|---|---|---|
| Strategic Leadership and Governance Alignment (SLGA) | Responsible Leadership | Leadership and Governance | Input/Process | Executive commitment, sustainability mandates, accountability systems, leadership sense-making |
| Curriculum and Pedagogical Innovation (CPI) | Institutional and Learning Theories | Curriculum and Pedagogy | Process/Output | Integration of sustainability competencies, interdisciplinary design, faculty training, experiential learning |
| Research and Knowledge Mobilization (RKM) | Resource-Based Theory (RBT) | — (Linked to Strategy and Metrics) | Process/Output | Cross-disciplinary collaboration, policy engagement, applied research partnerships |
| Institutional Policies and Accountability Mechanisms (IPAM) | Institutional Theory (IT) | Metrics and Data | Process | KPI systems, audit routines, data governance, reporting transparency |
| Operational Sustainability and Resource Management (OSRM) | Resource-Based Theory/Continuous Improvement (CMMI, PDCA) | Operations | Process/Output | Energy, waste, procurement, carbon management, circular-resource efficiency |
| Stakeholder Engagement and Societal Responsibility (SESR) | Responsible Leadership/Institutional Legitimacy | Bridging Mechanism (reflected in Leadership and Strategy domains) | Output/Outcome | Internal and external engagement structures, community partnerships, trust, co-created knowledge, societal impact |

**Explanatory Note**

- The Stakeholder Engagement and Societal Responsibility (SESR) component functions as a boundary-spanning mechanism rather than a discrete readiness domain. Grounded in Responsible Leadership, SESR integrates participatory engagement across internal stakeholders (faculty, students, and staff) and external actors (communities, industry, policymakers).
- Its enabling conditions, such as governance mandates, leadership accountability, and participatory inclusion, are assessed within the Leadership and Strategy domains of the RMI.
- Its outcomes, trust, co-created knowledge, and societal legitimacy, are captured through the IPO model's Output and Outcome indicators (Section 6.3).

- This alignment preserves conceptual integrity between SIF's systemic architecture and the RMI's internal readiness logic, ensuring that institutional maturity and societal responsibility remain linked through a unified feedback mechanism.

## Appendix G. Proposition–Indicator Crosswalk (IPO ↔ RMI)

Table A11 maps propositions P1–P5 to the corresponding theoretical lenses, RMI domains, IPO stages, and indicators.

**Table A11.** Proposition–indicator crosswalk (IPO ↔ RMI): mapping SIF propositions (P1–P5) to theoretical lenses, relevant RMI domains, IPO stage, and illustrative indicators.

| Proposition ID | Proposition (Verbatim from Section 5.2) | Underlying Theoretical Lens | Relevant RMI Domain(s) | IPO Construct (Stage) | Illustrative Indicators (Appendix D Codes) |
|---|---|---|---|---|---|
| P1 | Sustainability pressures drive organizational change only when leaders interpret them and translate them into aligned governance arrangements and resource commitments. | Institutional Theory (IT) + Responsible Leadership (RL) | Leadership and Governance, Strategy | Input → Process | SLGA-INP1 Leadership KPI coverage; SLGA-INP2 Executive mandate and budget authority; STR-INP1 Sustainability budget ratio; STR-INP2 Multi-year earmark coverage. External pressure is proxied by the External Composite Readiness index (Appendix B, "External Composite Readiness"). |
| P2 | Sustainability moves beyond symbolic commitment when it becomes embedded in monitoring systems, accountability structures, and everyday routines. | Institutional Theory + Resource-Based Theory (RBT) | Metrics and Data, Operations, Leadership and Governance | Process → Output | IPAM-INP1 Policy stack completeness; IPAM-INP2 Policy review discipline; SLGA-PROC1 Governance cadence with quorum; IPAM-PROC1 PDCA close-rate. Outcomes: OSRM-OUT1 Scope 1 + 2 emissions intensity change; OSRM-OUT2 Waste diversion rate. |
| P3 | Equity, inclusion, and legitimacy shape the durability of sustainability integration by influencing trust, participation, and institutional accountability. | Responsible Leadership + Institutional Theory | Strategy, Leadership and Governance, Metrics and Data | Input → Output | EQ-OUT1 Equity parity index; EQ-OUT2 Global South/underserved collaboration coverage; SESR-OUT1 SESR coverage; SESR-OUT2 SESR transparency; SGI. |

| | | | | | |
|---|---|---|---|---|---|
| P4 | Progress toward systemic integration depends on feedback processes that trigger corrective action and support institutional learning. | Resource-Based Theory + Continuous Improvement Logic [15] | Metrics and Data, Operations, Leadership and Governance | Process → Output → Feedback | IPAM-PROC1 PDCA close-rate; OSRM-PROC2 M and V compliance for operations projects; CPI-PROC2 Curriculum refresh interval; change in domain scores between $T_1$ and $T_2$ (computed fields, File S1). |
| P5 | Systemic integration emerges when academic and operational domains are structurally linked through shared metrics, aligned governance, and coordinated routines. | Resource-Based Theory + Systems Theory/Responsible Leadership | Curriculum and Pedagogy, Operations, Metrics and Data, Strategy | Process → Output | CPI-PROC1 Program ESD coverage; RKM-PROC1 External co-authorship share; OSRM-PROC1 Sustainable procurement penetration; CPI-OUT1 Graduate literacy attainment; RKM-OUT2 Co-developed solutions adopted; OSRM-OUT1 Scope 1 + 2 emissions intensity change (tested as an academic × operational interaction). |

**Interpretive Notes**

1. Mechanism mapping: each proposition corresponds to a testable segment of the SIF mechanism (Pressure → Interpretation → Reconfiguration → Routinization → Feedback Closure → Coupling/Decoupling).
2. Indicator Anchoring: Indicator IDs reference detailed operational definitions in Appendix D (Tables A4–A7).
3. Temporal Sequencing: Inputs precede processes and outputs, aligning measurement with PDCA gating to ensure evidence of consolidation before progression.
4. Integration with RMI: Indicators feed directly into domain-level RMI scoring, enabling quantitative validation of each proposition's theoretical pathway.
5. Empirical Application: During validation (Section 9), these linkages guide hypothesis testing through correlational and path-analysis models linking RMI scores to IPO outcomes.

## Appendix H. Validation and Analysis Protocol

*Measurement.* The RMI scores the five domains with constructs aligned to P1–P5 (Appendix G); scoring and inter-rater adjudication follow Section 7.3. An IPO-derived KPI panel adds seven indicators aligned with GRI [89] and SASB [90], covering governance transparency, sustainability literacy, interdisciplinary research funding, operational efficiency, and community impact, with formulas and sources in Appendix D. Mechanism probes use 8 to 12 semi-structured interviews, process tracing of minutes and policy documents, and, if needed, a stakeholder micro-survey.

*Analysis.* A convergent parallel mixed-methods design [92] triangulates the strands. Quantitative analysis computes pre-post deltas with 95% confidence intervals. Where multiple timepoints or staggered implementations exist, Difference-in-Differences or Interrupted Time Series models with cluster-robust standard errors assess incremental change. Qualitative evidence is analyzed through realist coding for context–mechanism–

outcome patterns that test the pathway (Pressure to Interpretation to Resource Reconfiguration to Routinization to Feedback Closure to Coupling). Findings merge into joint displays so that results can be interpreted in mechanism terms rather than as correlations alone.

*Reliability and data quality.* Thresholds are inter-rater ICC ≥ 0.70 for continuous domain scores, Cohen's $\kappa \geq 0.60$ for categorical judgments, and Cronbach's $\alpha \geq 0.70$ for composite indices, each reported with 95% confidence intervals. ETL quality checks track completeness, freshness, and audit error rates (target ≤ 5%). All transformations and adjudication decisions are logged with version control, and sensitivity analyses test robustness with and without outliers or imputed values.

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