GGGI

Global Green Growth Index 2.0

Concepts and Methods for Assessing Green Growth
Performance, Potential, and Pathways

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Part of GGGI's technical guidelines series

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ACKNOWLEDGEMENTS

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ACRONYMS AND ABBREVIATIONS

AB	Access to Basic Services and Resources
AFOLU	Agriculture, Forestry, and Other Land Use
APEC	Asia-Pacific Economic Cooperation
BE	Biodiversity and Ecosystem Protection
CO2	Carbon Dioxide
CPF	Country Planning Frameworks
CV	Cultural and Social Value
DALY	Disability-Adjusted Life Year
DBSCAN	Density-Based Clustering Method
EE	Efficient and Sustainable Energy
EQ	Environmental Quality
ESRU	Efficient and Sustainable Resource Use
EW	Efficient and Sustainable Water Use
GB	Gender Balance
GDP	Gross Domestic Product
GE	GHG Emissions Reduction
GEO	Green Economic Opportunities
GESI	Gender Equality and Social Inclusion
GGGI	Global Green Growth Institute
GGKP	Green Growth Knowledge Partnerships
GGPM	Green Growth Performance Measurement
GHG	Greenhouse Gas
GJ	Green Employment
GN	Green Innovation
GNI	Gross National Income
GRI	Green Recovery Index
GT	Green Trade
GV	Green Investment
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
IQR	Interquartile range
LDC	Least Developed Countries
LUCF	Land Use Change and Forestry
ME	Material Use Efficiency
NCP	Natural Capital Protection
NDC	National Determined Contributions
OECD	Organisation for Economic Co-operation and Development
OECS	Organisation of Eastern Caribbean States
PA	Protected Area
PM2.5	Particulate matter with a diameter of less than 2.5 micrometers
SDGs	Sustainable Development Goals
SE	Social Equity
SI	Social Inclusion
SIDs	small island developing states
SL	Sustainable Land Use
SO	GGGI's Strategic Outcome
SP	Social Protection

EXECUTIVE SUMMARY

The Green Growth Index 2.0 provides an updated and expanded methodological framework for assessing countries' progress toward green, inclusive, and resilient development.
Building on the conceptual foundations and core structure established in the 2019 Green Growth Index Technical Report, the Index retains its four-dimensional framework while extending its analytical scope beyond level-based performance measurement. Green Growth Index 2.0 introduces a complementary assessment of green growth potential to capture recent transition momentum, and integrates performance and potential into a pathway-based framework that characterizes patterns of green growth transition across countries. This Technical Guideline documents the concepts, data structures, and analytical methods underpinning these developments, with an emphasis on transparency, comparability, and methodological coherence. It details the preparation and validation of indicator databases, normalization and aggregation procedures, robustness and sensitivity analyses, and expert validation processes applied consistently across performance, potential, and pathway components.

The guideline is designed as a technical reference to support replication, adaptation, and responsible application of the Green Growth Index at global, regional, and national levels.
Consistent with this technical purpose, it does not present country results or policy conclusions; instead, it provides a rigorous methodological basis for analysis, comparison, and informed policy dialogue. The methodological framework builds directly on the approach documented in the 2019 Technical Report, the first publication of the Green Growth Index, ensuring continuity and comparability across successive applications of the Index. A clear conceptual distinction is maintained between green growth performance, which measures levels of achievement relative to sustainability benchmarks, and green growth potential, which reflects recent transition momentum derived from growth-rate dynamics. This distinction responds to empirical evidence that countries with similar performance levels may exhibit markedly different patterns of recent progress. Green growth pathways are introduced as an integrative lens that combines performance and potential to characterize transition dynamics in a structured and interpretable manner, without implying scenario-oriented prediction or policy prescription.

The measurement of green growth performance provides a systematic assessment of countries' levels of achievement
across the four dimensions of green growth (i.e., efficient and sustainable resource use, natural capital protection, green economic opportunities, and social inclusion), building on the indicator framework established in earlier editions of the Index. Performance indicators reflect outcomes relative to sustainability benchmarks or normative reference values and are normalized using distance-to-target methods to ensure interpretability and cross-country comparability. Aggregation follows a transparent and consistent structure across pillars and dimensions, preserving balance across thematic areas while limiting undue influence from individual indicators. Particular attention is paid to data preparation, indicator directionality (i.e., positive or negative

relationship with green growth), and handling missing or extreme values to ensure the robust of the results. Performance scores are subject to robustness checks and validation procedures, including sensitivity analysis and expert review, which assess the stability and plausibility of country scores and rankings without altering the underlying methodology. The performance index provides a stable reference point for interpreting transition dynamics and growth potential.

The assessment of green growth potential extends the Index beyond level-based measurement by capturing recent transition momentum through growth-rate analysis.
Potential indicators are derived from time-series data on green growth performance indicators and reflect changes in green growth outcomes over recent years rather than absolute achievement levels. To ensure comparability across indicators and countries, growth rates are prepared by transforming data, smoothing, and handling extreme values, recognizing the greater volatility inherent in growth-based measures. Potential scores are normalized using peer-group benchmarking (i.e., income groups) rather than global reference values (i.e., sustainability targets), reflecting the relative and context-dependent nature of transition momentum. Aggregation procedures mirror those applied to performance indicators to maintain internal consistency. Validation focuses on the plausibility, coherence, and interpretability of growth dynamics across peers and over time, supported by expert judgement and graphical analysis. The potential index complements performance assessment by providing a comparative representation of recent green growth dynamics.

Green growth pathways provide an integrative analytical framework for jointly interpreting green growth performance and potential.
By positioning countries within a two-dimensional performance–potential space, pathways characterize distinct patterns of transition dynamics that reflect the interaction between current achievement levels and recent momentum. Four quadrant-based pathways are identified: (A) Leaders in Motion, (B) Achievers Losing Momentum, (C) Emerging Improvers, and (D) Slow Movers. Pathways are defined using consistent classification rules and interpreted as descriptive, relative patterns rather than predictive dynamics. Analysis of pathway dynamics over time highlights the "non-linear and reversible" nature of green growth transitions and supports peer-based learning and structured interpretation of heterogeneity across countries. This reflects the reality that green growth transitions can accelerate, stall, or reverse over time, depending on policy choices, external conditions, and structural contexts, rather than following a fixed or linear progression. The policy relevance of pathways lies in framing dialogue around transition momentum and structural constraints, without prescribing policy actions or implying causal relationships.

Stakeholder participation is embedded throughout the design, validation, and interpretation of the Green Growth Index.
Engagement is treated as a core design requirement rather than a

communication add-on, ensuring that the Index reflects policy relevance, technical credibility, and contextual knowledge while maintaining analytical rigor and comparability. A structured and iterative engagement process is applied to conceptual framing, indicator screening, data and methods validation, and design-stage interpretation of results, with clearly defined roles for international expert groups, regional institutions, national government experts, technical partners, and scientific and thematic experts. This engagement framework supports the application of the Index at global, regional, and national levels, including benchmarking, trend analysis, country planning frameworks, academic research, and evidence-based dialogue. Regional and peer-group applications translate global insights into more context-specific comparisons, while national applications emphasize participatory analysis and capacity building to inform green growth strategies and planning processes. Across all application levels, clear analytical boundaries and principles for responsible use are emphasized, clarifying what the Index can and cannot be used for and helping users avoid over-interpretation of results beyond their analytical scope.

The Green Growth Index addresses analytical challenges inherent to composite indices and cross-country assessment.
Key challenges relate to data availability and quality, cross-country comparability, aggregation and weighting choices, interpretation of results, and the use of forward-looking analysis. These challenges are addressed through indicator screening, data validation, robustness checks, and structured stakeholder engagement embedded throughout the design and application of the Index. At the same time, limitations remain, particularly those related to uneven data coverage and differences in institutional and analytical capacity across countries. To address these constraints, the Index is developed in close collaboration with technical partners and data specialists to improve global and national databases, and capacity building is treated as an integral component of national applications. By clearly identifying both challenges and mitigation measures, the Index strengthens transparency, analytical credibility, and informed use of results. To further support transparency and responsible use, the Index is accompanied by an open evidence library that enables users to download the underlying databases and access GitHub repositories containing the Index models and programming codes.

The Green Growth Index 2.0 provides a coherent and robust analytical framework for assessing green growth performance and dynamics across countries and over time.
Through continuous refinement of its conceptual framework, methods, and data foundations, the Index has evolved to enhance its relevance for policy-oriented and academic analysis. The integration of performance assessment with complementary analysis of potential and pathways under Green Growth Index 2.0 strengthens comparative assessment, structured interpretation, and multi-sectoral dialogue, while maintaining methodological consistency. The structured design process and multi-stakeholder engagement underpin the Index's credibility and policy relevance. Continued collaboration with technical partners, data specialists, and national institutions, together with sustained capacity building, will be essential to further improve data quality, analytical robustness, and effective use of the Green Growth Index across global, regional, and national applications.
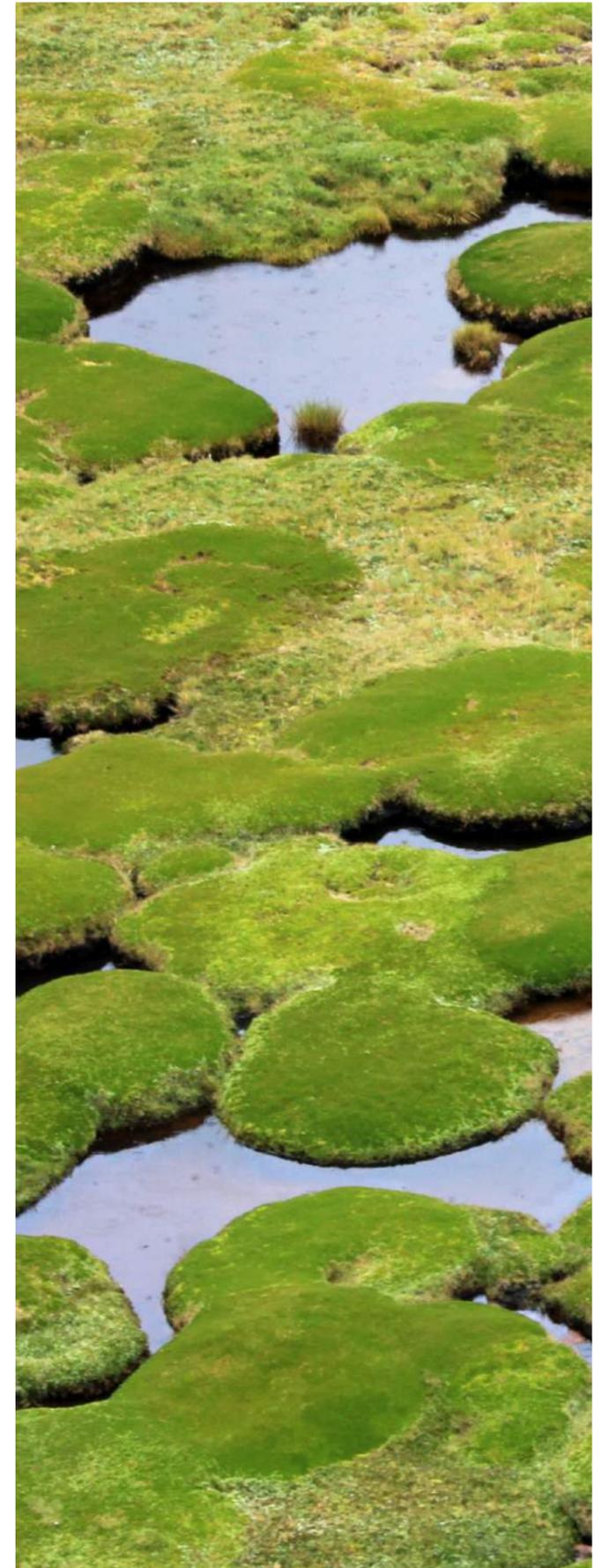
INTRODUCTION

1.1. History

The Green Growth Index was developed by the Global GreenGrowth Institute (GGGI) to provide a systematic and policy-relevant tool for measuring countries' progress toward green, inclusive, and resilient development. The initial conceptual and methodological frameworks of the Index were established through a multi-year consultative process between 2016 and 2019, involving international experts, regional stakeholders, and national practitioners. This process culminated in the publication of the *Green Growth Index Technical Report* in 2019,[1] which documented the concepts, indicator framework, and methods underpinning the Global Green Growth Index and its applications at global and national levels. The original Green Growth Index was framed around four interlinked dimensions, including efficient and sustainable resource use, natural capital protection, green economic opportunities, and social inclusion, reflecting GGGI's definition of green growth as a development pathway that delivers economic growth while maintaining environmental sustainability and social inclusiveness. These dimensions were perationalized using a structured set of indicators selected on the basis of scientific evidence, expert judgment, and policy relevance. The indicators were benchmarked against internationally recognized sustainability targets, including the Sustainable Development Goals, the Paris Agreement, and biodiversity-related targets.

Between 2019 and 2024, the conceptual framework and core methodology described in the 2019 Green Growth Index Technical Report were consistently applied to produce the annual Global Green Growth Index and to develop national Green Growth Indices. Over this period, repeated applications of the Index supported the assessment of countries' relative performance and their distance to sustainability targets, as well as cross-country comparison and policy dialogue. At the same time, practical application revealed limitations inherent in a performance-only approach, particularly in its ability to capture recent progress, emerging momentum, and differences in the pace of green growth transitions. In response to these observations, and building on the experience gained through successive applications, GGGI developed the Green Growth Index 2.0. Introduced and applied for the 2025 edition of the Global Green Growth Index, this updated framework retains the original four-dimensional structure to ensure continuity and comparability over time. At the same time, it extends the analytical scope of the Index by complementing performance measurement with an assessment of green growth potential based on recent growth trends in indicators, and by explicitly characterizing green growth pathways that link current performance to transition momentum.

This Technical Guideline updates the methodological documentation presented in the 2019 Green Growth Index Technical Report by describing the concepts, data structures, and analytical methods underpinning Green Growth Index 2.0. It reflects the evolution of the Index in response to empirical application and methodological refinement, while maintaining consistency with the foundational principles that have guided the Green Growth Index since its inception. In line with its technical purpose, the guideline does not present country results or rankings, but instead provides methodological guidance to support transparent application, replication, and adaptation of the Green Growth Index 2.0 at global, regional, and national levels.

1.2. Purpose and Scope

The purpose of this Technical Guideline is to provide a comprehensive, up-to-date methodological reference for the Green Growth Index 2.0. It builds on the conceptual and methodological foundations documented in the 2019 Green Growth Index Technical Report and reflects refinements introduced through successive applications of the Index between 2019 and 2024. During this period, the Index was applied annually at the global level and adapted for use in regional and national contexts, generating practical experience that informed further methodological development. In particular, this guideline responds to the need to complement the assessment of green growth performance with additional analytical elements that capture recent progress and differences in the pace of green growth transitions. The guideline is intended to support transparent and consistent implementation of the Green Growth Index 2.0 by clearly documenting the underlying concepts, indicator structures, data preparation steps, and analytical methods. It is designed for analysts, researchers, and policy practitioners involved in producing global, regional, or national Green Growth Indices, as well as for by users seeking to understand the Index's methodological basis. Consistent with its technical orientation, the guideline focuses on methods and procedures rather than interpretation of results, and it does not present country scores, rankings, or policy conclusions.

The scope of this Technical Guideline covers the complete set of conceptual and methodological components required to operationalize the Green Growth Index 2.0. This includes the four-dimensional green growth framework, principles for indicator selection and classification, data sources and preparation, and methods for measuring green growth performance, assessing green growth potential, and characterizing green growth pathways. The guideline also documents the normalization, benchmarking, aggregation, and validation procedures applied to ensure comparability and methodological soundness across countries and over time. The methods described apply to the Global Green Growth Index, regional assessments, and national Green Growth Indices, and are flexible to accommodate differences in data availability while preserving consistency with the core framework. At the same time, the guideline explicitly defines its limits. It does not provide detailed indicator metadata, country-level analysis, policy recommendations, or forward-looking projections. These elements are addressed in a complementary summary report[2], metadata report,[3] and online dashboard (https://greengrowthindex.gggi.org/). By delineating its scope in this way, the guideline serves as a technical reference that supports replication, adaptation, and further development of the Green Growth Index 2.0, while maintaining continuity with the methodological principles established in earlier work by the GGGI and its international partners. Since its initial publication, the Green Growth Index has been applied and reviewed in collaboration with an expanding set of international and national partners, contributing to methodological refinement through diverse application contexts.

1.3. Structure of the Report

This Technical Guideline is structured to guide the reader through the conceptual foundations, methodological components, and applications of the Green Growth Index 2.0 in a logical, sequential manner. The report's structure reflects the analytical steps required to design, implement, validate, and apply the Index in a transparent and consistent manner. It begins with conceptual clarification and progresses through data preparation and measurement, before addressing stakeholder participation, applications, challenges, and conclusions. This structure allows readers to engage selectively with sections most relevant to their analytical or policy needs, while maintaining a coherent narrative across chapters.

Following this introductory chapter,

Chapter 2
presents the analytical frameworks underpinning the Green Growth Index, including the conceptual framework that defines green growth and the methodological framework for operationalizing it through dimensions, pillars, and indicators.

Chapter 3
describes the data and methods applied to construct the Index. It covers data sources and preparation, measurement of green growth performance, assessment of green growth potential, characterization of green growth pathways, and the associated procedures for transformation, normalization, aggregation, and validation.

Chapter 4
focuses on stakeholder participation and policy applications. It documents the principles and processes guiding stakeholder engagement in the design and interpretation of the Index. It explains how the Green Growth Index is applied at global, regional, and national levels, including the extended potential and pathways analysis introduced under Green Growth Index 2.0.

Chapter 5
discusses key challenges and limitations associated with composite index construction and cross-country assessment, and outlines measures to address them through methodological design, validation, data improvement, and capacity building.

Chapter 6
concludes the guideline by synthesizing the main methodological insights and highlighting considerations for the continued refinement and responsible application of the Green Growth Index across different contexts.

Overall, the report's structure is designed to support a clear understanding, replication, and appropriate use of the Green Growth Index 2.0 by analysts, researchers, and policy practitioners working with the Index.

Figure 1. Conceptual Framework of the Green Growth Index

ANALYTIC FRAMEWORKS

This chapter presents the analytical frameworks that underpin the design and implementation of the Green Growth Index. It clarifies the conceptual foundations of green growth and outlines the methods for translating this concept into a structured framework of dimensions, pillars, and indicators. The chapter establishes the analytical logic that guides indicator selection, aggregation, and interpretation, and provides the basis for consistent measurement across countries and over time. By defining the conceptual, indicator, and methodological underpinnings of the Index, the chapter sets the groundwork for the data preparation, measurement, and validation procedures described in Chapter 3.
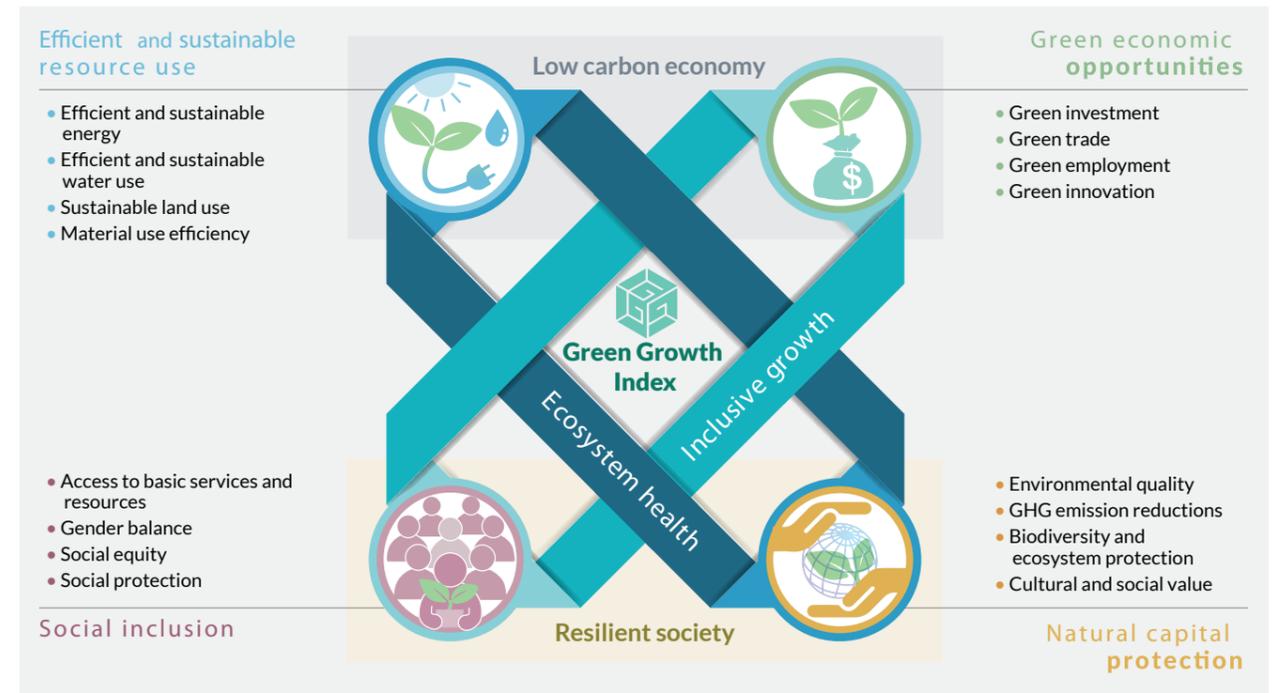
2.1. Conceptual Framework

Green Growth Index 2.0 is grounded in GGGI's definition of green growth, which conceptualizes it as a development approach that seeks to deliver economic growth that is both environmentally sustainable and socially inclusive. Green growth emphasizes pursuing economic development pathways that are low-carbon and climate-resilient, prevent or remediate pollution, maintain healthy and productive ecosystems, create green jobs, reduce poverty, and enhance social inclusion.[4] This definition reflects the understanding that economic, environmental, and social objectives are not competing goals, but mutually reinforcing elements of sustainable development. Within the Green Growth Index, green growth is therefore treated as a multidimensional concept that integrates economic performance with environmental sustainability, social

inclusion, and resilience to long-term risks and shocks. The conceptual framework of the Green Growth Index is structured around four closely interlinked dimensions: efficient and sustainable resource use, natural capital protection, green economic opportunities, and social inclusion (Figure 1). These dimensions provide a comprehensive representation of the key pillars for assessing green growth across countries and over time. Efficient and sustainable resource use captures the management of energy, water, land, and materials to support long-term productivity. Natural capital protection reflects the conservation and sustainable use of ecosystems and biodiversity. Green economic opportunities focus on investment, innovation, employment, and trade associated with green sectors. Social inclusion addresses access to basic services, equity, gender balance, and social protection. As illustrated in Figure 1, these four dimensions are interconnected through the overarching concepts of a low-carbon economy, ecosystem health, inclusive growth, and a resilient society, highlighting the integrated nature of green growth.

The conceptual framework applied in Green Growth Index 2.0 remains unchanged from that presented in the 2019 Green Growth Index Technical Report. Maintaining this continuity ensures comparability of results over time and across successive applications of the Index at global, regional, and national levels. By preserving the same core dimensions and conceptual logic, the Index allows users to track progress consistently while incorporating methodological refinements in measurement and analysis. This continuity also supports the application of the framework in regional and national contexts by maintaining alignment with the

global structure, enabling cross-country comparison while allowing indicators to be adapted to regional and national circumstances. Within the Green Growth Index, the conceptual framework serves several essential functions. It provides the basis for selecting and organizing indicators in a coherent and policy-relevant manner, ensuring that measurement reflects the multidimensional nature of green growth. It also structures the interpretation of results by clarifying how different aspects of green growth relate to one another within an integrated system. Finally, the framework ensures coherence across global, regional, and national applications of the Index by providing a standard conceptual reference that underpins all analytical components. In this way, the conceptual framework provides the foundation for the methodological and indicator frameworks of Green Growth Index 2.0.

2.2. Indicator Framework

The indicator framework of the Green Growth Index 2.0 provides the operational bridge between the conceptual framework described in Section 2.1 and the analytical methods presented in Section 2.3. While the conceptual framework defines what is meant by green growth, the indicator framework specifies how this concept is represented empirically through a structured set of measurable variables. Indicators are organized in a hierarchical structure comprising dimensions, pillars, and indicators, ensuring coherence between the conceptual foundations of green growth and its empirical representation. The four dimensions defined in the conceptual framework represent the The four dimensions defined in the conceptual framework represent the main components of green growth, while pillars serve as thematic groupings that organize related indicators within each dimension (Figure 1). This hierarchical structure ensures that the multidimensional nature of green growth is preserved as it moves from conceptual definition to measurement. By structuring indicators in this way, the

framework supports systematic aggregation of information, providing a clear foundation for subsequent analytical steps.

Indicators included in the Green Growth Index are selected based on clearly defined criteria to ensure their relevance, comparability, and applicability across countries and over time. Selection is guided by conceptual alignment with the green growth framework, relevance to the Sustainable Development Goals (SDGs), and responsiveness to priorities identified by GGGI Member Countries and Partners. Indicators are further required to support international comparison by covering a broad set of countries, including developing and least developed countries, and to allow performance benchmarking against established sustainability targets. Practical considerations play a central role in the selection process, including the availability of publicly accessible online data sources and sufficient time-series coverage from 2010 onward. Final indicator selection is validated through expert review and approval by the Green Growth Index international expert group, ensuring that the indicator set collectively and coherently reflects the multiple dimensions of green growth.

Expert consultation plays an important role in selecting and validating the indicators used in the Green Growth Index. Throughout the development and refinement of the indicator framework, international experts, sector specialists, and national practitioners have been engaged to review the conceptual relevance, technical soundness, and practical applicability of proposed indicators. These consultations help ensure that indicators remain meaningful across diverse development contexts and policy environments and adequately reflect evolving priorities related to green growth. Expert input is also used to identify gaps, overlaps, and potential improvements in the indicator framework, contributing to its iterative refinement over time. While quantitative criteria such as data availability and consistency remain essential, expert judgment provides

an additional layer of validation, strengthening the analytical credibility and policy relevance of the Index. Annex 1 presents the evolution of the indicator framework in the Global Green Growth Index since 2019, highlighting how annual expert reviews informed the replacement of proxy variables with more relevant green growth indicators and the addition of contemporarily relevant indicators, such as gender, circular economy, and innovation.

The indicator framework is designed to support the consistent application of the Green Growth Index 2.0 at global, regional, and national levels, while allowing some flexibility to address data constraints. For global assessments, a common set of indicators is applied to maximize cross-country comparability. At the national level, adaptations may be necessary to reflect differences in data availability or country-specific contexts, including the use of proxy indicators where appropriate. Such adaptations are guided by the principle that the core structure of dimensions and pillars should be preserved, ensuring that indicators remain analytically compatible with the methods used to assess green growth performance, potential, and pathways. In this way, the indicator framework provides the necessary inputs for the methodological framework described in the following section, which specifies how indicators are used to construct the analytical components of the Green Growth Index 2.0.

2.3. Methodological Framework

Building on the indicator framework described in the preceding section, the methodological framework of the Green Growth Index 2.0 defines how indicators are used analytically to measure, compare, and interpret green growth across countries and over time. While the indicator framework specifies the structure and content of the indicators included in the Index, the methodological framework establishes the analytical steps through which these indicators are combined and interpreted systematically and transparently. The methodological framework is designed to ensure that indicators representing different dimensions and pillars of green growth are integrated coherently, enabling the consistent assessment of broad policy objectives related to economic growth, environmental sustainability, social inclusion, and resilience. By clearly defining the relationships between indicators and analytical processes, the framework supports aggregation and disaggregation of results at different levels of detail, while preserving internal coherence across the Index. It also provides the basis for ensuring comparability across countries with diverse development contexts and data environments, and for maintaining consistency in application over time. Green Growth Index 2.0 comprises three interrelated analytical components: green growth performance, green growth potential, and green growth pathways, as defined in Box 2.1. Green growth performance assesses the current level of achievement of countries relative to sustainability benchmarks across the four dimensions of the Index (Figure 1). Green growth potential complements this assessment by capturing recent progress and the pace of change in underlying indicators, independent of current performance levels. Green growth pathways relate performance and potential by jointly considering levels of achievement and recent progress, thereby characterizing patterns of green growth transition across countries. Together, these three components provide a more comprehensive analytical perspective, allowing the Index to reflect both current status and transition dynamics. The combined use of these components enables differentiation between countries that have achieved high levels of performance,

those that are progressing rapidly from lower starting points, and those facing persistent challenges in both aspects. The interlinkages among performance, potential, and pathways are illustrated in Figure 2, which highlights their complementary roles within the overall methodological framework of Green Growth Index 2.0.

The methodological framework of Green Growth Index 2.0 builds directly on the approach documented in the 2019 Green Growth Index Technical Report, ensuring continuity and comparability across successive applications of the Index. The methods used to measure green growth performance remain consistent with earlier editions, preserving the established structure of dimensions, pillars, and indicators. The introduction of green growth potential and pathways extends the analytical scope rather than changing the underlying conceptual framework. These additional components respond to insights gained through repeated application of the Index between 2019 and 2024, particularly the need to capture differences in the pace and direction of progress toward sustainability goals. Experience from global and national applications demonstrated that countries with similar performance levels may exhibit markedly different patterns of recent progress, underscoring the analytical value of distinguishing between achievement levels and momentum. To clarify this distinction and its methodological implications, Table 1 summarizes the key methodological differences between the performance and potential components of the Green Growth Index, including their analytical objectives, reference frames, normalization approaches, and score interpretations. By retaining core methodological principles while expanding the analytical lens, Green Growth Index 2.0 maintains consistency with previous editions while enhancing its relevance for policy analysis.

The methods are designed to support the application of the Green Growth Index 2.0 at multiple levels, including global assessments, regional analyses, and national Green Growth Indices. It emphasizes cross-country comparability and consistency over time, while allowing for flexibility in data availability and contextual adaptation within a common analytical structure. Such flexibility is particularly important for national applications, where data coverage and indicator relevance may vary, but alignment with the global framework remains essential for comparability. The methodological framework also provides a clear foundation for the data preparation, measurement, and analytical procedures described in Chapter 3, as well as for the validation and quality assurance processes discussed in Chapter 4. By clearly distinguishing between conceptual foundations, methodological structure, and empirical implementation, the framework supports appropriate interpretation of results by analysts, researchers, and policy practitioners. Consequently, the methodological framework ensures that the Green Growth Index 2.0 can be applied transparently, interpreted appropriately, and further developed consistently.

Figure 2. Methodological Framework for the Green Growth Index 2.0
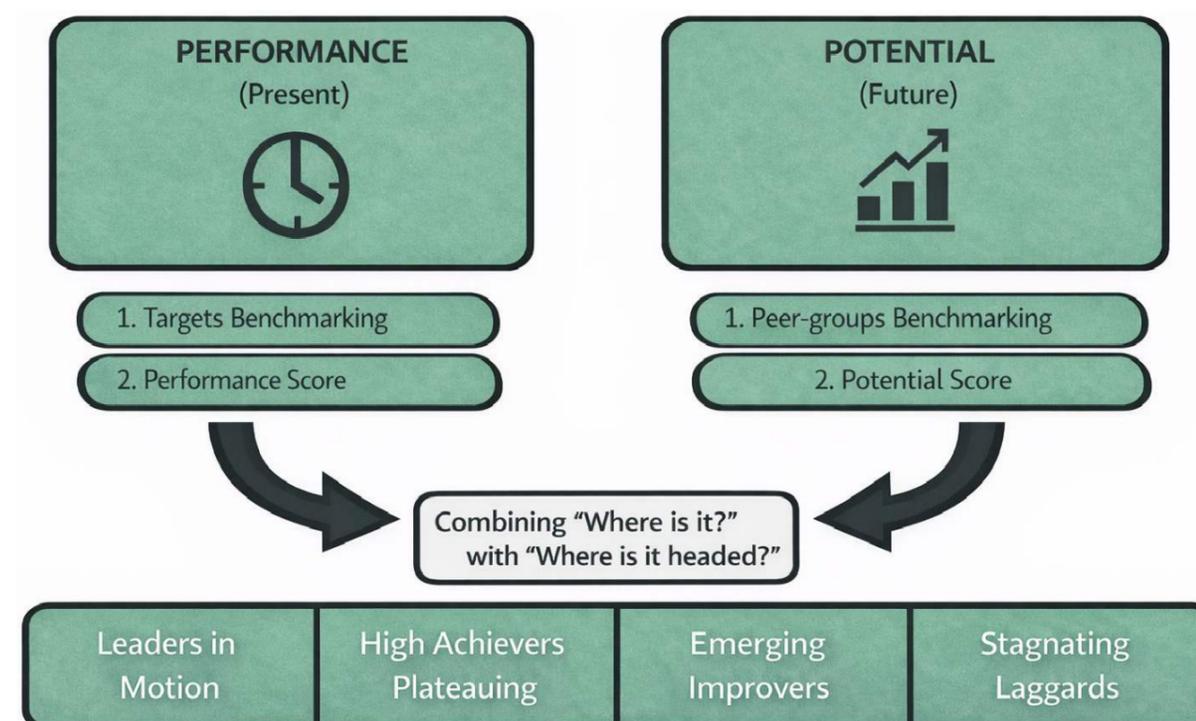
Table 1. Key Methodological Differences Between Performance and Potential Indices

Aspect	Performance Index	Potential Index
Analytical objective	Assess the current level of achievement relative to sustainability benchmarks	Assess recent transition momentum based on growth dynamics
Nature of assessment	Level-based (static)	Growth-based (dynamic)
Primary reference frame	Absolute sustainability targets	Relative peer-group distributions
Benchmarking basis	Normative benchmarks derived from SDGs, international targets, scientific reference values, or top performers	Empirical benchmarks derived from the distribution of growth rates within peer groups
Role of peer groups	Not applied in normalization	Central to normalization, growth is evaluated relative to structurally similar countries
Normalization logic	Min–max rescaling relative to fixed lower and/or upper target bounds	Rescaling relative to peer-group percentile bounds
Treatment of extreme values	Values exceeding targets are capped to prevent scores above the maximum	Growth values outside the defined percentile thresholds are capped to limit the influence of extreme values
Interpretation of high scores	High proximity to sustainability targets	Strong relative transition momentum compared to peers
Interpretation of low scores	Large distance from sustainability targets	Weak relative momentum within the peer group
Sensitivity to structural conditions	Directly reflects differences in development level and structural characteristics	Partially controls for structural differences through peer-group comparison
Temporal interpretation	Changes reflect cumulative progress toward sustainability	Changes reflect acceleration or deceleration of transition momentum
Handling of missing or non-informative value	Scores not computed if minimum data coverage requirements are not met	Neutral midpoint value assigned to avoid undue influence on aggregated potential score
Scale of normalized scores	Bounded absolute scale from 1 to 100	Bounded relative scale from 1 to 100
Role in green growth pathways	Defines the current position of countries in the green growth transition	Defines the direction and speed of transition relative to peers

Box 2.1. Components of the Green Growth Index 2.0

Green growth performance refers to a country's current level of achievement across the dimensions and indicators of the Green Growth Index, measured relative to defined sustainability benchmarks or targets. It reflects how close a country is to achieving desired outcomes in efficient and sustainable resource use, natural capital protection, green economic opportunities, and social inclusion at a given point in time. Performance provides a static assessment of progress toward green growth objectives and enables comparison across countries and over time. In the Green Growth Index framework applied before 2025, performance serves as the basis for assessing current progress toward green growth objectives.

Green growth potential captures the recent pace and direction of change in green growth performance, based on observed trends in the underlying indicators. It reflects the extent to which a country is making progress toward sustainability targets, independent of its current level of achievement. By focusing on growth dynamics rather than performance levels, potential provides insight into emerging momentum, capacity for improvement, and the likelihood of future progress in the green growth transition. In Green Growth Index 2.0, green growth potential complements performance by capturing recent progress and the capacity for improvement.

Green growth pathways describe the relationship between a country's current green growth performance and its green growth potential. They characterize patterns of green growth transition by jointly considering levels of achievement and recent progress, thereby allowing countries to be grouped by their stage and direction of transition. Green growth pathways support comparative analysis and interpretation by highlighting differences in transition dynamics across countries and over time. In Green Growth Index 2.0, green growth pathways are used to relate and compare green growth performance and potential.

3

DATA AND METHODS

Figure 3. Analytical Workflow of the Green Growth Index 2.0

GREEN GROWTH PERFORMANCE

Prepare indicator databases			
Download databases	Align data formats	Indicator scaling	Impute missing data

Validate indicator databases		
Check data outliers	Check correlations	Review data coverage

Normalization of indicators	
Rescaling min-max	Benchmarking against targets

Aggregation at different levels		
Indicators (Arithmetic)	Pillars (Geometric)	Dimensions (Geometric)

AI-driven robustness check		
Model uncertainty analysis	Input data sensitivty	Analysis of explanatory power

Validation of performance Scores

GREEN GROWTH POTENTIAL

Transform databases into growth rates		
Compute log growth	Five-year moving average	Winsorize growth rates

Validate growth-rate relative to peers	
Temporal pattern consistency	Peer-group anomaly detection

Normalize growth relative to peers	
Rescaling min-max	Benchmarking against income group

Aggregation at different levels		
Indicators (Arithmetic)	Pillars (Geometric)	Dimensions (Geometric)

AI-driven robustness check		
Model parameter uncertainty	Input data sensitivity	Analysis of explanatory power

Validation of potential scores

GREEN GROWTH PATHWAYS

Leaders in Motion	Emerging Improvers	Achievers Losing Momentum	Slow Movers

Building on the conceptual, indicator, and methodological frameworks described in Chapter 2, this chapter presents the data and analytical methods used to construct the Green Growth Index 2.0. While the preceding chapter defined the structure of the Index and the relationships among its analytical components, the focus here is on how indicators are prepared, processed, and combined in practice to derive measures of green growth performance, assess green growth potential, and identify green growth pathways. The methods described in this chapter are designed to ensure transparency, consistency, and comparability across countries and over time, while remaining adaptable to differences in data availability and quality.

Figure 3 provides an overview of the analytical workflow applied in the Green Growth Index 2.0, illustrating the main steps involved in the construction of performance and potential indices and their integration into green growth pathways. The figure highlights the parallel treatment of performance and potential, from data preparation and validation through normalization, aggregation, and robustness checks, as well as the point at which these components are combined to characterize patterns of green growth transition. The figure is intended to serve as a visual guide to the structure of the methods, rather than a detailed description of individual procedures.

The chapter is organized into three sections corresponding to the three analytical components of the Index. Section 3.1

describes the methods used to measure green growth performance. Section 3.2 presents the approach used to assess green growth potential. Section 3.3 explains how performance and potential are combined to identify green growth pathways.

3.1. Performance Measurement

This section describes the measurement of green growth performance, representing the core component of the Green Growth Index. The performance measurement framework builds directly on the methodology documented in the 2019 Green Growth Index Technical Report and remains largely unchanged in its conceptual structure and computational approach. It assesses countries' levels of achievement across the four dimensions of green growth using a standardized set of indicators normalized against sustainability benchmarks or reference values. The focus of this section is to document the data preparation, normalization, and aggregation procedures applied to construct the performance index, providing the groundwork for the extended assessment of potential and pathways introduced under Green Growth Index 2.0.

3.1.1. Data Preparation

The preparation of data for the green growth indicators, which were identified based on the selection approach described in Section 2.2, is guided by four main considerations: the use of
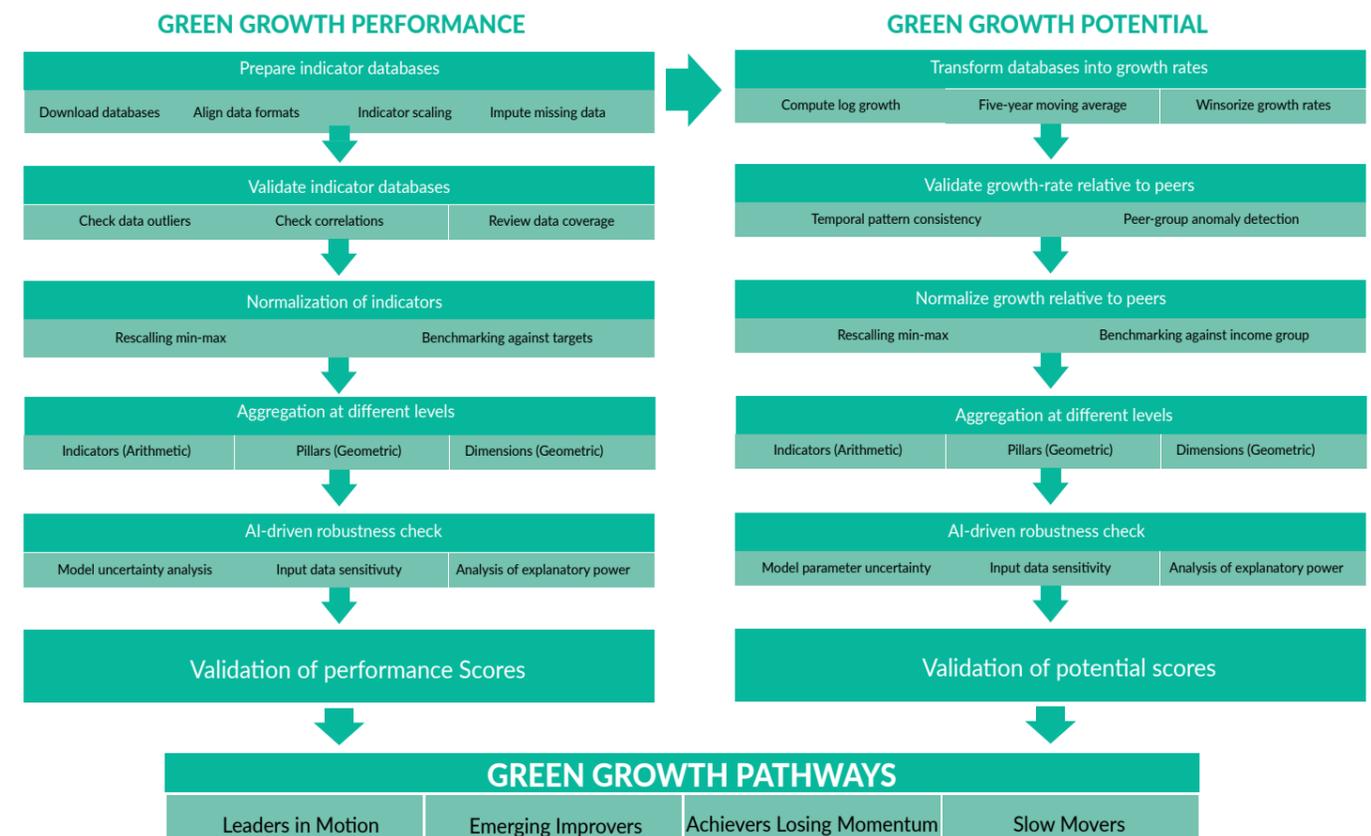
publicly available data sources, the harmonization of time series and assurance of internal consistency, the scaling of indicators to enable meaningful comparison, and the transparent treatment of missing data. Together, these considerations aim to ensure that the data used in the Index are comparable across countries and over time, analytically sound, and suitable for constructing measures of green growth performance. The indicators applied in the 2025 Global Green Growth Index are presented in Annex 1, while detailed information on indicator definitions, data sources, units, coverage, and limitations is provided in the accompanying Metadata Report for the 2025 Green Growth Index 2.0.[5]

First, indicator data are compiled exclusively from publicly available international data sources. This approach supports transparency, replicability, and broad country coverage, and allows users to trace indicators back to their original sources. The use of internationally recognized data sets also facilitates consistency in indicator definitions and measurement methodologies across countries. For each indicator, the most recent available data are used, subject to minimum coverage requirements, while maintaining alignment with historical time series where possible. This practice follows earlier editions of the Index and enables the results to be updated regularly without introducing discontinuities in the underlying data.

Second, data preparation includes procedures to harmonize time series and ensure internal consistency across indicators and countries. Differences in data availability across indicators and reporting periods are addressed by aligning observations to common reference years when feasible and by applying

predefined rules to use the closest available data points. Efforts are made to preserve the integrity of observed data by identifying and checking data points that typographical errors may have distorted. Harmonization also involves ensuring consistency in indicator units, definitions, and temporal coverage, providing a coherent dataset for subsequent analytical steps.

Third, indicators are scaled where necessary to enable meaningful cross-country comparison. Scaling is applied primarily to account for differences in population size, economic scale, or land area, and to ensure that indicators reflect intensity, efficiency, or relative performance rather than absolute levels. Scaling pactices follow those applied in earlier editions of the Green Growth Index and are treated as an integral part of data preparation rather than analytical transformation. Throughout this process, care is taken to preserve the original meaning and policy relevance of each indicator.

Finally, the treatment of missing data is guided by the principle of minimizing imputation and maintaining transparency. Where indicator data are unavailable for a substantial number of countries or years, proxy variables may be used to represent the underlying concept, provided they meet the indicator selection criteria described in Section 2.2. Imputation is limited to small data gaps to preserve cross-country comparability and data credibility. Indicators with extensive missing data are reviewed carefully and may be excluded from specific applications if minimum coverage thresholds are not met.

Box 3.1. Identification and Treatment of Outliers in Indicator Databases

As part of data validation, the distributions of individual indicators are examined to identify extreme values that may indicate data errors, inconsistencies, or atypical reporting patterns. Boxplots are used as a diagnostic tool to identify and review potential outliers prior to normalization. The boxplot illustrates the median, the interquartile range, and the lower and upper fences that define the expected range of values, as well as observations that fall outside this range.

Outliers are identified using the interquartile range (IQR), defined as the difference between the 75th and 25th percentiles of the indicator distribution. The lower and upper fences are calculated as:

$$\text{Lower fence} = Q_{25} - \mu \times \text{IQR}$$
$$\text{Upper fence} = Q_{75} + \mu \times \text{IQR}$$

where Q_{25} and Q_{75} denote the 25th and 75th percentiles, respectively, and μ is a predefined multiplier. In the Green Growth Index, a multiplier of $\mu=3.0$ is applied as a conservative threshold to

avoid excessive identification of extreme values, particularly in indicators with skewed distributions or large cross-country variation. While lower multipliers are commonly recommended in the literature, a higher threshold is used to reduce the risk of capping values that reflect understandingly extreme but valid country conditions.[6]

Identification of outliers does not imply their automatic exclusion or modification. Potential outliers are reviewed on a case-by-case basis to determine whether they reflect genuine country-specific characteristics, data errors, or inconsistencies in reporting. Where feasible, benchmarking against sustainability targets or reference values is preferred to statistical capping (see Section 3.1.3). When benchmarking is not applicable and extreme values cannot be corrected by data correction, values may be capped at the lower or upper fence before to normalization.
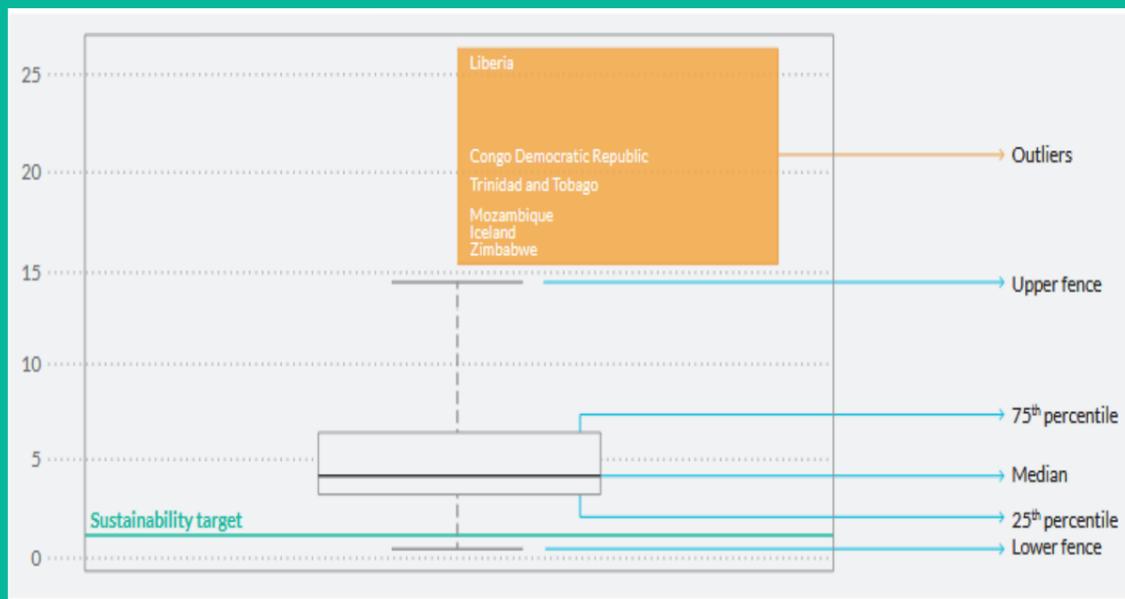
Source: Acosta et al. (2019)[7]

Box 3.2. Technical Specification of Correlation Analysis for Indicator Validation

Correlation analysis is applied to assess internal consistency across indicators as part of data validation. The Green Growth Index applies bivariate Pearson correlation coefficients to pairs of indicators. For two indicators X and Y, observed across n countries, the Pearson correlation scoefficient r_{XY} is defined as:

$$r_{XY} = \frac{\sum_{i=1}^{n}(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum_{i=1}^{n}(X_i - \bar{X})^2}\sqrt{\sum_{i=1}^{n}(Y_i - \bar{Y})^2}}$$

where $\bar{X}$ and $\bar{Y}$ denote sample means. Pearson correlation is applied, given that indicators are continuous variables, and extreme outliers are addressed during data validation.

Correlation analysis is conducted using the absolute value of correlation coefficients, $|\,r_{XY}\,|$, as the sign of the correlation is not considered relevant for validation purposes due to indicator directionality and normalization procedures. Correlations are examined within pillars and across conceptually related indicators.

For validation purposes, correlation values between 0.10 and 0.90 are considered acceptable. Values exceeding 0.90 may indicate potential redundancy, while values below 0.10 may suggest weak conceptual linkage or data inconsistency requiring further review.

Only statistically significant correlations are considered. Statistical significance is assessed using standard hypothesis testing for Pearson correlation coefficients, with the following thresholds:

- $p < 0.01$ (1 percent significance level)
- $p < 0.05$ (5 percent significance level)
- $p < 0.10$ (10 percent significance level)

Only correlations with $p \leq 0.10$ are retained for validation analysis. Correlation results are used solely to support data validation and indicator review. They do not provide guidance on indicator weighting, aggregation, or the interpretation of green growth performance or causal relationships.

Correlation coefficients are interpreted using indicative ranges adopted in the 2019 Index:

Absolute correlation (r)	Interpretation
0.90 - 1.00	Very high (potential redundancy)
0.70 - 0.89	Acceptable (high)
0.30 - 0.69	Ideal
0.10 - 0.29	Acceptable (low)
< 0.10	Very low (weak conceptual linkage)

3.1.2. Validation of Indicator Databases

Validation of indicator databases is undertaken after data preparation and before normalization and aggregation, and serves as a dedicated quality-control step in the construction of the Green Growth Index. While data preparation focuses on compiling, harmonizing, scaling, and imputing indicator datasets, validation aims to ensure that the prepared data are plausible, internally consistent, and suitable for analytical use. Validation focuses on identifying potential data errors, including outliers, inconsistencies related to correlations, and anomalies arising from data limitations, reporting differences, or processing steps. It provides a structured basis for reviewing and, where necessary, revising indicator datasets before further analysis.

The first step in data validation is to examine indicator distributions and identify potential outliers. For each indicator, summary statistics and distributional patterns are assessed to identify extreme values or irregular distributions that may indicate data issues. Visual inspection and descriptive analysis are used to distinguish between values that reflect genuine country-specific conditions and those that may result from reporting errors, unit inconsistencies, or other anomalies. Outliers are not removed automatically; instead, they are reviewed on a case-by-case basis to determine whether they should be retained, corrected, or excluded. This approach reflects the principle that extreme values can contain meaningful information while ensuring that implausible data points do not exert excessive influence on subsequent analysis. Box 3.1 describes the approach for capping outliers.

Secondly, validation includes checks for internal consistency across indicators, using correlation analysis as a diagnostic tool. Bivariate Pearson correlation coefficients are examined within pillars and across conceptually related indicators to assess whether observed relationships are consistent with the conceptual framework and indicator definitions (Box 3.2). Correlations are evaluated by their absolute magnitude, as relationships may be reflected by either positive or negative values, depending on the indicator's directionality. On the one hand, very high correlations may indicate potential redundancy among indicators. On the other hand, very low correlations between closely related indicators may indicate weak conceptual linkage or possible data inconsistencies, which require further review of indicator definitions, units, or source data. Only statistically significant correlations are considered for validation purposes. Correlation analysis is applied solely to support data validation before normalization and aggregation and does not inform indicator weighting, performance assessment, or inference of causal relationships.

A final validation step involves reviewing data coverage and assessing the overall readiness of indicator datasets for analytical use. Indicators are examined to ensure that minimum coverage requirements are met for country representation and temporal completeness, enabling meaningful comparisons across countries and over time. In successive editions of the Green Growth Index following 2019, additional validation has involved comparing updated databases with those used in previous editions to identify gaps, revisions, or discontinuities in reported data. Annex 2 presents an example of such comparisons, which help detect changes arising from data revisions by source providers, updates in estimation methodologies, or revisions to historical series. Where significant divergences are identified, indicator datasets are reviewed to assess their implications for comparability and interpretation. Only indicator datasets that meet coverage requirements and demonstrate consistency across database updates are taken forward to normalization and aggregation. Documentation of identified data gaps, revisions, and validation outcomes is provided in annexes accompanying the Index to support transparency and informed interpretation.

3.1.3. Normalization and Benchmaking of Performance Indicators

Normalization is applied to validated indicator datasets to enable meaningful comparison and aggregation across indicators, pillars, and dimensions of the Green Growth Index. Because indicators are expressed in different units and scales, normalization is required to convert them to a standard metric before aggregation. In the Index's analytical workflow, normalization is performed after data preparation and validation, and before aggregating indicator values. This sequencing ensures that only datasets that have passed validation checks are normalized and used to construct performance scores. Normalization standardizes indicator values for comparative purposes without altering the underlying data or their substantive meaning. The normalized values reflect countries' relative performance and do not represent absolute levels of sustainability. They should therefore be interpreted in light of the underlying indicator definitions.

The Green Growth Index applies a consistent normalization method across all performance indicators to ensure comparability over time and across countries. Indicators are normalized to a common scale, with higher values indicating better green growth performance. Indicator directionality is explicitly considered in the normalization process. Indicators

that contribute positively to green growth are normalized such that higher raw values correspond to higher normalized scores, while indicators that reflect negative contributions are normalized inversely. This distinction ensures that normalized scores are interpretable consistently across the Index. The normalization approach applied in Green Growth Index 2.0 follows the method established in the 2019 Index, supporting continuity and comparability across editions.

All performance indicators in the Green Growth Index are benchmarked against sustainability targets to provide a consistent, policy-relevant basis for normalization and interpretation. Target values are defined using three complementary criteria. First, where available, indicators are benchmarked against targets associated with the Sustainable Development Goals (SDGs), reflecting internationally agreed normative ambitions. For SDG indicators, both explicit targets and implicit reference values are used, drawing on internationally recognized analytical frameworks to ensure consistency and global applicability. Second, for indicators not directly linked to SDG targets, benchmark values are drawn from targets or reference values suggested in the scientific literature and reports by international organizations. Where scientific or policy-based targets are available, including those proposed in sectoral assessments by international organizations, these values are adopted to anchor normalization in established evidence and practice. Third, when neither normative targets nor scientifically defined reference values are available, benchmarks are empirically determined as the average performance of the top five countries. In cases where no such targets exist, either for specific SDG indicators or for non-SDG indicators, the average performance of the top five countries provides an empirical benchmark that reflects observed best practice while avoiding undue influence from single extreme values.

The above criteria are applied to define the lower and/or upper bounds for the normalization functions described in Box 3.3, ensuring that all indicators are normalized against clearly defined, transparent reference points. Depending on the indicator, benchmark values may represent a single sustainability target or an acceptable target range, corresponding to the one-target and two-target normalization cases presented in Box 3.3. This approach is consistent with methods applied in other global sustainability indices and supports cross-country comparability. Benchmark values are applied uniformly across countries and over time, and normalized scores should be interpreted as relative measures of performance against defined sustainability targets.

3.1.4. Aggregation across Indicators, Pillars, and Dimensions

Aggregation in the Green Growth Index is guided by three key considerations: the hierarchical structure for combining indicators, the aggregation functions applied at different levels, and the data coverage requirements that determine whether aggregation is performed. Together, these considerations ensure that aggregation is conceptually coherent, analytically consistent, and transparent. By clearly defining how normalized indicators are combined and under what conditions aggregated scores are produced, the aggregation framework supports comparability across countries and over time while preserving the multidimensional nature of green growth.First, the Green Growth Index applies a hierarchical aggregation structure that mirrors the conceptual framework (Figure 4). Normalized indicators are first aggregated into pillar scores, which are then aggregated

Box 3.3. Normalization and Benchmarking of Performance Indicators

This box presents the benchmarking and normalization functions used to compute performance scores in the Green Growth Index. The approach follows min–max rescaling with explicit lower and upper bounds derived from sustainability targets. Normalized scores are computed on a bounded scale from 1 to 100, where higher values indicate better performance relative to defined sustainability targets.

Let:
X_i = observed value of an indicator for country i
X_i^* = normalized performance score
$X_{\min}, X_{\max}$ = lower and upper bounds of the indicator
a =1, b =100 = lower and upper bounds of the normalized scale
The general normalization function is:

$$X_i^* = a + \frac{X_i - X_{\min}}{X_{\max} - X_{\min}}(b - a)$$

The specification of $X_{\min}$ and $X_{\max}$, and the treatment of extreme values, depend on the relationship between the indicator and green growth, as described in the cases below.

Case 1: Positive relationship with green growth, no country has reached the target Assumptions

- Indicator has a positive relationship with green growth
- Sustainability target defines the upper bound
- No observed value exceeds the target

$$X_{\min} = \min (X_i), X_{\max} = T$$

The general normalization function is applied directly. The sustainability target corresponds to the maximum normalized score of 100.

Case 2: Negative relationship with green growth, no country has reached the target Assumptions

- Indicator has a negative relationship with green growth
- Sustainability target defines the lower bound
- No observed value falls below the target

$$X_{\min} = T, X_{\max} = \max (X_i)$$

The normalization function is applied such that lower raw values (closer to the target) result in higher normalized scores.

Case 3: Positive relationship with green growth, some countries exceed the target Assumptions

- Indicator has a positive relationship with green growth
- Sustainability target defines the upper bound
- Some observed values exceed the target

Observed values exceeding the target are capped:

$$X_i = \min (X_i, T)$$

Normalization is then applied using:

$$X_{\min} = \min (X_i), X_{\max} = T$$

This ensures that countries exceeding the target do not receive scores above 100.

Case 4: Negative relationship with green growth, some countries exceed the target Assumptions

- Indicator has a negative relationship with green growth
- Sustainability target defines the lower bound
- Some observed values fall below the target

Observed values below the target are capped:

$$X_i = \max (X_i, T)$$

Normalization is then applied using:

$$X_{\min} = T, X_{\max} = \max (X_i)$$

This ensures that countries exceeding the sustainability target do not receive scores above 100.

Case 5: Indicators with both lower and upper sustainability targets Assumptions

- Indicator has an acceptable performance range defined by a lower and upper target
- Values below the lower target and above the upper target are undesirable

Let T_L and T_U denote the lower and upper sustainability targets, respectively.

Observed values are capped as follows:

Box 3.3. Continuation

$$X_i = \begin{cases} T_L, & X_i < T_L \\ X_i, & T_L \leq X_i \leq T_U \\ T_U, & X_i > T_U \end{cases}$$

Normalization bounds are defined as:

$$X_{\min} = T_L, X_{\max} = T_U$$

The general normalization function is then applied.

All values within the acceptable range receive the maximum normalized score of 100, while values outside the range receive progressively lower scores depending on their distance from the nearest bound.

Interpretation Notes: Sustainability targets define the normalization bounds and serve as a reference for interpreting performance across indicators. The lower bound of the normalized scale is set to 1, reflecting the lowest observed performance while avoiding zero values that may be misinterpreted as the absence of performance. Normalization is applied only after data preparation and validation to ensure that normalized scores are based on consistent and quality-assured indicator datasets. The five cases presented above ensure consistent treatment of indicators with different relationships to green growth and different target structures, while maintaining comparability across indicators and countries.

into dimension scores, and finally combined to produce the composite Index. This hierarchical structure ensures internal coherence between the conceptual foundations of green growth and the analytical construction of the Index. The same aggregation structure is applied consistently across all countries and years, enabling results to be examined at the indicator, pillar, dimension, and Index levels. By maintaining a fixed, transparent hierarchy, the Index facilitates the interpretation of performance patterns and supports the analysis of strengths and weaknesses across the different components of green growth.

Second, different aggregation functions are applied at different levels of the hierarchy to reflect varying assumptions about substitutability among components. At the first level of aggregation, normalized indicators within each pillar are combined using the arithmetic mean, reflecting an assumption of partial substitutability among indicators that capture related aspects of performance. At higher levels, geometric aggregation is applied to combine pillar scores into dimension scores and dimension scores into the composite Index. The use of geometric means at these levels limits full compensability, ensuring that low performance in one pillar or dimension cannot be fully offset by high performance in another. No explicit weights are assigned at any aggregation level. Instead, equal weighting is applied by design, ensuring that all indicators, pillars, and dimensions contribute uniformly and that the aggregation structure remains transparent and neutral.

And finally, aggregation is performed subject to data coverage requirements to preserve comparability and interpretability of results. At the pillar level, arithmetic aggregation is performed only when scores are available for at least two of the three underlying indicators. If scores are missing for more than one indicator within a pillar due to data limitations, the pillar score is not computed. Similarly, at the dimension level, geometric aggregation is performed only when scores are available for at least three of the four underlying pillars. If more than one pillar score is missing, the dimension score is not computed. At the final aggregation level, the composite Index is computed only for countries with complete dimension scores. Missing dimension values are not permitted at this level, as incomplete dimensional coverage would undermine comparability and introduce implicit weighting across countries. Aggregated scores should be interpreted as relative measures of green growth performance, reflecting the combined information from underlying components and the aggregation structure described above.

Figure 4. Methods of aggregation at the indicator, pillar, and dimension levels.
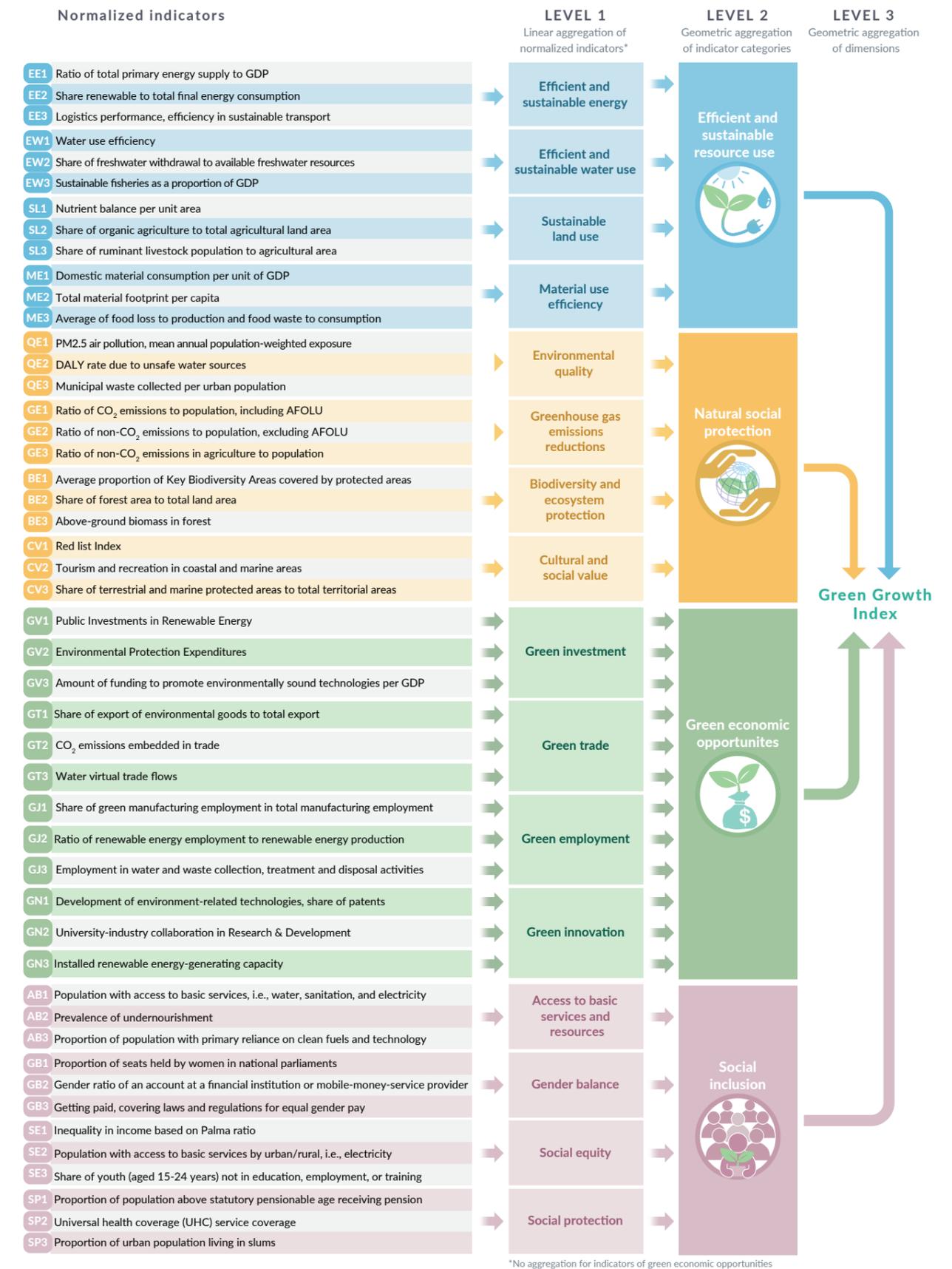
Box 3.4. Aggregation across Indicators, Pillars, and Dimensions

This box presents the technical specification for aggregating normalized performance scores across indicators, pillars, dimensions, and the composite Green Growth Index. The aggregation structure, functions, and coverage rules presented below follow the methodology applied in the 2019 Green Growth Index Technical Report, with updates reflecting the current uniform structure of indicators and pillars. Aggregation follows a hierarchical structure, applying different aggregation functions and data coverage rules at each level.

Definitions
Let:
$x_{i,j}$= normalized score of indicator j for country i
$P_{i,k}$= pillar score k for country i
$D_{i,l}$= dimension score l for country i
GGI_i= composite Green Growth Index score for country i

In the current structure of the Green Growth Index, each pillar comprises three indicators, each dimension comprises four pillars, and the Index comprises four dimensions.

Level 1:
Aggregation of Indicators into Pillars
Pillar scores are computed as the arithmetic mean of normalized indicator scores:

$$P_{i,k} = \frac{1}{n_k} \sum_{j=1}^{n_k} x_{i,j}$$

where n_k is the number of available indicator scores for pillar k.

Coverage rule
- $P_{i,k}$ is computed only if scores are available for at least two of the three indicators within the pillar.
- If scores are missing for more than one indicator, the pillar score is not computed.

Level 2:
Aggregation of Pillars into Dimensions
Dimension scores are computed as the geometric mean of pillar scores:

$$D_{i,l} = \left(\prod_{k=1}^{m_l} P_{i,k} \right)^{1/m_l}$$

where m_l is the number of available pillar scores for dimension l.

Coverage rule
- $D_{i,l}$ is computed only if scores are available for at least three of the four pillars within the dimension.
- If more than one pillar score is missing, the dimension score is not computed.

Level 3:
Aggregation of Dimensions into the Composite Index
The composite Green Growth Index score is computed as the geometric mean of dimension scores:

$$GGI_i = \left(\prod_{l=1}^{4} D_{i,l} \right)^{1/4}$$

Coverage rule
- The composite Index is computed only when all scores for the four dimensions are available.
- Missing dimension scores are not permitted at this level.

Weighting and Interpretation: No explicit weights are applied at any aggregation level; equal weighting is applied by design through the aggregation structure, i.e., where the number of indicators is the same across pillars, and the number of pillars is the same across dimensions. The use of geometric aggregation at higher levels limits full compensability, ensuring that low performance in one pillar or dimension cannot be fully offset by high performance in others. Aggregated scores are relative measures of green growth performance and should be interpreted in dconjunction with the underlying indicator and pillar scores to fully understand the sources of observed results.

3.1.5. Robustness Check and Model Validation

Robustness and validation are integral components of the Green Growth Index methodology and are applied to assess the stability, reliability, and interpretability of Index results. Robustness analysis supports confidence in cross-country comparisons and temporal analysis by examining how results respond to methodological assumptions, indicator updates, and data availability. In the Green Growth Index, robustness and validation encompass four complementary analytical components: uncertainty analysis of methodological choices; sensitivity analysis of indicators and sustainability targets; assessment of analytical power and internal coherence; and evaluation of confidence levels based on data availability; These components are applied at different stages of the Index's development, reflecting whether underlying methodological elements are stable or subject to change over time.

An uncertainty analysis of methodological choices was conducted as a baseline robustness assessment for the Green Growth Index published in 2019. This analysis examined the sensitivity of Index scores and rankings to alternative specifications of core methodological elements, including normalization methods, aggregation functions, outlier treatment approaches, and weighting assumptions. The objective was to assess structural uncertainty in Index construction and to determine whether results were driven by specific methodological choices. The analysis demonstrated that overall patterns and country rankings were broadly stable across reasonable alternative specifications. As these core methodological elements have remained unchanged since 2019, a full uncertainty analysis is not repeated in subsequent annual reports. Instead, the results of the 2019 assessment provide a stable methodological baseline for later Index updates.

Sensitivity analysis of indicators and sustainability targets is conducted regularly as part of successive Index editions. Unlike the core methodological structure, the indicator framework and underlying databases are updated annually to reflect improvements in data availability, replacement of proxy variables, and revisions in reported values across international data sources.
Sensitivity analysis is implemented using Monte Carlo analysis [8] to assess the robustness of Green Growth Index results in changes in indicator values and to variations arising from missing data (Box 3.5). In recent reports, Monte Carlo simulations are used to examine the effects of perturbations in indicator values and of missing values on relative country rankings, rather than on index scores alone. This approach is particularly important given the large year-to-year disparities in indicator databases. The purpose of the analysis is to ensure that observed changes in country ranks primarily reflect substantive changes in green growth performance rather than artefacts of data revisions or gaps. Sensitivity analysis focuses on the stability of rank patterns and rank dispersion, rather than exact numerical values.

Analytical power and internal coherence checks are applied as validation tools, particularly in recent annual reports where indicator updates have been more frequent. These checks assess whether the indicators in the Index meaningfully explain variation in composite scores and whether relationships among indicators and aggregated results are consistent with the conceptual framework. Correlation and regression diagnostics are used to examine the association between individual indicators, pillar scores, and the composite Index. The objective is to assess construct validity and internal coherence, ensuring that no single indicator or component disproportionately drives results. These analyses complement indicator selection and validation procedures and support confidence in the analytical integrity of the Index.

Confidence levels based on data availability are evaluated annually as part of quality assurance and transparent communication of data limitations. Confidence levels reflect the completeness, consistency, and temporal coverage of indicator data across countries and years, while accounting for differences in data availability across indicators and reporting cycles. Confidence assessment serves two complementary purposes. First, it ensures that Index scores, particularly those associated with lower confidence levels, are interpreted cautiously due to underlying data constraints. Second, it provides countries with feedback on data gaps in their indicator coverage, supporting efforts to strengthen national statistical systems and improve data availability in future Index editions. Confidence levels do not affect Index scores or rankings, but they provide essential contextual information for responsible interpretation and policy use of the Green Growth Index.

Box 3.5. Monte Carlo-Based Sensitivity Analysis of Green Growth Index Ranks

This box presents the technical specification of the Monte Carlo analysis used to assess the sensitivity of Green Growth Index country ranks to changes in indicator values and missing data. Monte Carlo–based sensitivity analysis builds on the robustness framework introduced in the 2019 Green Growth Index Technical Report and has been applied systematically in subsequent reports to address annual changes in indicator values and database coverage. Monte Carlo analysis is used as a robustness tool to test the stability of country rankings. It assesses whether observed rank patterns remain consistent when indicator values vary within plausible ranges, reflecting uncertainty in the underlying data.

Definitions
Let:
$X_{i,j}$ = observed value of indicator j for country i
$X_{i,j}^{(s)}$ = simulated value of indicator j for country i in simulation s
$GGI_i^{(s)}$ = composite Green Growth Index score for country i in simulation s
$R_i^{(s)}$ = rank of country i in simulation s
$R_i^{(0)}$ = rank of country i in the baseline Index
S = number of Monte Carlo simulations

Simulation Design
Monte Carlo simulations are conducted under two main scenarios:

A. Perturbation of Indicator Values
For each simulation s, indicator values are perturbed as:

$$X_{i,j}^{(s)} = X_{i,j} + \varepsilon_{i,j}^{(s)}$$

where

$$\varepsilon_{i,j}^{(s)} \sim \mathcal{N}(0, \sigma_j^2)$$

and σ_j is defined as a proportion of the observed indicator range or historical variability. Perturbations are bounded to ensure simulated values remain within plausible limits.

B. Simulation of Missing Indicator Values
To assess sensitivity to missing data, indicators are randomly removed according to observed missing-data patterns across countries and years. For each simulation s, a subset of indicator values is set to missing:

$$X_{i,j}^{(s)} = \emptyset$$

The Index is then recomputed using the same data coverage requirements described in Sections 3.1. 1–3.1.4. This step captures the effect of year-to-year changes in data availability within the underlying indicator databases.
Index Reconstruction and Ranking
For each simulation s:

$$GGI_i^{(s)} = f\left(X_{i,1}^{(s)}, \dots, X_{i,J}^{(s)}\right)$$

where $f(\cdot)$ denotes the full Index construction process, including normalization and hierarchical aggregation.
Countries are then ranked:

$$R_i^{(s)} = \operatorname{rank}\left(GGI_i^{(s)}\right)$$

Sensitivity Metrics
Sensitivity is evaluated using rank-based measures, including:
- Rank deviation:

$$\Delta R_i^{(s)} = R_i^{(s)} - R_i^{(0)}$$

- Average rank deviation:

$$\Delta \bar{R}_i = \frac{1}{S} \sum_{s=1}^{S} | \Delta R_i^{(s)} |$$

- Rank confidence interval, defined by selected percentiles (e.g. 5th–95th) of $\left\{R_i^{(s)}\right\}$
Results are summarized across simulations to assess the magnitude and distribution of rank changes.

Interpretation Notes: Monte Carlo analysis evaluates the robustness of Green Growth Index results to plausible data perturbations and missing-value scenarios, rather than to extreme or implausible cases. The analysis focuses on the stability of country rankings, which is more relevant for cross-country comparison than variability in Index scores. Monte Carlo results do not modify baseline Index scores or rankings but provide diagnostic information on the sensitivity of results to data changes. These findings support cautious interpretation of rank changes, particularly for countries affected by data gaps or large variations in underlying indicator databases.

3.1.6. Validation of Performance Index Scores

Validation of performance Index scores is undertaken to assess whether the results produced by the Green Growth Index are internally coherent, analytically credible, and meaningful for interpretation and policy use. Unlike earlier validation steps that focus on data quality, indicator selection, and methodological robustness, score-level validation examines the behavior of aggregated results. This validation relies on a combination of quantitative diagnostics and expert judgement, supported by graphical outputs available through the online interactive dashboard. The objective is to ensure that Index scores and rankings reflect the underlying indicator information in a consistent and interpretable manner.

A first validation approach examines the consistency of scores across aggregation levels. Performance scores are reviewed across indicators, pillars, dimensions, and the composite Index to verify that higher-level results are coherent with underlying component scores. This includes checking whether strong or weak performance at the composite level is supported by corresponding patterns at the dimension and pillar levels, and whether inconsistencies can be explained by aggregation effects rather than data or methodological errors. The hierarchical structure of the Index facilitates this validation by allowing systematic inspection of score profiles across levels.

Validation also assesses the absence of dominant components in determining composite Index scores. Although geometric aggregation at higher levels limits full compensability by design, additional checks are conducted to ensure that no single pillar or dimension disproportionately drives overall performance. Using graphical diagnostics, the relative contributions of pillars and dimensions are examined across countries to confirm balanced representation of the four dimensions of green growth. This validation step supports interpreting composite scores as genuinely multidimensional measures rather than reflections of performance on a narrow subset of components.

The plausibility of cross-country performance patterns is evaluated through expert judgement, informed by graphical comparison of scores, rankings, and distributions across countries and regions. Validation focuses on whether observed patterns align with broad expectations given countries' development contexts, structural characteristics, and known policy and environmental conditions. This does not imply benchmarking against external indices or formal prediction, but rather ensures that results are reasonable, interpretable, and free from obvious anomalies that could signal data or methodological issues.

An additional validation approach focuses on temporal stability and trend coherence of performance scores. Using time-series visualizations available in the interactive dashboard, changes in scores and rankings over time are examined to assess whether trends are smooth and interpretable. Abrupt changes are reviewed in relation to known data revisions, indicator updates, or real-world developments. This validation helps distinguish genuine performance dynamics from artefacts introduced by changes in data availability or indicator definitions, and supports reliable interpretation of trends.

Finally, validation of performance Index scores explicitly considers the relationship between scores, confidence levels, and data coverage. Index results are interpreted alongside confidence levels derived from data availability to ensure that scores with lower confidence are treated with appropriate caution. This validation step reinforces responsible use of the Index by highlighting where limited data coverage may affect the reliability of results, and by informing countries of data gaps that can be addressed to improve future Index editions. Confidence levels do not alter Index scores, but they provide essential context for validation and interpretation.

These combined validation approaches support confidence in the Green Growth Index as a coherent and credible analytical tool. By combining structured graphical diagnostics with expert judgement, validation of performance Index scores ensures that results are robust, interpretable, and suitable for informing policy dialogue at global, regional, and national levels.

3.2. Potential Assessment

This section introduces the assessment of green growth potential as an analytical extension of the Green Growth Index. The potential assessment complements performance measurement by capturing recent transition momentum based on changes in green growth indicators over time, rather than levels of achievement. It is designed to support comparative interpretation of countries' relative capacity and readiness for green growth transition, using the same indicator framework and validated data sources as the performance index. By focusing on growth dynamics and recent trends, the potential assessment provides additional insight into how countries are progressing relative to peers while maintaining consistency with the Index's core methodological principles.

3.2.1. Data Preparation and Transformation into Growth Rates

The potential assessment introduced in Green Growth Index 2.0 complements performance measurement by capturing the recent pace and direction of change in green growth indicators. Unlike performance measurement, which assesses current levels of achievement relative to sustainability targets, potential assessment focuses on growth dynamics derived from historical indicator trends. The potential index uses the same set of indicators and the same validated indicator databases as the performance index. No additional indicators are introduced for potential assessment, and all data preparation and validation steps described in Section 3.1 apply equally to the indicators used for growth analysis.

The transformation from performance indicators to growth measures is undertaken to enable comparison of relative change across countries and indicators with different units and scales.[9] Logarithmic growth rates are used for three main reasons. First, they measure proportional change rather than absolute differences, allowing meaningful comparisons of growth across indicators with different magnitudes and units. Second, logarithmic growth treats increases and decreases symmetrically, avoiding bias toward indicators with large baseline values. Third, log growth reduces scale effects and limits the influence of extreme values, which is particularly important when assessing recent changes across heterogeneous country contexts. These properties make logarithmic growth rates well-suited for assessing green growth potential, where the objective is to capture the pace and direction of change rather than levels of achievement. Growth rates are calculated only for periods where consecutive annual observations are

available, and indicators with insufficient temporal coverage are excluded from growth computation for the corresponding years. The resulting growth-rate indicators reflect recent developments in green growth performance, independent of current performance levels.

Indicator time series may exhibit short-term volatility due to data revisions, measurement noise, or temporary shocks, which can be amplified when growth rates are computed. This volatility is particularly pronounced for indicators with small baseline values or uneven reporting intervals, where minor changes in reported data may result in disproportionately large year-to-year growth rates. To address this issue and to improve cross-country comparability, growth rates are smoothed using a moving average. [10] A fixed five-year moving average is applied to the computed logarithmic growth rates to balance responsiveness to recent changes with the need for stable and interpretable growth signals. A shorter averaging window would leave growth measures overly sensitive to transitory fluctuations and data revisions, while a longer window would risk over-smoothing and obscuring genuine changes in growth dynamics, including periods of acceleration or deceleration. The five-year window, therefore, provides a pragmatic compromise that captures sustained improvement or decline without masking meaningful transitions. Smoothing is applied after growth rates are computed and does not alter the underlying indicator values, nor does it imply projection or forecasting. Instead, it supports interpreting potential as a measure of recent momentum based on observed data.

Even after smoothing, growth-rate series may still contain extreme values arising from base effects, data revisions, or temporary shocks. To further strengthen robustness and comparability, smoothed growth rates are winsorized. Winsorization limits the influence of extreme observations by constraining values at the lower and upper tails of each indicator's distribution within a country's time series, [11] while preserving the overall structure and temporal pattern of growth dynamics. This step is applied as a robustness safeguard and does not alter the underlying performance indicators, the Index's aggregation structure, or its weighting scheme.

The outcome of this step is a set of smoothed and winsorized growth-rate indicators that correspond directly to the performance indicators used in the Index. These growth indicators serve as the inputs to subsequent steps of the potential assessment, including validation of growth-rate indicators, peer-based normalization, and aggregation. The technical specifications for the growth transformation, smoothing, and winsorization procedures are presented in Box 3.6.

Box 3.6. Transformation of Performance Indicators into Growth Measures

This box presents the technical specification used to transform validated performance indicators into growth measures for assessing green growth potential. The transformation methods presented in this box were introduced as part of Green Growth Index 2.0 to support the assessment of green growth potential and complement the performance measurement framework applied in earlier Index editions. Growth measures are derived from indicator time series to capture the recent pace and direction of change, independent of current performance levels.

Logarithmic Growth Rate
Let:
$X_{i,j,t}$ = value of indicator j for country i in year t
$g_{i,j,t}$ = annual growth rate of indicator j for country i between years $t-1$ and t
The indicator values $X_{i,j,t}$ correspond to the validated performance indicators described in Section 3.1 and differ only by the inclusion of an explicit time index.

The annual growth rate is computed using the logarithmic difference:

$$g_{i,j,t} = \ln\left(X_{i,j,t}\right) - \ln\left(X_{i,j,t-1}\right)$$

Growth rates are computed only for years where consecutive, valid observations are available. Indicators with insufficient temporal coverage are excluded from growth-rate computation for the corresponding years.

Log growth rates measure relative change, ensuring comparability across indicators with different units and scales. This transformation treats proportional increases and decreases symmetrically and reduces the influence of scale effects.

Smoothing of Growth Rates Using Moving Averages
Let:
$g_{i,j,t}$ = smoothed growth rate of indicator j for country i in year t

To reduce short-term volatility arising from data revisions, measurement noise, or temporary shocks, growth rates are smoothed using a moving average. A five-year moving average is applied as follows:

$$\bar{g}_{i,j,t} = \frac{1}{5}\sum_{k=0}^{4} g_{i,j,t-k}$$

The moving average is computed only when growth rates are available for all five years within the averaging window. Smoothing is applied after growth rates are computed and does not alter the underlying indicator values.

Winsorization of Smoothed Growth Rates
Let:
$\tilde{g}_{i,j,t}^{w}$ = winsorized smoothed growth rate of indicator j for country i in year t
$\tilde{g}_{i,j} = \{\tilde{g}_{i,j,t} : t \in T_{i,j}\}$ = time series of smoothed growth rates for indicator j and country i over all years with valid observations
α_L, α_U = lower and upper winsorization limits (set to 0.01 and 0.01, respectively)

To limit the influence of residual extreme values that may persist after smoothing, smoothed growth rates are winsorized within a country's time series for each indicator.

Values below the lower quantile are set equal to that quantile, and values above the upper quantile are set equal to that quantile:

$$\tilde{g}_{i,j,t}^{w} = \begin{cases} Q_{\alpha_L}(\tilde{g}_{i,j}) & \text{if } \tilde{g}_{i,j,t} < Q_{\alpha_L}(\tilde{g}_{i,j}) \\ Q_{\alpha_U}(\tilde{g}_{i,j}) & \text{if } \tilde{g}_{i,j,t} > Q_{\alpha_U}(\tilde{g}_{i,j}) \\ \tilde{g}_{i,j,t} & \text{otherwise} \end{cases}$$

Winsorization is applied after smoothing along the time dimension of each indicator in a country and serves as a robustness safeguard to limit the influence of extreme values arising from base effects, data revisions, or temporary shocks.

Interpretation Notes: Log growth rates represent the recent pace and direction of change in indicator values rather than absolute progress toward sustainability targets. Temporal smoothing captures underlying trends while reducing the influence of short-term fluctuations. Winsorized smoothed growth rates serve as inputs to the validation, normalization, and aggregation steps of the green growth potential assessment.
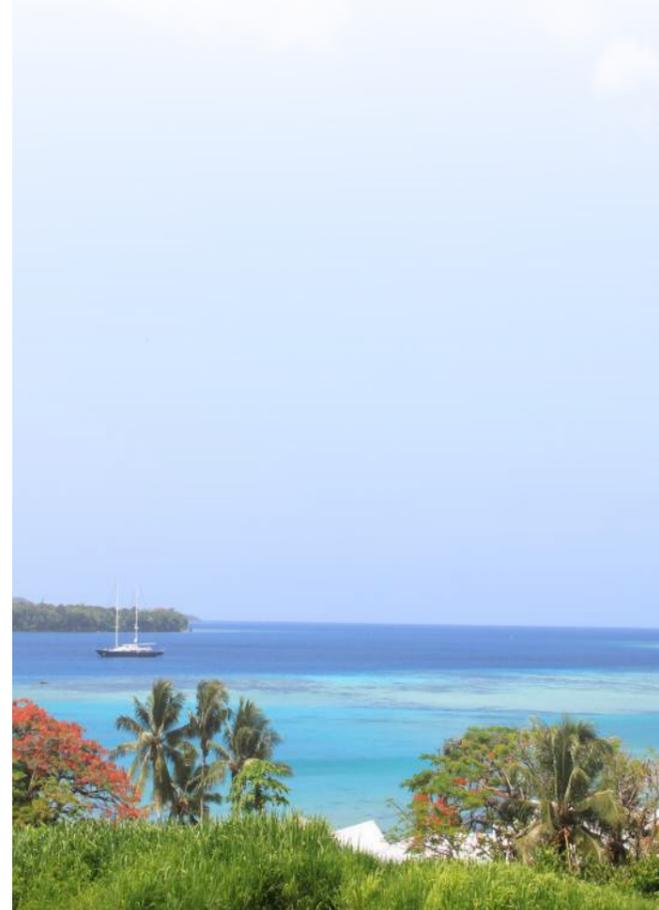
3.2.2. Validation of Growth Rate Indicators

Validation of growth rate indicators is a critical step in the potential assessment, as growth rates are derived measures obtained by transforming and smoothing validated performance indicators. While the underlying indicators and databases have already undergone the data preparation and validation procedures described in Section 3.1, additional validation is required to ensure that the resulting growth dynamics are plausible, stable, and interpretable. Validation of growth rate indicators focuses on identifying implausible patterns arising from data revisions, reporting inconsistencies, or short-term volatility that could distort the assessment of potential. The objective of this validation step is not to mechanically modify or correct growth rates, but to support expert judgement and ensure that the growth signals used in the potential index reflect meaningful and sustained dynamics. To this end, three complementary validation approaches are applied: temporal pattern consistency checks, anomaly detection in growth rates, and peer-group pattern recognition.

Temporal pattern consistency checks are applied as the first validation step, reflecting the central role of temporal dynamics in interpreting growth-based potential. Growth potential is intended to capture recent momentum rather than short-term fluctuations, and implausible temporal patterns undermine this interpretation. Temporal consistency checks, therefore, examine whether smoothed growth rates exhibit abrupt changes, excessive volatility, or frequent reversals in direction over time, each of which signals a different form of temporal inconsistency.[12] First, abrupt accelerations or decelerations may indicate data revisions, methodological changes in data collection, or exceptional shocks. Second, persistently volatile growth rates may reflect unstable reporting rather than genuine underlying dynamics. And third, frequent switching between positive and negative growth weakens the interpretation of growth as sustained momentum and suggests a lack of directional coherence. These three diagnostics are complementary rather than redundant, as they jointly capture changes in level, stability over time, and direction of change. AI-assisted time-series diagnostics are used in a supporting role to enhance the detection of such patterns, particularly change-point detection to identify potential structural breaks. AI outputs are used as screening signals rather than automated corrections, and all flagged cases are subject to expert review. Temporal diagnostics are applied at the country–indicator level to distinguish structural trends from noise, ensuring that growth rates convey coherent, interpretable signals before normalization and aggregation. Technical details of the temporal pattern consistency checks are presented in Box 3.7.

Anomaly detection in growth rates complements temporal consistency checks by identifying growth observations that diverge markedly from peer-group patterns, even if they appear temporally stable. Growth rates are particularly prone to anomalous behavior because small base values can generate extreme growth rates; data revisions or redefinitions may introduce artificial jumps; and reporting errors can be amplified by logarithmic transformations. Traditional outlier detection applied to indicator levels is therefore not sufficient for identifying anomalies in growth dynamics. Anomaly detection is applied within peer groups and focuses on identifying growth observations that are structurally unusual relative to countries with similar characteristics. Density-based clustering, implemented as an unsupervised machine-learning method, is used to classify growth-rate observations that do not belong to dense peer-group

patterns and may warrant further scrutiny.[13] This AI-assisted approach avoids reliance on global thresholds and instead defines anomalous behavior relative to local peer-group structure, which is particularly appropriate for growth dynamics in heterogeneous country contexts. Importantly, anomalous growth rates are not treated as errors or automatically excluded. They may reflect genuine transitions, policy-driven changes, or data artefacts that require contextual interpretation. Anomaly detection serves as a diagnostic tool to flag potentially influential observations prior to normalization and aggregation. The technical specification of this approach is provided in Box 3.8.

The two validation approaches mentioned above are applied as complementary diagnostics to support expert judgement in the potential assessment. Temporal pattern consistency checks focus on stability and coherence over time, anomaly detection identifies isolated or unusual growth observations, and peer-group pattern recognition assesses structural plausibility in a comparative context. Validation at the peer-group level is particularly important because growth rates are normalized relative to peer-group benchmarks, with minimum and maximum reference values defined by the 10th and 90th percentiles of the peer-group distribution. Ensuring that growth-rate indicators are plausible and internally consistent within each peer group, therefore, helps prevent extreme or structurally implausible values from unduly influencing the normalization process. No single validation approach is decisive, and validation outcomes are interpreted jointly using graphical diagnostics. Growth rate indicators that pass validation are used as inputs to subsequent normalization and aggregation steps, ensuring that the potential index is based on growth dynamics that are robust, interpretable, and suitable for cross-country comparison.

Box 3.7. Temporal Pattern Consistency Checks for Growth Rate Indicators

This box presents the technical procedures used to assess the temporal consistency of growth rate indicators as part of the validation of growth dynamics for the potential assessment. Temporal consistency checks are applied to identify implausible or unstable growth patterns that may arise from data revisions, reporting inconsistencies, or short-term shocks, and to support expert review prior to normalization and aggregation. To complement rule-based diagnostics, AI-based time-series analysis is used to identify structural irregularities in growth dynamics, including abrupt changes and deviations from typical temporal patterns.

Input Data
Let:
$\bar{g}_{i,j,t}$= smoothed growth rate of the indicator j for country i in year t, as defined in Box 3.6 Temporal consistency checks are applied at the country–indicator level using consecutive observations of $\bar{g}_{i,j,t}$.

a. Growth Rate Changes (First Differences)
Let:
$\Delta\bar{g}_{i,j,t}$= change in smoothed growth rate of the indicator j for country i between years $t-1$ and t

First differences of smoothed growth rates are computed as:

$$\Delta\bar{g}_{i,j,t} = \bar{g}_{i,j,t} - \bar{g}_{i,j,t-1}$$

Large absolute values of $\Delta\bar{g}_{i,j,t}$ indicate abrupt accelerations or decelerations in growth dynamics, which may reflect data revisions, methodological breaks, or exceptional shocks. This diagnostic flags potential structural breaks in growth patterns that warrant further examination.

b. Volatility Assessment
Let:
$\sigma_{i,j,t}$= rolling volatility of smoothed growth rates for the indicator j and country i at time t
k= length of the rolling time window

Volatility is computed as the standard deviation of smoothed growth rates over a rolling window:

$$\sigma_{i,j,t} = \text{SD}(\bar{g}_{i,j,t-k:t})$$

Elevated volatility indicates persistent instability in growth rates, which may reduce the interpretability of growth as a measure of potential. Volatility assessment complements first-difference analysis by identifying sustained noise rather than isolated breaks.

c. Sign Reversal and Directional Stability
Let:
$\bar{g}_{i,j,t}$= smoothed growth rate of the indicator j for country i in year t
$S_{i,j,t}$=sign($\bar{g}_{i,j,t}$)= direction of smoothed growth rate
$N_{i,j,t}$= number of sign reversals over a predefined time window of length k

The number of sign reversals is computed as:

$$N_{i,j,t} = \sum_{h=1}^{k} \mathbb{I}\left(S_{i,j,t-h} \neq S_{i,j,t-h-1}\right)$$

where $\mathbb{I}(\cdot)$ is an indicator function that equals 1 when the condition holds and 0 otherwise.

A high value of $N_{i,j,t}$ indicates frequent switching between positive and negative growth, reflecting low directional stability. Frequent sign reversals undermine the interpretation of growth as sustained momentum and may signal short-term volatility, data inconsistencies, or structural breaks.

d. AI-Assisted Temporal Pattern Detection (Change-Point Detection)
Let:
$\tilde{g}_{i,j,1:T}$= time series of smoothed growth rates for the indicator j and country i
$\tau_{i,j}^{(m)}$ = detected change-point m, with m=1,…,M
AI-assisted change-point detection algorithms are applied to identify points in time where the statistical properties of the smoothed growth-rate series change.

A change-point is defined as a time τ such that:

$$\bar{g}_{i,j,1:\tau} \sim F_1 \text{ and } \bar{g}_{i,j,\tau+1:T} \sim F_2, F_1 \neq F_2$$

where F_1 and F_2 denote distinct data-generating processes.

Change-point detection complements diagnostics (a–c) by explicitly identifying the timing of structural breaks, which may correspond to data revisions, methodological changes, or exceptional economic or environmental shocks. The method is implemented as an unsupervised machine-learning procedure that produces candidate breakpoints, which are used solely as diagnostic signals.

Box 3.7. Continuation

Computational Procedure

For each country and indicator, the following steps are applied:
1. Compute smoothed growth rates $\bar{g}_{i,j,t}$.;
2. Calculate first differences $\Delta \bar{g}_{i,j,t}$.;
3. Compute rolling volatility $\sigma_{i,j,t}$ over the selected window.;
4. Assess directional stability through sign reversal counts $N_{i,j,t}$.; and
5. Flag growth patterns exhibiting abrupt changes, high volatility, or frequent sign
6. reversals for expert review.

No automatic correction or exclusion of growth rates is performed at this stage.

Interpretation and Use: Temporal pattern consistency checks are applied as diagnostic tools to support expert judgement. Flagged growth patterns are not automatically treated as errors and may reflect genuine structural change, policy interventions, or real-world shocks. Results from temporal diagnostics are interpreted in conjunction with density-based anomaly detection (Box 3.7), peer-group comparisons, and information on data coverage. Together, these checks enhance the robustness and interpretability of growth-based indicators used in the potential assessment.

Scope and Limitations: Temporal consistency diagnostics depend on the length and quality of available time series and are therefore used as screening tools rather than decision rules. Window lengths and thresholds are applied consistently across countries and indicators, but results remain subject to expert interpretation and contextual knowledge.Change-point detection complements diagnostics (a–c) by explicitly identifying the timing of structural breaks, which may correspond to data revisions, methodological changes, or exceptional economic or environmental shocks. The method is implemented as an unsupervised machine-learning procedure that produces candidate breakpoints, which are used solely as diagnostic signals.

Box 3.8. Anomaly Detection in Growth Rate Indicators Using Density-Based Clustering

This box describes the technical approach used to identify anomalous growth-rate observations as part of the validation of growth rate indicators for the potential assessment. Anomaly detection is applied as a diagnostic step to flag growth patterns that deviate markedly from peer-group behavior and may warrant further expert review before normalization and aggregation. Density-based clustering is an unsupervised machine-learning method that identifies structure in growth-rate data without relying on predefined labels or distributional assumptions. By identifying growth observations that diverge markedly from peer-group patterns, this step enhances the robustness and interpretability of the potential assessment.

Input Data and Scope
Let:
$\bar{g}_{i,j,t}$ = smoothed growth rate of the indicator j for country i in year t, as defined in Box 3.6
$\bar{g}_{i,t} = (\bar{g}_{i,1,t}, \bar{g}_{i,2,t}, \cdots, \bar{g}_{i,J,t})$ = vector of smoothed growth rates for the country i across indicators
$P(i)$ = peer group to which country i belongs (e.g., income group)
Anomaly detection is applied within peer groups and uses smoothed growth rates to reduce the influence of short-term volatility.

Density-Based Clustering Method
Anomaly detection is implemented using density-based spatial clustering of applications with noise (DBSCAN). DBSCAN identifies dense regions in the data space and classifies observations that do not belong to any dense cluster as noise.

Let:
ε = neighborhood radius defining the maximum distance between two observations for them to be considered neighbors
$minPts$ = minimum number of observations required to form a dense region
For each peer group P and year t, DBSCAN is applied to the set of growth-rate observations:

$$\mathcal{G}_{P,t} = \{\bar{g}_{i,t} \mid i \in P\}$$

An observation $\bar{g}_{i,t}$ is classified as:

- a core point if at least $minPts$ observations lie within distance ε,
- a border point if it lies within ε of a core point but does not itself satisfy the density condition,
- a noise point if it is not assigned to any cluster.

Noise points are identified as anomalous growth-rate observations.

Computational Procedure
For each peer group and year, the following steps are applied:
1. Construct the set of smoothed growth-rate vectors $\mathcal{G}_{P,t}$.;
2. Apply DBSCAN using predefined values of ε and $minPts$.;
3. Identify observations classified as noise; and
4. Flag these observations for expert review.

No automatic correction, removal, or adjustment of growth-rate values is performed at this stage.

Interpretation and Use: Anomalous growth-rate observations identified through density-based clustering are not automatically treated as data errors. Such observations may reflect genuine structural changes, policy-driven transitions, or data artefacts arising from reporting inconsistencies or revisions. Flagged observations are reviewed in conjunction with temporal pattern diagnostics, peer-group comparisons, and information on data coverage. The objective of anomaly detection is to support expert judgement and to ensure that isolated or implausible growth patterns do not unduly influence subsequent peer-based normalization.

Scope and Limitations: The results of density-based clustering depend on the choice of ε and $minPts$ parameters and are therefore used as screening tools rather than decision rules. Anomaly detection complements, but does not replace, expert review and other validation procedures applied to growth rate indicators.

3.2.3. Normalization of Growth Relative to Peers

Growth-rate indicators derived for assessing green growth potential capture the recent pace and direction of change in underlying performance indicators. However, raw growth rates are not directly comparable across indicators, countries, or years for several reasons. First, growth dynamics differ substantially in scale, dispersion, and volatility across sectors and development contexts. Second, growth rates are strongly influenced by baseline levels, giving rise to "catch-up and saturation effects"[14] that can mechanically amplify or dampen observed growth independently of underlying transition momentum.[15] Third, growth rates lack a natural unit of interpretation analogous to the level-based sustainability benchmarks used for performance measurement, and their desirability may differ across indicators depending on directionality (i.e., direction of change). Finally, growth rates are often sensitive to short-term shocks, data revisions, and measurement noise, further undermining comparability across time and countries. Normalization is therefore required to transform heterogeneous growth trends into a common, interpretable metric of relative transition momentum that can be aggregated and compared across countries.

Unlike performance indicators, growth-based indicators cannot be benchmarked against absolute sustainability targets. Growth potential reflects relative momentum rather than achievement, and its interpretation is inherently comparative. For this reason, benchmarking of growth rates in the Green Growth Index 2.0 is conducted relative to peer-group distributions rather than against global reference values. Peer-group benchmarking ensures that growth dynamics are evaluated within structurally comparable contexts, accounting for systematic differences in growth volatility, dispersion, and baseline conditions across development stages. It also avoids structural bias that may occur when global reference frames are dominated by growth patterns reflecting economic and institutional contexts that are not comparable. Peer groups are defined ex ante using income-based classifications (i.e., World Bank income groups) and are applied consistently across indicators and years. Benchmarking growth rates within peer groups is essential for interpretability, as countries at different income levels often exhibit systematically different growth patterns, including catch-up effects in lower-income contexts and saturation effects in higher-income contexts. Global reference frames would therefore risk overstating or understating growth potential where observed dynamics are largely driven by structural conditions rather than policy-driven transition momentum. By situating each country's growth dynamics relative to its peers, peer-group benchmarking provides a more interpretable and policy-relevant measure of transition momentum and supports meaningful comparisons and learning among countries facing similar constraints and opportunities.

Benchmarking plays a central role in normalizing growth rates. Because growth potential has no predefined target, benchmarking is required to contextualize observed growth dynamics within each peer group. Benchmarking does not imply normative judgments about sufficient or optimal growth; rather, it provides a descriptive reference that positions each country's growth relative to the distribution observed among its peers. In the Green Growth Index 2.0, benchmarking is implemented using percentile-based bounds derived from the peer-group distribution of growth rates for each indicator and year. This approach allows growth potential to be interpreted as relative

momentum within the observed range of peer performance. Percentile-based benchmarking is adopted to enhance the robustness and interpretability of growth normalization. Growth-rate distributions are often skewed and may contain extreme values arising from data revisions, base effects, or short-term shocks. Using the 10th and 90th percentiles as lower and upper reference bounds limits the influence of such extremes while preserving meaningful variation across the distribution's central range. Benchmarking is performed within peer groups and by year, ensuring that normalization reflects contemporaneous and structurally comparable growth dynamics.

Following benchmarking, growth rates are rescaled relative to the peer-group bounds to obtain normalized growth potential scores, ranging from 0 to 100. The resulting scores are unitless and bounded, reflecting a country's relative position within the peer-group distribution for a given indicator and year. Higher normalized values indicate stronger transition momentum relative to peers, while values closer to the lower bound indicate weaker momentum. Scores near the midpoint reflect average peer-group performance. Normalization preserves ordinal relationships within peer groups and ensures that growth potential scores are comparable across indicators and suitable for aggregation. Indicator directionality is explicitly accounted for in the normalization process. While higher growth rates represent favorable transition dynamics for many indicators, growth in certain indicators reflects deterioration in green growth outcomes. To ensure consistent interpretation, normalized scores for indicators with negative directionality are adjusted such that higher values uniformly indicate more favorable transition momentum. This directional consistency is essential for coherent aggregation and interpretation of growth potential across pillars and dimensions.

Normalization procedures also account for edge cases and data limitations. Situations may arise in which peer-group growth distributions exhibit no dispersion, or in which growth-rate observations are missing for specific country–indicator–year combinations. In such cases, normalization using percentile bounds is neither feasible nor stable. To avoid artificially penalizing or rewarding countries due to data constraints, a neutral midpoint value is assigned. This treatment ensures that missing or non-informative growth signals do not exert undue influence on aggregated potential scores, while preserving comparability across countries and years. The normalized growth potential scores produced by this process constitute the indicator-level inputs for aggregating green growth potential at the pillar, dimension, and index levels. Box 3.9 presents the normalization and benchmarking.

3.2.4. Aggregation of Growth Potential Scores

Aggregation of growth potential scores follows the same hierarchical structure, weighting scheme, and aggregation functions as those applied to performance indicators. Indicator-level scores are aggregated sequentially to the pillar, dimension, and overall index levels using identical procedures, as described in Box 3.4. No additional aggregation rules are introduced for the growth potential, ensuring full methodological consistency between the performance and potential components of the Green Growth Index 2.0.

The inputs to aggregation are the normalized growth potential scores derived in Section 3.2.3. These scores represent relative transition momentum within peer groups and incorporate

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Box 3.9. Normalization and Benchmarking of Growth Relative to Peers

This box presents the normalization and benchmarking approach used to transform validated growth-rate indicators into comparable measures of green growth potential. In contrast to performance indicators, which are normalized against absolute sustainability targets, growth-based indicators are normalized relative to growth dynamics observed among structurally similar countries. This peer-relative approach reflects the inherently comparative nature of growth potential and supports meaningful interpretation of transition momentum across heterogeneous development

Input Data, Peer Groups, and Benchmarking Framework
Let:
$g_{i,c,t}$ denote the smoothed logarithmic growth rate of the indicator i for country c in year t, as defined in Box 3.6
$P(c)$ denote the peer group to which country c belongs
$\mathcal{G}_{i,P,t} = \{g_{i,c,t} : c \in P\}$ denote the set of growth rates for the indicator i observed among all countries in the peer group P in year t
$Q_q(\cdot)$ denote the empirical quantile operator at the probability level $q \in (0,1)$

Peer groups are defined ex ante using income-based categories and are applied consistently across all indicators and years. Benchmarking is conducted within peer groups rather than across the full set of countries to ensure that growth dynamics are evaluated relative to countries with broadly comparable structural characteristics, development stages, and baseline conditions. Global benchmarking would risk conflating structurally driven differences in growth dynamics with genuine transition momentum. Peer-group benchmarking, therefore, provides a more appropriate and interpretable reference frame for assessing relative green growth potential.

Because growth potential has no natural sustainability target analogous to those used for performance indicators, benchmarking is required to contextualize observed growth rates. Benchmarking is implemented using the empirical distribution of growth rates within each peer group. For each indicator i, peer group P, and year t, lower and upper reference bounds are defined as:

$$p10_{i,P,t} = Q_{0.10}(\mathcal{G}_{i,P,t}), \; p90_{i,P,t} = Q_{0.90}(\mathcal{G}_{i,P,t})$$

The use of the 10th and 90th percentiles limits the influence of extreme or anomalous growth observations while preserving meaningful variation across the central range of the peer-group distribution. These bounds provide a robust and policy-relevant reference for assessing relative transition momentum within each peer group.

Normalization of Growth Rates
Let:
$\tilde{g}_{i,c,t}$ denote the normalized growth potential score of the indicator i for country c in year t
Normalized growth scores are computed as:

$$\tilde{g}_{i,c,t} = \frac{g_{i,c,t} - p10_{i,P(c),t}}{p90_{i,P(c),t} - p10_{i,P(c),t}}$$

where normalization is performed within the peer group $P(c)$.

Values of $\tilde{g}_{i,c,t}$ are bounded to the interval [0,1], such that growth rates below the 10th percentile receive a score of 0, and those above the 90th percentile receive a score of 1. Intermediate values are mapped proportionally between these bounds. This transformation yields a unitless measure of relative transition momentum within each peer group. The final scores are multiplied by 100 to align with the performance scores.

Treatment of Indicator Directionality
Let:
$d_i \in \{+1, -1\}$ denote the directionality (i.e., direction of change) of the indicator i, where +1 indicates that higher growth reflects more favorable green growth dynamics and −1 indicates the opposite
For indicators with negative directionality ($d_i = -1$), normalized scores are adjusted as:

$$\tilde{g}^*_{i,c,t} = 1 - \tilde{g}_{i,c,t}$$

where $\tilde{g}^*_{i,c,t}$ denotes the direction-adjusted growth potential score. This transformation ensures that higher normalized values consistently indicate more favorable transition momentum across all indicators.

Box 3.9. Continuation

Handling of Edge Cases and Missing Information

Edge cases may arise when the peer-group growth distribution exhibits zero dispersion (i.e. $p90_{i,P,t}$ $=p10_{i,P,t}$) or when growth-rate observations are missing for a given country, indicator, and year. In such cases, normalization using percentile bounds is neither feasible nor stable.
To address these situations, a neutral midpoint value is assigned:

$$\tilde{g}_{i,c,t} = 0.5$$

This approach avoids artificially penalizing or rewarding countries due to data limitations or a lack of variation within peer groups. It ensures that missing or non-informative growth signals do not exert undue influence on aggregated potential scores while preserving comparability across countries and years.

Interpretation: Normalized growth potential scores are bounded between 0 and 100 and reflect a country's relative position within the peer-group distribution of growth dynamics for a given indicator and year. Scores close to 100 indicate strong transition momentum relative to peers, scores close to 0 indicate weak momentum, and scores near the midpoint reflect average peer-group performance. These normalized scores serve as the basis for aggregating into pillar-, dimension-, and index-level measures of green growth potential and for subsequent characterization of green growth pathways.

adjustments for the direction of change in individual indicators, as well as for edge cases and missing information (Box 3.9). Aggregation, therefore, operates on fully normalized and internally consistent indicator-level. Aggregation, therefore, operates on fully normalized and internally consistent indicator-level potential scores, without further transformation at this stage. As with performance aggregation, indicator weights and missing-data rules are applied consistently across all levels of aggregation.

While the mathematical aggregation procedures are identical to those used for performance measurement, the interpretation of aggregated growth potential scores differs fundamentally (Table 1). Aggregated potential scores summarize average relative momentum across indicators within a pillar or dimension, rather than levels of achievement relative to sustainability benchmarks. High aggregate potential indicates comparatively strong transition dynamics among structurally similar countries (i.e., income peer group). In contrast, low aggregate potential reflects relatively weak momentum, even when current performance levels are already high (see Section 3.3). Aggregation smooths short-term volatility at the indicator level by averaging across multiple growth dynamics, while preserving meaningful differences in relative transition momentum across pillars, dimensions, and countries.

Aggregated growth potential scores form the basis for subsequent robustness checks and validation of growth dynamics (Section 3.2.5) and constitute a core input to the classification of green growth pathways (Section 3.3). By maintaining identical aggregation structures for performance and potential while preserving their distinct interpretations, the Green Growth Index 2.0 enables coherent integration of level-based and momentum-based assessments within a unified analytical framework.

## 3.2.5. Robustness and Validation of Growth Dynamics

Robustness and validation analyses are conducted to assess the stability and internal coherence of the growth dynamics derived in the preceding steps. Structural model uncertainty is not reassessed for the potential index, as the aggregation hierarchy, weighting scheme, and aggregation functions used to construct growth potential scores are identical to those applied in the performance index and were subject to comprehensive structural validation in the 2019 Green Growth Index Technical Report. The introduction of green growth potential represents an extension in analytical focus, from levels of achievement to rates and directions of change, rather than a modification of the underlying model structure. Accordingly, robustness and validation efforts for the potential index focus on three aspects: Model parameter uncertainty, including uncertainty arising from parameter choices and data preparation assumptions; Input data sensitivity, focusing on input specifications that are specific to growth-rate indicators; and Analysis of explanatory power and internal coherence, looking at diagnostic assessment of the internal coherence of aggregated growth dynamics.

Model parameter uncertainty is assessed by examining the sensitivity of growth potential scores to alternative parameter values used in the preprocessing and benchmarking of growth rates. Two aspects are considered: the percentile bounds used for peer-group normalization and the winsorization limits applied to cap extreme growth rates. First, in the baseline specification, growth dynamics are benchmarked within peer groups using

the 10th and 90th percentiles of the peer-group growth distribution. These parameter choices are particularly relevant for growth-rate indicators, which often exhibit skewed distributions, large cross-country dispersion, and sensitivity to base effects and short-term shocks. Uncertainty analysis, therefore, explores alternative percentile bounds, such as the 5th and 95th percentiles, to assess the robustness of relative momentum signals. Second, winsorization is applied to smoothed growth-rate series to limit the influence of extreme positive or negative growth observations that may arise from one-off shocks, base effects, or data irregularities. In the baseline specification, extreme values are capped using symmetric winsorization limits of 0.01, ensuring that the most extreme observations do not disproportionately influence subsequent normalization and aggregation. These thresholds are varied as part of the uncertainty analysis to assess whether relative momentum signals and country rankings remain stable under reasonable changes in the treatment of extremes, or whether they are influenced mainly by a small number of extreme observations.

Input data sensitivity analysis addresses uncertainty arising from the construction of growth-rate series and the handling of non-informative observations (i.e., zeros or missing values), which are central considerations for growth-based indicators. Two aspects are considered: the length of the smoothing window used to derive growth dynamics and the treatment of edge cases where growth signals are missing or non-informative. First, in the baseline specification, annual log growth rates are smoothed using a centered five-year rolling window to reduce short-term volatility and measurement noise. This choice reflects a balance between capturing recent transition momentum and limiting sensitivity to transitory fluctuations. Sensitivity analysis, therefore, examines alternative smoothing window lengths to assess the extent to which growth potential scores depend on the chosen temporal window, and whether observed momentum reflects persistent transition dynamics or short-term variability. Second, the treatment of edge cases is examined. In the baseline specification, cases in which normalization is infeasible, such as missing growth observations or zero dispersion within peer groups, are assigned a neutral midpoint value of 0.5 following normalization. Sensitivity analysis ensures that the frequency and influence of such midpoint assignments are evaluated under alternative data availability conditions, allowing assessment of whether growth potential measures are robust to data gaps or limited temporal coverage, or whether non-informative observations unduly shape them.

Analysis of explanatory power and internal coherence complements uncertainty and sensitivity analysis by examining whether aggregated growth potential scores meaningfully reflect underlying indicator-level dynamics. Correlation analysis is used to assess the relationship between indicator-level growth potential scores and aggregated scores at the pillar, dimension, and index levels, providing diagnostic evidence on the preservation of growth signals through successive stages of aggregation. Descriptive regression-based analyses are also employed to examine the relative contributions of indicators and pillars to overall growth potential scores, helping identify concentration effects or the dominance of specific components. These analyses are used strictly for validation and diagnostic purposes and do not inform reweighting or structural modification of the index. Together, they support the assessment of whether the aggregation framework coherently summarizes diverse growth dynamics into interpretable measures of relative transition momentum.
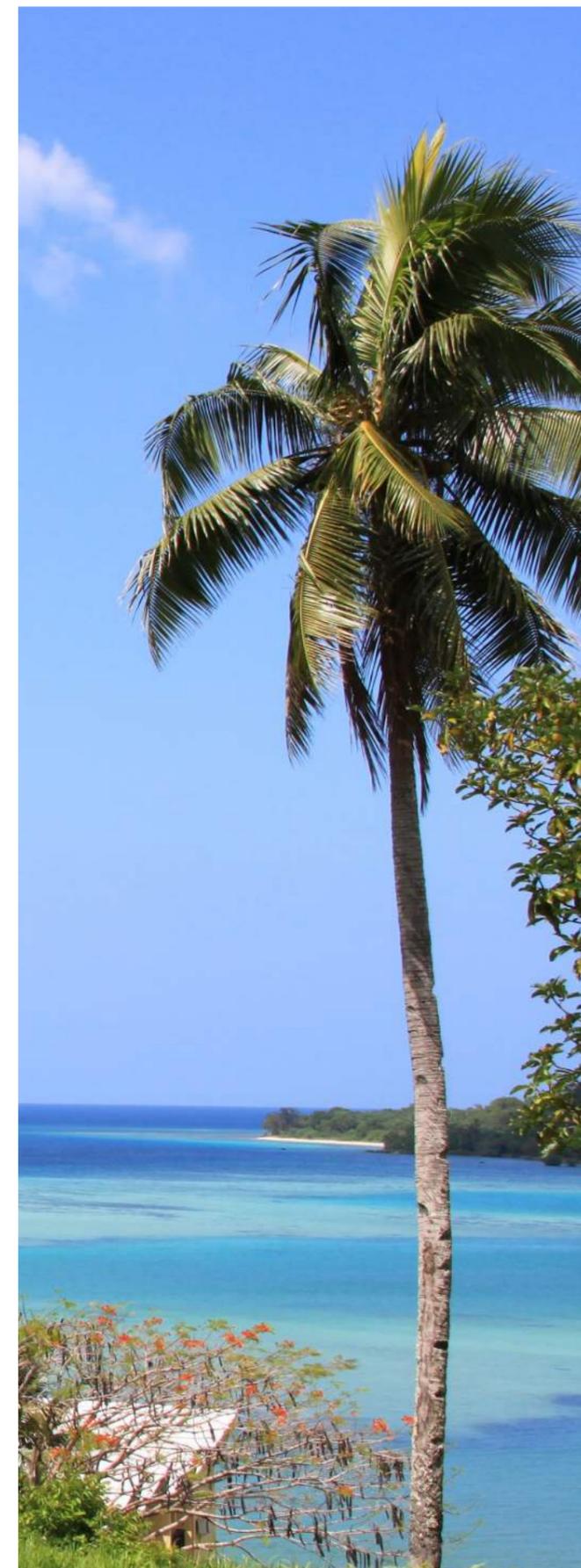
3.2.6. Validation of Potential Index Scores

Validation of green growth potential index scores differs in scope and purpose from the validation of performance index scores presented in Section 3.1.6. While performance validation focuses on assessing the plausibility of level-based scores relative to sustainability benchmarks, external reference indicators, and established empirical patterns, validation of potential scores addresses the plausibility and internal coherence of relative growth dynamics. Growth potential scores do not represent levels of achievement and are not intended to predict future outcomes. Accordingly, their validation cannot rely on comparisons with absolute targets or external outcome indicators; instead, it focuses on whether relative momentum signals behave consistently across peers, dimensions, and time. Validation methods for potential scores differ from the robustness and sensitivity analyses discussed in Section 3.2.5, which assess the stability of results under alternative parameter values and data assumptions. In contrast, the validation procedures presented here examine the internal consistency and analytical plausibility of potential scores produced under the baseline specification.

Validation of potential index scores, therefore, focuses on three complementary aspects: the plausibility of relative momentum signals within peer groups, the temporal plausibility of growth dynamics, and the cross-dimensional coherence of aggregated potential scores. Together, these checks support confidence that potential scores provide a meaningful and interpretable summary of recent transition dynamics.

Peer-group plausibility validation assesses whether potential scores are interpretable and consistent within the peer contexts used for benchmarking. Since growth potential is defined relative to peer-group distributions, validation examines countries' positions within these distributions and identifies cases where relative momentum is unusually high or low compared to structurally similar countries. Such assessments focus on whether observed growth dynamics are plausible given shared development characteristics, baseline conditions, and typical transition patterns within each peer group. Such cases do not imply measurement error, but they signal the need for closer analytical review using graphical outputs and country context to ensure that observed growth dynamics are not driven by spurious effects or isolated indicator behavior. This peer-relative perspective supports validation of growth potential as a comparative measure of transition momentum, ensuring that differences in potential reflect meaningful variation among comparable countries rather than distortions arising from data structure or benchmarking.

Temporal plausibility validation examines the stability and evolution of potential scores over time. Growth potential scores are expected to reflect sustained transition dynamics rather than short-lived fluctuations. Validation, therefore, reviews year-to-year changes in potential scores to identify abrupt reversals, fluctuations, or discontinuities that may be inconsistent with underlying transition processes. The assessment focuses on whether observed changes exhibit continuity and directional coherence over time, in line with the gradual nature of structural transitions in environmental, economic, and social systems. Temporal patterns are assessed through a systematic review of time-series visualizations and trend profiles for potential scores at the indicator, pillar, and dimension levels. Where abrupt changes or irregular patterns are observed, these are examined in relation to underlying indicator behavior, data availability, and

relevant contextual factors, including policy shifts or external shocks, to distinguish plausible changes in transition momentum from spurious patterns arising from volatility, sparse time series, or data revisions. This validation step supports confidence that potential scores capture meaningful temporal patterns in growth dynamics and are suitable for comparative analysis over time.

Cross-dimensional coherence validation assesses whether growth potential signals are consistent across dimensions and aggregation levels. This involves examining whether underlying pillar-level dynamics broadly support high or low potential in a given dimension, or whether a narrow subset of indicators drives aggregated results. Rather than applying additional statistical tests, this assessment is conducted through a systematic review of graphical outputs and comparative visualizations across dimensions and aggregation levels, informed by expert judgement and contextual knowledge. Graphical patterns are examined to assess whether potential scores reflect balanced, interpretable growth dynamics across dimensions, or whether isolated indicators or atypical patterns dominate them. This validation step supports confidence that aggregated potential scores meaningfully summarize diverse transition dynamics within the established index structure and that observed patterns are analytically plausible given country contexts and known transition processes.

As with performance validation, validation of potential index scores does not lead to adjustment of normalized scores, aggregation rules, or weighting schemes. The purpose of these validation procedures is diagnostic, supporting transparent interpretation of growth potential scores and informing subsequent analytical use, including the classification of green growth pathways in Section 3.3.

3.3. Green Growth Pathways

This section presents the green growth pathways framework, which integrates information from performance and potential assessments to characterize patterns of green growth transition across countries. Pathways provide a structured, comparative lens for interpreting how current levels of green growth achievement interact with recent transition momentum, without implying predictions or policy prescriptions. By positioning countries within a combined performance–potential analytical plane, the pathways framework supports descriptive analysis of transition dynamics and facilitates peer-based comparison. The performance–potential plane provides a two-dimensional representation in which countries are positioned according to their relative levels of performance (x-axis) and potential (y-axis). The approach is designed to enhance the interpretability of Index results while remaining fully grounded in the validated indicator framework and methods described in the preceding sections.

3.3.1. Conceptual Framework and Purpose of Green Growth Pathways

Green growth performance scores provide a snapshot of countries' current levels of achievement across the dimensions of green growth, while growth potential scores capture recent transition momentum relative to peers. Interpreting these two measures in isolation can obscure important differences in transition dynamics. Countries with similar performance levels may be progressing at significantly different speeds, and countries exhibiting strong recent momentum may still face substantial gaps

in current outcomes. A pathway-based perspective is therefore introduced to integrate information on performance and potential, thereby providing a more comprehensive understanding of countries' transition states within the Green Growth Index framework.
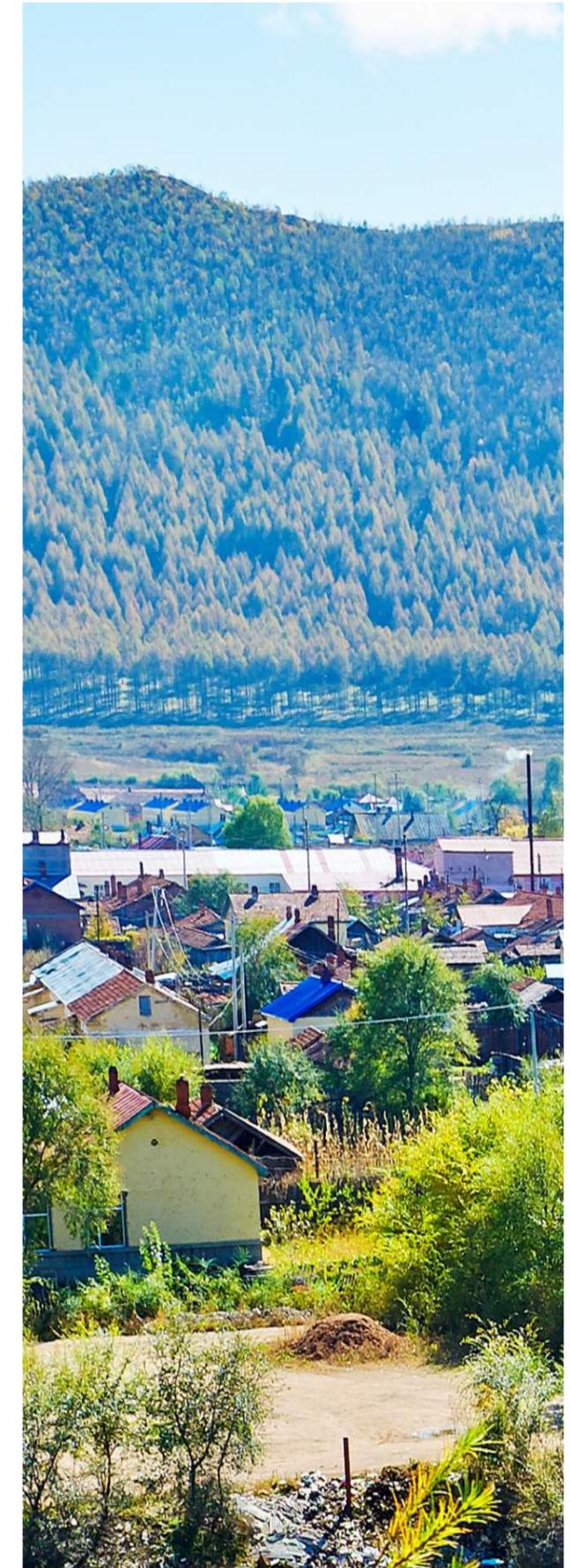
Green growth pathways are defined as analytical classifications based on the joint positioning of countries in the performance–potential plane. They describe relative transition states that reflect the interaction between accumulated outcomes and recent growth dynamics, rather than representing projected trajectories or future pathways. Pathways are inherently comparative and descriptive, allowing countries to be assessed in relation to peers facing similar structural conditions. They do not imply linear or irreversible progress, nor do they prescribe specific policy choices or sequences.

The conceptual basis of the pathway framework rests on the complementary nature of performance and potential. Performance scores reflect long-term outcomes shaped by structural, institutional, and policy factors, while potential scores capture recent changes in these outcomes relative to peer-group benchmarks. Joint interpretation of these measures enables differentiation between countries with mature systems experiencing slower marginal gains, countries undergoing catch-up dynamics driven by accelerated progress, and countries facing persistent constraints in both achievement and momentum. This combined perspective provides a more complete picture of green growth transitions. Pathways complement, rather than replace, the underlying index scores and are intended to support transparent interpretation rather than to generate new rankings. Within the Green Growth Index, pathways serve as an analytical lens for interpreting heterogeneity in transition dynamics across countries and over time. They support comparative analysis across peer groups, facilitate identification of shared transition patterns, and provide a structured basis for discussing the interaction between current performance and recent progress in subsequent sections of the report.

It is important to note the scope and limits of pathway analysis. Pathways do not predict future performance outcomes, nor do they assume linear or deterministic transitions between states. Movement across pathways may be non-linear and reversible, reflecting changes in relative momentum, structural conditions, or external shocks. Pathway classification is sensitive to relative positioning within the performance–potential plane and should be interpreted in conjunction with country context and detailed indicator-level information. The following sections define the quadrant-based pathways on the performance–potential plane, describe how countries are classified within this framework, and examine the dynamics and validation of pathway assignments over time.

3.3.2. Definition of Quadrant-Based Green Growth Pathways

Green growth pathways are defined using a two-dimensional framework that jointly considers countries' current levels of green growth performance and their recent transition momentum as captured by growth potential scores. As illustrated in Figure 5, countries are positioned within a performance–potential plane, where the horizontal axis represents green growth performance, reflecting the level of achievement across dimensions, and the vertical axis represents green growth potential, capturing recent momentum relative to peers. The intersection of these two

dimensions divides the space into four analytical quadrants, each corresponding to a distinct green growth pathway.Quadrant boundaries are defined using reference thresholds applied consistently across countries and years. In the baseline specification, global median values of performance and potential scores are used as reference lines to distinguish relatively high and low achievement and momentum. These thresholds serve as analytical benchmarks for classification and do not affect the underlying performance or potential scores. Countries located near quadrant boundaries are interpreted with caution, and pathway assignment is considered a relative, descriptive classification rather than a precise or deterministic categorization.The four quadrant-based green growth pathways are defined as follows.

Leaders in Motion (Quadrant A)

occupy the upper-right quadrant of the framework and are characterized by both high performance and high potential. Countries in this pathway have achieved relatively strong green growth outcomes while maintaining above-average transition momentum.

Achievers Losing Momentum (Quadrant B)

are located in the lower-right quadrant and combine high performance with relatively low potential. This pathway reflects a context in which strong current outcomes coexist with slowing recent progress, often associated with maturity effects or reduced incremental gains.

Emerging Improvers (Quadrant C)

positioned in the upper-left quadrant, display relatively low current performance but high potential, indicating accelerated transition momentum and catch-up dynamics relative to peers.

Slow Movers (Quadrant D)

occupy the lower-left quadrant and are characterized by both low performance and low potential, reflecting limited recent progress alongside persistent gaps in green growth outcomes.

Pathway definitions are applied uniformly across countries and years and do not introduce additional aggregation, weighting, or normalization beyond those used to construct the performance and potential indices. Pathway assignment does not modify index scores and should be interpreted as a structured summary of countries' joint position within the performance–potential plane. As such, pathways provide an analytical lens for organizing and comparing transition dynamics, rather than an additional scoring layer or ranking mechanism. The four quadrant-based green growth pathways are defined as follows.

3.3.3. Dynamics and Analytical Use of Green Growth Pathways

Green growth pathways are dynamic and may evolve over time as countries' performance levels and transition momentum change. Because pathway classification is based on annually updated performance and potential scores, countries may move across quadrants in response to shifts in relative achievement, changes in transition momentum, or both. Such movements are not assumed to be linear or irreversible. Transitions across pathways may reflect sustained changes in underlying dynamics, temporary accelerations or slowdowns, or the influence of external shocks. Pathway analysis, therefore, focuses on identifying persistent transition dynamics over time rather than isolated year-to-year movements. Figure 6 illustrates these dynamics by tracing country trajectories within the performance–potential plane over multiple years, highlighting both the direction and persistence of pathway movements.

Interpretation of pathway transitions requires attention to the direction and persistence of movement within the performance-potential plane. For example, movement from Emerging Improvers to Leaders in Motion indicates that accelerated transition momentum has been accompanied by rising performance levels, suggesting strengthening of progress. By contrast, shifts from Leaders in Motion to Achievers Losing Momentum reflect contexts in which strong performance is maintained but recent momentum has weakened, often associated with maturity effects or diminishing marginal gains. Transitions from Slow Movers to Emerging Improvers signal the emergence of transition momentum despite continued performance gaps. In contrast, persistent positioning in the Slow Movers quadrant may indicate structural, institutional, or contextual constraints that affect both achievement and momentum. The examples shown in Figure 6 demonstrate how such transitions can occur gradually over time, rather than through abrupt changes in a single year.

Beyond temporal analysis, green growth pathways provide a structured framework for comparative assessment across countries and peer groups. By jointly considering performance and potential, pathways enable distinguishing countries with similar achievement levels but divergent momentum profiles, as well as countries with comparable momentum from different starting points. This facilitates peer-based learning and comparative analysis by highlighting shared transition characteristics and challenges among countries occupying similar positions in the performance–potential space. Table 2 summarizes the typical performance-potential profiles, transition dynamics, and analytical interpretation associated with each pathway, providing a structured reference for comparative analysis across countries and regions. Green growth pathways have direct relevance for policy dialogue and strategic analysis, while remaining analytically neutral and non-policy prescriptive. They provide a concise way to frame discussions about where countries stand in their transition processes and how recent momentum aligns with existing performance levels. For countries classified as Leaders in Motion, pathways highlight the importance of sustaining momentum while managing increasing complexity and trade-offs. Achievers Losing Momentum highlight the need for innovation, efficiency gains, or policy adjustments to maintain progress. Emerging Improvers point to contexts where recent acceleration may warrant support to consolidate gains and sustain momentum, while Slow Movers highlight situations where inherent constraints and capacity gaps may be limiting both achievement and momentum. As summarized in Table 2,

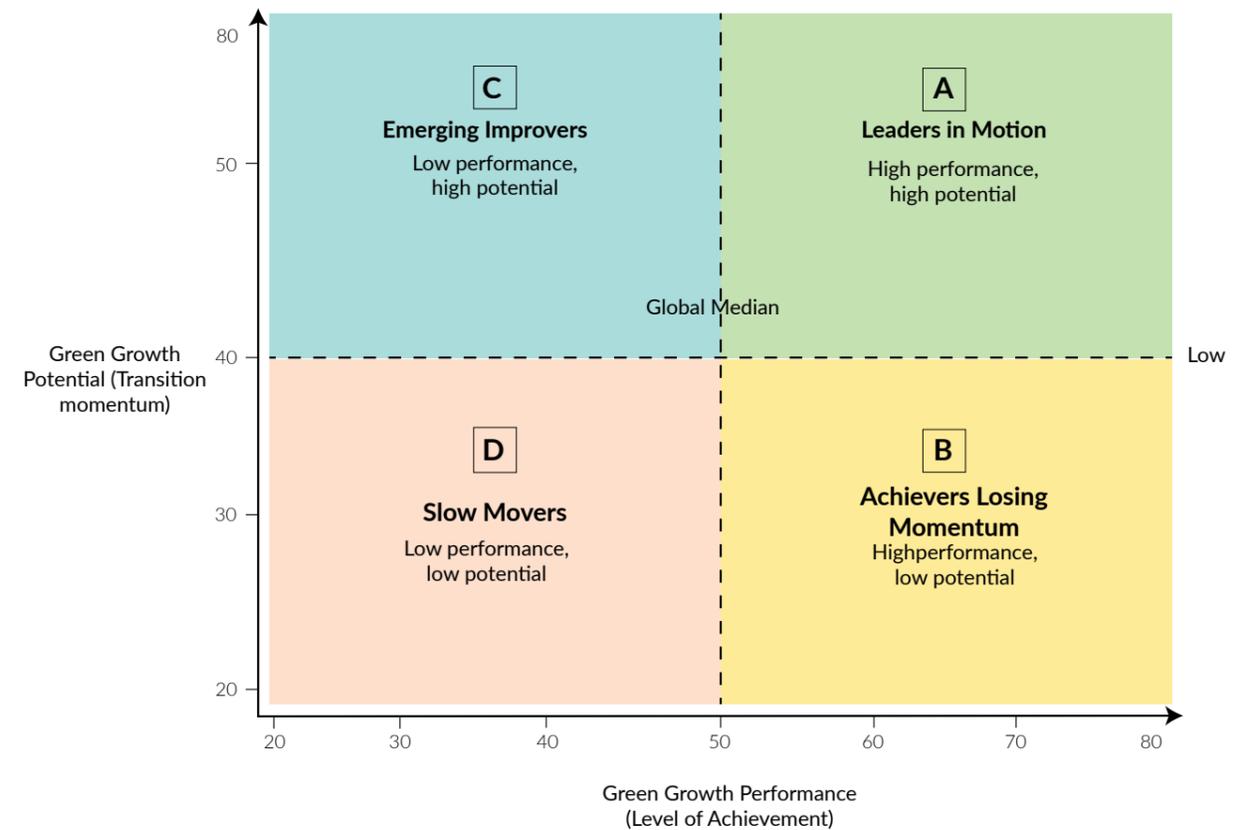**Figure 5. Illustration of Quadrant-Based Green Growth Pathways On the Performance-Potential Plane**

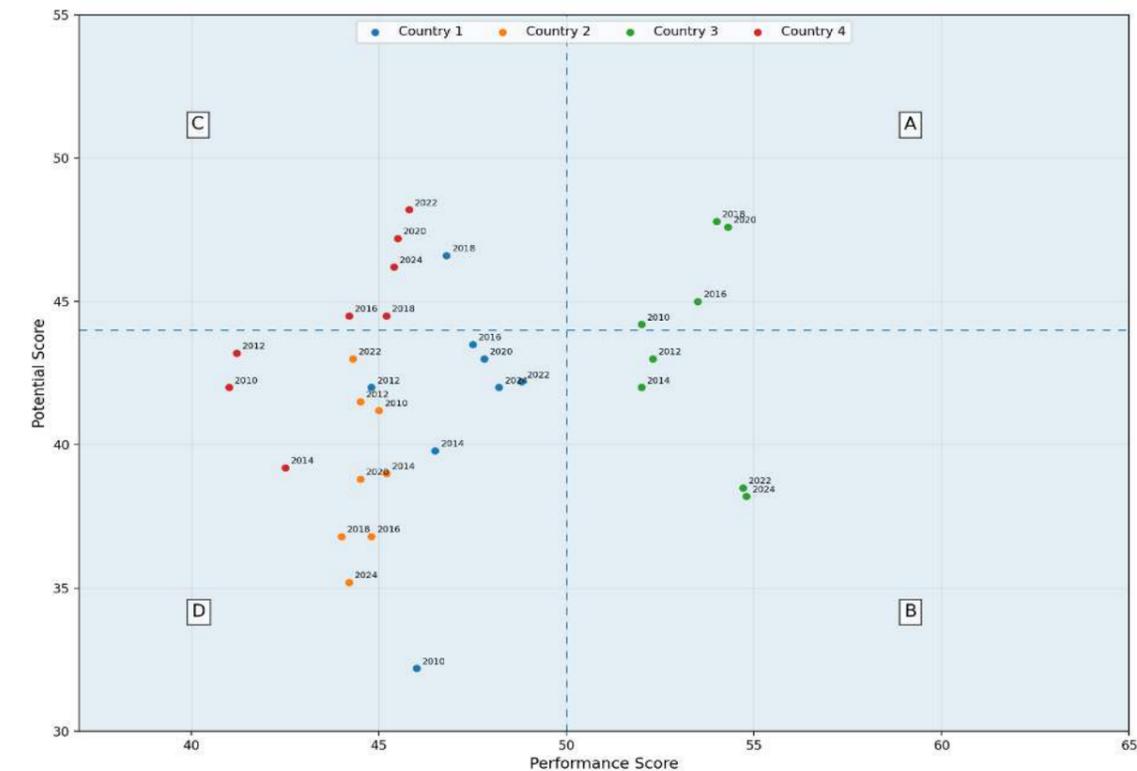**Figure 6. Illustration of Dynamics Of Green Growth Pathways**

Table 2. Analytical interpretation and Policy relevance of the Green Growth Pathways

Pathway	Performance–Potential Profile	Typical Transition Dynamic	Analytical Interpretation	Policy Relevance (Non-prescriptive)
Leaders in Motion	High performance, high potential	Sustained or advancing momentum at relatively high levels of achievement	Indicates consolidated outcomes alongside continued progress; momentum is broad-based rather than driven by isolated indicators	Focus on sustaining momentum, managing complexity, and addressing emerging trade-offs as systems mature
Achievers Losing Momentum	High performance, low potential	Slowing or decelerating momentum despite strong current outcomes	Reflects maturity effects or diminishing marginal gains; performance remains strong but recent progress has moderated	Highlights the need for innovation, efficiency improvements, or policy adjustments to prevent long-term stagnation
Emerging Improvers	Low performance, high potential	Accelerating momentum from lower starting points; catch-up dynamics	Signals rapid relative progress that has not yet translated into high performance levels	Suggests opportunities to consolidate gains and support sustained acceleration through targeted interventions
Slow Movers	Low performance, low potential	Limited or weak momentum alongside persistent outcome gaps	Indicates constrained transitions, potentially driven by structural, institutional, or contextual barriers	Draws attention to structural constraints and capacity gaps that may require targeted support and enabling conditions

the policy relevance of pathways lies in framing priorities and implementation timing rather than prescribing specific policy actions.

At the same time, pathway analysis has clear limits. Pathways are sensitive to relative positioning and should be interpreted alongside detailed indicator-level evidence and country context. Small movements near quadrant boundaries may reflect marginal changes in scores rather than substantive shifts in transition dynamics. Pathways do not predict future performance, nor do they imply converging or diverging trends. Their analytical value lies in organizing information on performance and momentum in a transparent and interpretable way, with figures such as Figure 6 and summary tables such as Table 2 serving as complementary tools for interpretation rather than definitive assessments. The observed dynamics of green growth pathways over time provide the basis for expert validation of the pathway assignments discussed in the following subsection, which assesses the plausibility and internal consistency of the pathway classifications within the broader analytical framework.

3.3.4. Validation of Pathway Classifications

Validation of green growth pathways assesses whether countries' positions within the quadrants are analytically plausible, internally consistent, and interpretable within the established performance–potential framework. Because pathways combine two distinct analytical constructs, i.e., level-based performance and relative transition momentum, into a joint classification, validation is necessary to ensure that this integration produces meaningful and credible interpretations rather than mechanical or misleading groupings. Unlike robustness and sensitivity analyses, which examine the stability of scores under alternative assumptions, pathway validation focuses on the coherence of the resulting classifications.

Validation is conducted through four complementary checks:
(i) consistency between performance and potential positions,
(ii) temporal plausibility of pathway trends,
(iii) cross-dimensional coherence of underlying signals, and
(iv) plausibility of pathway placement within peer-group contexts. Together, these checks support confidence that pathway classifications provide a meaningful summary of transition dynamics without altering underlying index results.

The first validation step examines **performance–potential consistency** to ensure that pathway classifications reflect coherent combinations of achievement and transition momentum. Countries' positions within the performance–potential plane are reviewed to identify cases where pathway classification appears difficult to interpret, such as unusually high momentum at very high levels of performance or persistently low momentum despite moderate achievement. Such configurations do not imply measurement error, but they signal the need for closer analytical review to confirm that pathway placement reflects genuine transition dynamics rather than artefacts of aggregation or short-term fluctuations.

The second validation step assesses the **temporal plausibility of pathway trends**. Because green growth pathways are expected to reflect sustained transition dynamics rather than short-lived variation, validation reviews the evolution of pathway positions over time. Abrupt or frequent shifts across pathways are examined to determine whether they correspond to meaningful changes in underlying indicators or reflect volatility, data gaps, or boundary effects. Emphasis is placed on identifying persistent movements and coherent trajectories, consistent with the dynamic interpretation of pathways discussed in Section 3.3.3.

The third validation step focuses on **cross-dimensional coherence**, examining whether pathway assignments are broadly supported across dimensions and aggregation levels. This involves reviewing whether a country's pathway position reflects balanced

dynamics across multiple pillars and dimensions, or whether it is driven disproportionately by a narrow subset of indicators. Graphical inspection and expert judgement are used to assess whether pathway signals capture diversified transition dynamics rather than isolated or dominant effects within specific components.

The fourth validation step evaluates **peer-group plausibility** by examining pathway assignments within the comparative contexts used for benchmarking growth potential. Because potential scores are defined relative to peer-group distributions, pathway placement is reviewed to identify cases where countries appear unusually positioned relative to structurally similar peers. Such cases prompt closer examination of indicator behavior and contextual factors, ensuring that pathway classifications remain interpretable within comparable development and structural conditions.

Finally, pathway validation is completed through expert judgement and contextual review, which integrates the resultsof the four validation checks with country knowledge and analytical experience. Expert review is used to interpret flagged cases, assess plausibility, and document explanatory factors, without modifying computed scores or pathway assignments. Validation does not imply causal attribution, prediction of future pathways, or normative assessment of policy performance. Instead, it serves to ensure that green growth pathways function as a transparent, credible, and analytically sound framework for organizing and interpreting performance and transition momentum across countries and over time.

4

STAKEHOLDER PARTICIPANTS AND POLICY APPLICATIONS

This chapter builds on the methodological framework presented in the previous section by describing how stakeholder participation is embedded in the design, interpretation, and application of the Green Growth Index. While Chapter 3 focused on the data, indicators, and analytical methods used to construct the Index, this chapter shifts attention to the processes that ensure analytical outputs are credible, relevant, and appropriately used. It documents how structured stakeholder engagement supports validation, contextual interpretation, and transparency, and explains how the Green Growth Index is applied across global, regional, and national contexts. By linking methodological rigor with participatory processes and practical applications, Chapter 4 explains how the Index transitions from technical construction to informed analytical interpretation and policy dialogue.

4.1. Design and Stakeholder Engagement Process

The Green Growth Index adopts an expert-led, participatory design approach, in which stakeholder engagement is embedded as a core methodological component of the index development process. Rather than serving as a consultation for dissemination or policy advocacy, stakeholder participation in the Green Growth Index 2.0 is explicitly oriented toward index design, validation, and refinement. This approach reflects the understanding that

composite indices intended for policy use must be grounded in both technical rigor and informed expert judgment to ensure coherence, credibility, and long-term relevance. Stakeholder engagement under the Green Growth Index 2.0 is therefore structured around clearly defined design objectives, with different stakeholder groups contributing at specific stages of the index design cycle.

4.1.1. Principles Guiding Stakeholder Engagement

Stakeholder engagement in the Green Growth Index is guided by a coherent set of principles that collectively ensure the Index's analytical robustness, policy relevance, and legitimacy. These principles, including policy relevance, technical credibility, inclusiveness and interdisciplinarity, transparency and traceability, and iterative validation, define how expertise is mobilized and integrated across the index design cycle. Rather than serving as general consultation norms, they function as design safeguards that shape conceptual framing, indicator selection, and methodological validation, thereby directly influencing the structure and quality of the Index. Engagement is therefore treated as a design requirement, not as a communication or outreach add-on, and is embedded upstream in the analytical process.

A first guiding principle is **policy relevance**, which ensures that the Green Growth Index reflects priority dimensions of sustainable development as articulated in national strategies and internationally agreed frameworks. Through expert engagement, the Index framework and indicators are assessed for their relevance to real-world policy challenges, ensuring that measured outcomes align with policy-relevant aspects of green growth. This principle contributes to the Index by strengthening its analytical usefulness without predetermining policy choices or prescribing specific actions.

A second principle is **technical credibility**, achieved through expert-led validation of conceptual assumptions, indicator definitions, data sources, and methodological approaches. Engagement with international experts, statisticians, and thematic specialists provides a systematic check on methodological soundness and internal consistency. By anchoring design decisions in established statistical and indicator-construction methods used in global assessments, the Index establishes technical credibility through transparent methodological choices and consistent application of standards across indicators and countries. This strengthens the robustness, comparability, and interpretability of results across countries and over time, including when data constraints require the use of proxy indicators or estimation techniques.

Inclusiveness and interdisciplinarity form a third principle guiding stakeholder engagement. Green growth is inherently multi-dimensional, encompassing economic performance, environmental sustainability, and social inclusion. The engagement process, therefore, draws on expertise across these domains to avoid narrow or sector-specific interpretations of progress. This interdisciplinary approach contributes to the Index by ensuring balanced representation across dimensions, improving coherence among indicators, and making trade-offs and complementarities more visible within the analytical framework.

A fourth principle is **transparency and traceability**, which underpins confidence in the Index design process. Stakeholder inputs are systematically recorded, and their implications for indicator selection, methodological refinements, and framework updates are documented. This traceability contributes to the credibility of the Index by clarifying how expert feedback is translated into concrete design decisions and by ensuring that revisions are evidence-based rather than ad hoc.

Finally, stakeholder engagement is guided by the principle of **iterative learning**. The Green Growth Index is designed as a dynamic measurement framework that evolves as data availability improves, analytical methods advance, and policy contexts change. Engagement, therefore, occurs through multiple rounds of review and refinement over time rather than one-off consultations. This iterative approach contributes to the Index's long-term relevance and adaptability while preserving methodological continuity across updates.

The above-mentioned principles have guided stakeholder engagement in developing the Green Growth Index since its inception in 2019 and underpin the design, selection, validation, and refinement of indicators across successive editions. They provide continuity in how expertise is mobilized and integrated, while allowing the framework to evolve in response to new data, analytical advances, and policy contexts. These same principles will continue to guide the development of the Green Growth Index 2.0, ensuring that methodological innovation and expanded

analytical scope are grounded in established practices of technical rigor, transparency, and policy relevance.

4.1.2. Stakeholder Typology and Roles in the Design Process

The design of the Green Growth Index is supported by a clearly defined stakeholder typology that reflects the different forms of expertise required at various stages of index construction. This typology distinguishes stakeholders by the specific design functions they perform, rather than by their institutional affiliation or potential use of index results. Table 3 summarizes the main stakeholder categories involved in the design process and clarifies their respective roles. Across all stakeholder categories, a clear distinction is maintained between design oversight roles and advisory roles. Design oversight concerns design choices that directly affect the structure of the Index, including adjustments to the framework and decisions about indicator inclusion or exclusion. Advisory roles support these decisions through validation, technical review, and design-stage interpretation. This differentiation ensures that design decisions remain evidence-based and transparent, while enabling broad expert input.

International expert group plays a foundational role in maintaining both the conceptual and methodological integrity of the Green Growth Index. In addition to safeguarding the coherence of the overarching framework and the internal logic of dimensions and pillars, the expert group reviews and validates methodological innovations introduced over time, including new analytical approaches, validation procedures, and refinements embedded in the Green Growth Index 2.0. Their engagement ensures that changes to methods are technically sound, consistent with established measurement practices, and compatible with the objective of cross-country comparability. Through structured review and collective endorsement, international experts provide formal approval of methodological updates, thereby anchoring innovation in continuity and strengthening confidence in the evolution of the Index. Annex 3 presents the members of the international expert group, which was formed in 2019 to support the annual review of the Green Growth Index.

Regional institutions and practitioners contribute contextual knowledge that helps adapt the global framework to shared regional conditions. In addition to technical and practitioner expertise, government partners within the region are consulted as part of this engagement process, providing policy-informed perspectives on regional development priorities and structural characteristics. Their combined inputs are particularly relevant in regional and peer-group applications, where countries face similar economic structures, environmental constraints, or transition challenges. Through this collaborative process, regional institutions, practitioners, and government partners jointly contribute to strengthening and refining the indicator framework for regional applications, ensuring it remains analytically robust, contextually meaningful, and consistent with the Index's core structure.

National government experts contribute design-stage insights on relevance and feasibility, drawing on their sectoral and institutional expertise. In this role, they exercise design oversight alongside their advisory function, supporting the validation of key design assumptions within national contexts. In addition to assessing whether proposed indicators appropriately

capturenationally salient aspects of green growth and whether the underlying data sources and assumptions are credible within national statistical and institutional systems, government experts engage in technical analysis of index scores as part of the design and validation process. This includes assessing whether observed results plausibly reflect national conditions, identifying key challenges and opportunities for green growth transitions, and providing sector-specific perspectives on the drivers underlying index performance. Through this oversight and analysis at the design stage, national government experts help confirm the internal consistency and contextual plausibility of index results. This analytical contribution supports refinement of the indicator framework and validation of results, while remaining strictly confined to design-stage interpretation rather than policy formulation or decision-making.

Technical partners and data specialists contribute targeted expertise to strengthen indicator availability and data coverage for the Green Growth Index. Their engagement focuses on identifying data gaps for priority indicators, improving the availability of data that are not readily accessible through international databases, and supporting the inclusion of indicators that are analytically relevant but not yet widely reported. Through collaboration with data providers and technical partners, these stakeholders help ensure that indicators proposed for inclusion in the framework can be populated with credible and consistent data. This role is crucial for expanding measurement coverage in areas where international data resources remain limited, thereby enabling the Index to incorporate indicators that would otherwise be excluded due to data constraints.

Scientific and thematic experts provide independent analytical review and subject-matter depth, primarily drawing on academic and research institutions. GGGI invites these experts to contribute to the design and review process, and some engage proactively by requesting to serve as reviewers based on their recognized expertise. Many of these contributors are affiliated with or have served as authors and reviewers in international scientific assessment processes, including the Intergovernmental Panel on Climate Change (IPCC) and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). Their role focuses on reviewing analytical assumptions, indicator relevance, and the interpretation of results from a scientific perspective, particularly where indicators relate to complex environmental, climate, or social systems. Through formal review of draft reports and technical documentation, scientific and thematic experts help ensure that the Index is grounded in the latest scientific evidence, reflects emerging knowledge, and maintains credibility within the broader research community. This contribution strengthens the analytical foundation of the Index while remaining complementary to policy- and data-oriented inputs from other stakeholder groups.

Table 3. Stakeholder typology and roles in the Green Growth Index design process

Stakeholder category	Design focus	Main contributions	Role type
International expert groups	Conceptual and methodological integrity	Review and validate the overarching framework and analytical structure; assess alignment with international sustainability agendas; review, endorse, and approve methodological innovations introduced in the Green Growth Index 2.0 to ensure technical soundness and comparability	Design oversight and advisory
Regional institutions and practitioners	Regional contextualization	Assess relevance and interpretability of indicators under shared regional conditions; engage regional government partners to strengthen and refine the indicator framework for regional applications while preserving the core structure	Advisory
National government experts	Design-stage relevance, feasibility, and analytical validation	Evaluate alignment of indicators with national green growth priorities; assess credibility of data sources and assumptions; contribute to design-stage analysis of index scores by identifying key challenges and opportunities for green growth transitions using sectoral expertise	Design oversight and advisory
Technical partners and data specialists	Indicator availability and data coverage	Identify data gaps for priority indicators; support the generation and provision of data for indicators not available through international databases; improve data availability to enable inclusion of analytically relevant indicators in the framework	Advisory
Scientific and thematic experts	Scientific rigor and evidence-based review	Provide independent review of analytical assumptions, indicator relevance, and result interpretation; contribute scientific scrutiny drawing on academic research and international assessment processes such as IPCC and IPBES	Advisory
GGGI technical team	Integration, coordination, and governance	Coordinate stakeholder engagement; synthesize inputs across groups; apply design rules consistently; document revisions and ensure transparency throughout the design cycle	Design oversight and implementor

4.1.3. Stakeholder Engagement Across the Index Design Cycle

By adopting a structured stakeholder typology and clarifying associated roles, the Green Growth Index design process balances inclusiveness with analytical discipline, enabling the Index to draw on a wide range of expertise while maintaining transparency and accountability. Within this structured arrangement, the GGGI technical team plays a central coordinating and operational role, ensuring that inputs from different stakeholder groups are integrated coherently and applied consistently within the index framework. Acting as both the design oversight body and the implementer, the Green Growth Performance Measurement (GGPM) team is responsible for operationalizing agreed design principles, expert inputs, and methodological decisions. This includes planning and facilitating stakeholder engagement, synthesizing inputs across expert groups, and ensuring that design choices are implemented in line with established methodological rules. In this capacity, the GGPM team manages the practical aspects of index development, including indicator compilation, data processing, and documentation of methodological choices. The team also ensures that revisions and updates to the framework are systematically recorded and transparently communicated, thereby maintaining continuity across index editions.

Building on this structured coordination, stakeholder engagement in the Green Growth Index is structured as a continuous and iterative process that spans the full index design cycle, as illustrated in Figures 7 and 8. The figure presents stakeholder engagement as an expert-led, participatory structure organized around four interlinked design stages: conceptual framing, indicator screening, method validation, and index score interpretation. Engagement is not concentrated at a single point in the process; instead, it is deliberately sequenced to ensure that different forms of expertise are mobilized at stages where they contribute most effectively to analytical quality and coherence. The design cycle is iterative, with feedback loops connecting the four stages. Insights generated from index score interpretation may inform further method validation or indicator refinement, while findings from data and method validation can prompt adjustments to indicator definitions or conceptual assumptions. This cyclical structure enables continuous learning and refinement while preserving consistency and transparency across index editions. By embedding stakeholder engagement across all stages of the design cycle, the Green Growth Index ensures that expert inputs are systematically integrated, design decisions are traceable, and the integrity of the framework is maintained over time.

At the **conceptual framing stage**, stakeholder engagement focuses on establishing the analytical foundations of the Green Growth Index. Engagement at this stage involves international expert groups, regional institutions and practitioners, and national government experts, who collectively contribute to validating the overall framework, confirming the relevance of core dimensions and pillars, and ensuring alignment with internationally agreed sustainability agendas and national development priorities. This collaborative process was central to the development of the Green Growth Index conceptual framework, first published in 2019, which provides the common analytical foundation for all subsequent applications of the Index (Figure 8). All global, regional, and national applications of the Green Growth Index build on and adapt this shared framework, ensuring consistency in conceptual scope while allowing contextual refinement. As presented in Figure 1, the Green Growth Index framework defines the core dimensions and structure that guide indicator selection and methodological choices. By anchoring the design process in a shared and well-defined conceptual framework, stakeholder engagement at this stage ensures internal coherence. It provides a stable reference point for the indicator screening.

At the **indicator screening** stage, stakeholder engagement focuses on assessing the relevance, feasibility, and analytical contribution of candidate indicators. This stage brings together international expert groups, regional institutions and practitioners, national government experts, technical partners and data specialists, and scientific and thematic experts, ensuring that a wide range of perspectives informs indicator selection. Engagement at this stage supports the systematic review of indicators against agreed criteria, including policy relevance, conceptual alignment with the Green Growth Index framework, data availability, and cross-country comparability. The design process explicitly allows for cross-level review and validation, enabling expertise from different levels to inform indicator selection. An international expert group and scientific and thematic experts review and rate the indicators proposed not only for the Global Green Growth Index but also for national indices, providing an independent assessment of conceptual soundness, scientific validity, and methodological consistency. Conversely, national government experts review and rate the policy relevance of indicators used in regional indices, ensuring that regional indicator sets remain grounded in national policy contexts and development priorities. Technical partners and data specialists contribute by assessing data feasibility and identifying opportunities to improve indicator coverage where gaps exist. Through this multi-layered screening process, stakeholder engagement helps ensure that the final indicator set is analytically robust, contextually relevant, and fit for purpose across global, regional, and national applications.

At the **methods validation** stage, stakeholder engagement focuses on ensuring the technical soundness, internal consistency, and analytical robustness of the methodological approaches underpinning the Green Growth Index. Engagement at this stage primarily involves an international expert group, technical partners, and data specialists, and scientific and thematic experts, who contribute complementary expertise to the review of methodological assumptions and analytical procedures. Their inputs focus on validating the overall measurement architecture, including normalization approaches, aggregation structures, and robustness checks, with particular attention to transparency and comparability across countries. The core methods of the Green Growth Index were fully validated in 2019, before the publication of the first Green Growth Index report, thereby establishing the methodological foundations for subsequent applications. Further comprehensive validation was conducted in 2025 in conjunction with the introduction of the Green Growth Index 2.0, reflecting methodological refinements and the incorporation of new analytical elements (i.e., potential and pathways), as described in this Technical Guideline. Moreover, as part of this review process, the Green Growth Performance Measurement (GGPM) team conducted a dedicated technical consultation with the European Commission's Competence Centre on Composite Indicators and Scoreboards (COIN) to review both the existing and enhanced methods underpinning the Green Growth Index 2.0. This consultation provided an independent statistical assessment of data quality, the soundness of the multilevel index structure, and the implications of modelling assumptions, thereby strengthening methodological transparency and reliability. In addition to these comprehensive reviews, partial validation of selected methodological components, particularly those related to robustness checks and the use of weights, has been undertaken

Figure 7. Index design cycle under an expert-led participatory design approach
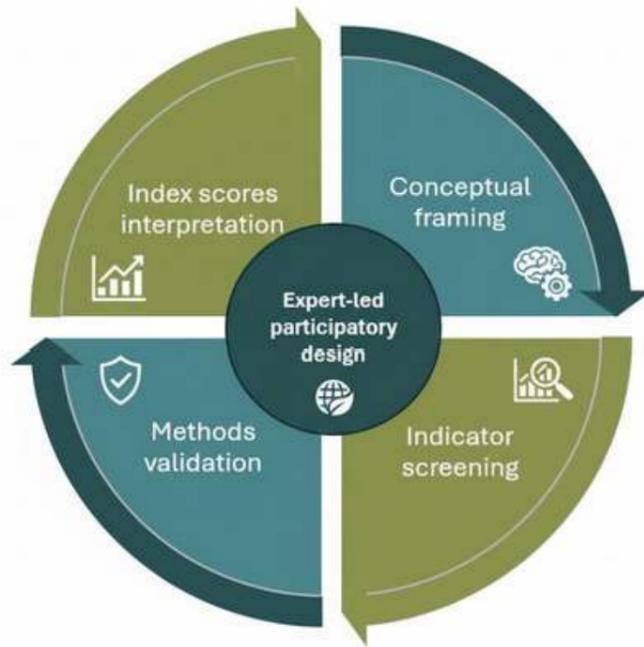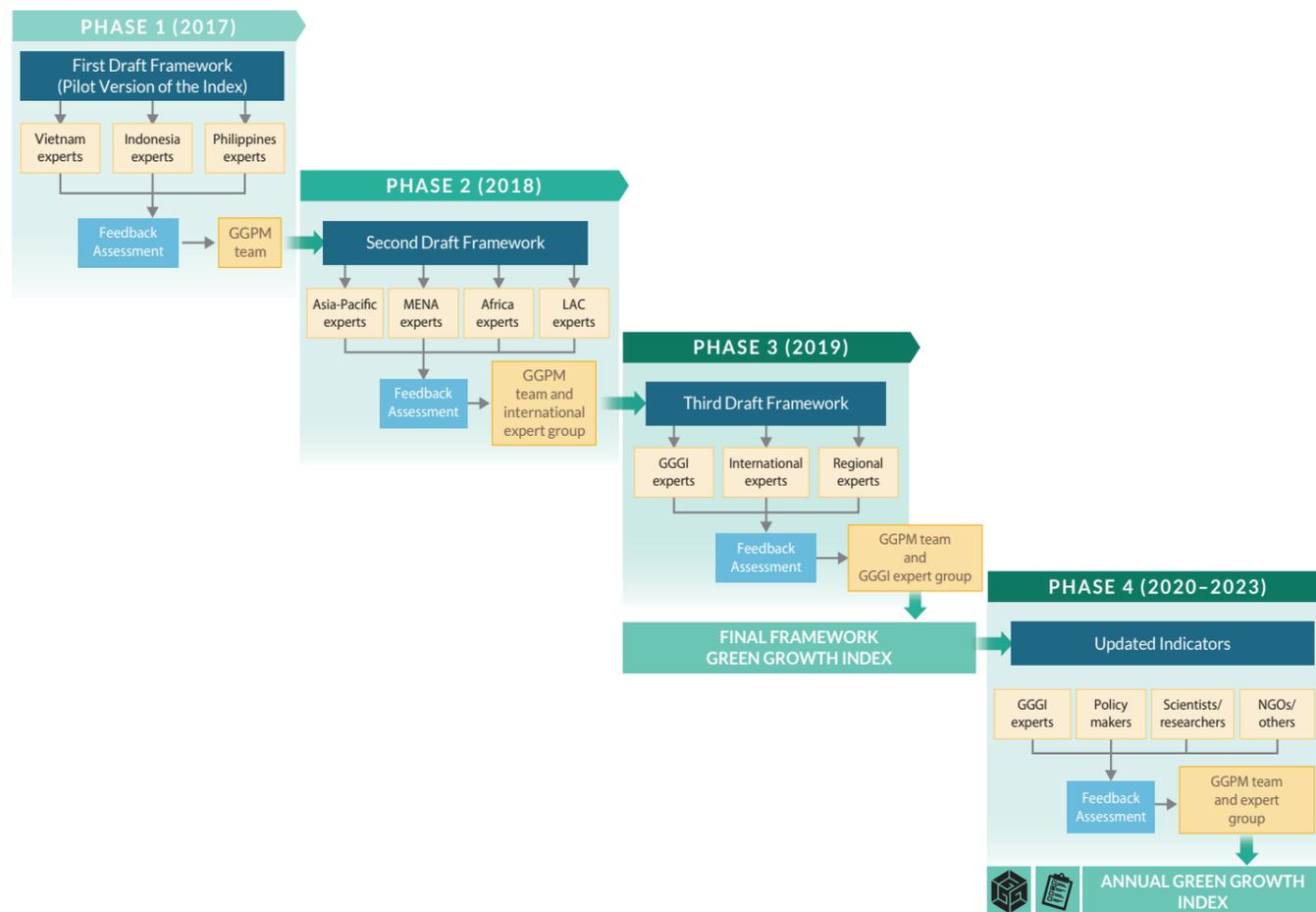

Figure 8. Iterative design process of the Green Growth Index

as part of the annual review process for the Global Green Growth Index reports. Methods are not validated separately for regional and national indices, as these applications apply the same methodological framework validated at the global level. Alignment with the globally validated methods ensures consistency and comparability across applications, while allowing regional and national indices to focus validation efforts on indicator relevance and data availability rather than methodological redesign.

At the **index score interpretation** stage, stakeholder engagement focuses on assessing the analytical plausibility and coherence of index results. Engagement at this stage supports systematic interpretation of scores, helping to verify whether observed patterns are consistent with underlying data, indicator behavior, and conceptual expectations. International expert groups and scientific and thematic experts, as well as the GGGI Publication Committee, contribute to this stage indirectly through the annual review of the Green Growth Index applied at the global and regional levels, providing an independent assessment of score structure, distributions, and trends. In national applications, index score interpretation is conducted more intensively through multi-day technical workshops involving national government experts. These engagements enable detailed examination of country-specific results, drawing on sectoral expertise to assess whether index scores plausibly reflect national conditions and development trajectories. Through structured group discussion, national experts assess key challenges and opportunities for green growth transitions, contributing policy insights to the assessment of index scores in the National Green Growth Index reports. Assessments of index scores using the enhanced analytical features of the Green Growth Index 2.0 have, to date, been developed for the Global Green Growth Index. The extension of score interpretation, incorporating potential and pathways for regional and national applications, will be determined in consultation with GGGI's relevant international and government

partners, reflecting considerations of analytical readiness, data availability, and intended use. This staged approach ensures that score interpretation remains technically robust and aligned with the Index's evolving scope.

To sum up, as illustrated in Figure 7, stakeholder engagement in the Green Growth Index is iterative and continuous. Feedback generated at each stage of the design cycle feeds into framework refinement and periodic updates, allowing the Index to evolve in response to new data, emerging analytical insights, and advances in measurement practices. Engagement mechanisms are institutionalized through regular expert reviews, documented revisions, and transparent methodological reporting, ensuring that the Index remains both stable and adaptable over time. By embedding stakeholder engagement throughout the full index design cycle, the Green Growth Index strengthens its technical robustness, legitimacy, and analytical relevance while maintaining a clear separation between index design and policy application, as addressed in the following sections.

4.1.4. Modalities of Stakeholder Engagement

Stakeholder engagement in the Green Growth Index is operationalized through a set of complementary modalities designed to support different functions across the index design cycle. These modalities translate the engagement principles and stakeholder roles described in the preceding sections into practical tools that enable structured, evidence-based input. Table 4 summarizes the main engagement modalities used in the design of the Index and links each modality to its primary designfunction, typical stage of use, and key outputs.

International expert consultations, conducted both virtually and in person, provide a structured forum for collective technical deliberation and validation. These consultations primarily involve

the international expert group and technical partners and data specialists, and are a core component of the annual review of the Global Green Growth Index. Through these engagements, participating experts review indicator performance, assess analytical consistency, and examine methodological implications arising from updates to data or framework elements. The annual international expert consultations are conducted in collaboration with the Green Growth Knowledge Partnerships (GGKP), which supports convening relevant expertise and facilitates knowledge exchange across institutions. Outputs from these consultations include agreed refinements to indicators or methods, clarification of analytical issues, and documented expert consensus or divergence, contributing directly to the robustness and transparency of the global index design process.

Participatory workshops are an integral component of the design process for national Green Growth Indices. These workshops are primarily conducted at the national level and involve national government experts and technical partners and data specialists, ensuring that technical discussions are grounded in country-specific policy contexts and data realities. Workshops are typically organized as intensive engagements lasting between two and five days, allowing sufficient time for in-depth review of indicators, examination of data availability, and structured interpretation of preliminary results. Participatory workshops are co-organized with GGGI's government partners, reinforcing national ownership of the design process while maintaining alignment with the core Green Growth Index framework. Through facilitated sessions, participants assess indicator relevance and feasibility, validate analytical plausibility of results, and identify data gaps or refinement needs. The extended duration and interactive format of these workshops enable detailed technical discussion and collective validation, contributing directly to refinement of the indicator framework and strengthening the credibility of national index design outcomes.

Targeted technical consultations are conducted as part of the design process for global, regional, and national Green Growth Indices to address specific technical and data-related issues. These consultations primarily involve technical partners and data specialists, as well as national government experts, focusing on indicator definitions, data gaps, and the identification of suitable proxies where required. Engagements are organized either by GGGI, through meetings with experts in relevant institutions, ministries, and line agencies, or by government counterparts participating in the design process, who convene consultations with colleagues across their respective ministries and line agencies. Through these targeted engagements, stakeholders provide focused input that supports the resolution of specific design challenges, improves data availability for priority indicators, and strengthens the operationalization of the indicator framework. By drawing directly on institutional knowledge within government systems and on technical expertise from data specialists, targeted technical consultations contribute to more robust, contextually grounded design outcomes for global, regional, and national applications of the Index.

Webinars are conducted as part of the design process for regional and national Green Growth Indices, serving as a complementary modality to support knowledge alignment and capacity building among participating stakeholders. These webinars are co-organized with GGGI government partners and primarily involve national government experts, technical partners, and data specialists, ensuring that all contributors share a common understanding of green growth concepts, the index

framework, and the underlying analytical logic. Engagement through webinars is particularly important in contexts where participants bring diverse sectoral and technical backgrounds to the design process.

Webinars are used during conceptual framing and in preparation for design-phase interpretation to establish a consistent analytical baseline across participants. They are also used to introduce and demonstrate the interactive online dashboard employed in participatory interpretation workshops, enabling stakeholders to engage effectively with index results and analytical tools. By strengthening shared understanding and technical familiarity, webinars support more informed and productive engagement in subsequent workshops and consultations.

Online expert surveys are used as a core engagement modality involving all stakeholder groups, including international expert groups, regional institutions and practitioners, national government experts, technical partners and data specialists, and scientific and thematic experts. For the global and regional Green Growth Indices, surveys enable the systematic collection of expert feedback from a broad, geographically diverse pool of contributors, allowing inputs to be gathered globally and across regions in a consistent, comparable manner. Surveys provide a structured mechanism for collecting expert feedback on the policy relevance of indicators and the identification of suitable proxy variables, supporting evidence-based decisions on indicator inclusion, particularly where indicators are debated or data constraints require trade-offs between analytical relevance and feasibility. In national applications, online expert surveys also play an important role in documenting the availability of data within national statistical and administrative systems. In these contexts, surveys are administered alongside participatory workshops and group discussions to support the validation of indicators and the structured interpretation of index scores. Findings from these surveys are integrated into national Green Growth Index reports, ensuring that expert judgments and country-specific information collected through the design process are systematically reflected in analytical outputs. Annex 4 present an example of an online expert survey on the policy relevance of green growth indicators.

Real-time structured polling is used as a facilitative engagement modality during international expert consultations and participatory workshops to elicit structured, interactive expert input. In international expert consultations, polling is conducted with the participation of the international expert group, while in participatory workshops it involves national government experts, technical partners and data specialists. Polling tools are used to capture immediate and anonymized feedback on the policy relevance of indicators, the analytical plausibility of index scores, and the suitability of methodological choices, complementing qualitative discussion with quantifiable inputs. The use of real-time polling supports active participation during consultations and workshops, encouraging structured reflection and balanced participation across expert groups. Results from these polls are systematically synthesized and integrated into the design of the Global and National Green Growth Indices, providing additional evidence to support design decisions and validation outcomes. Through this modality, expert judgments are captured transparently and efficiently, strengthening traceability and rigor in the index design process. Annex 5 provides examples of real-time polling on experts' analysis of index scores.

Expert reviews of draft reports and online dashboards are conducted for global, regional, and national Green Growth Indices as a final engagement modality supporting design validation and quality assurance. All stakeholders participating in the design process at the respective levels are invited to contribute to this review, ensuring that analytical results, indicator interpretations, and methodological explanations are examined from multiple expert perspectives. The participation of scientific and thematic experts is particularly valuable in the review of Global Green Growth Index reports, where independent scientific scrutiny strengthens the credibility and robustness of the analytical narrative. For global and regional indices, draft reports undergo a formal technical review by the GGGI publication committee before publication, providing an additional layer of institutional quality assurance. In national applications, final reports are subject to government partner approval before publication, reflecting national ownership of the design outcomes while maintaining alignment with the core Green Growth Index framework. Through this structured review process, expert feedback is incorporated into finalized analytical outputs, reinforcing transparency, accuracy, and consistency across index products.

These modalities provide a structured, coherent set of tools for engaging stakeholders throughout the index design cycle. Each

modality is linked to a specific design function and produces clearly defined outputs that feed directly into the development, validation, and refinement of the Index. This structured approach ensures that stakeholder engagement strengthens analytical rigor, consistency, and transparency in index design, while also supporting national ownership and an inclusive design process by enabling meaningful participation of government and technical experts.

4.2. Applications of the Green Growth Index

Section 4.2 focuses on the application of the Green Growth Index across different contexts, building on the design principles, stakeholder engagement, and validation processes described in Section 4.1. The emphasis shifts from how the Index is constructed to how its results are applied as analytical tools and, in specific contexts, to support policy-relevant processes.

The Green Growth Index is applied at global, regional, and national levels, as summarized in Table 5, to support comparative assessment and structured analysis of green growth performance. While all applications rely on the same core framework and validated methods, the scope, depth, and intended use of the analysis differ by application level, reflecting varying objectives and institutional contexts. Global applications emphasize benchmarking, trend analysis, and research use; regional

Table 4. Stakeholder engagement modalities and their design functions

Engagement modality	Primary design function	Typical design-stage use	Key outputs for index design
International expert consultations (virtual and in-person	Collective technical deliberation and validation	Indicator screening; methods validation	Agreed refinements to indicators or methods; clarification of analytical issues; documented expert consensus or divergence
Participatory Workshops	Assessment of indicator relevance and feasibility	Indicator screening	Shortlisted indicator sets; validation of analytical contribution and relevance; identification of gaps or overlaps
	Validation of the analytical plausibility of result	Index score interpretation	Confirmation of internal consistency; inputs for indicator framework refinement
Targeted technical consultations	Resolution of specific design issues	Indicator screening	Improved indicator definitions; identification of suitable proxies; strengthened data availability for priority indicators
Webinars	Knowledge alignment and capacity building for design	Conceptual framing; preparation for design-stage interpretation	Shared understanding of green growth concepts and index framework; familiarization with the interactive online dashboard used in participatory workshops
Online expert surveys	Structured collection of expert input	Conceptual framing; indicator screening; methods validation	Consolidated ratings and qualitative feedback on framework elements, indicators, and methodological assumptions
Real-time structured polling	Systematic collection of immediate, structured expert feedback	Indicator screening; methods validation; index score interpretation	Quantified expert ratings on policy relevance of indicators, plausibility of index scores, and suitability of methodological choices; anonymized feedback supporting transparent synthesis
Expert review of draft reports and online dashboards	Independent technical review and quality assurance	All stages	Reviewed and revised technical documentation; strengthened transparency and traceability of design choices

Table 5. Applications of the Green Growth Index at various levels

Levels of applications	Current geographical coverage	Types of applications
Global	Over 150 countries	• GGGI Members' Country Planning Frameworks (CPFs) • Track relative performance with peer countries • Serve as groundwork for developing other sustainability indices, including the Green Recovery Index (GRI), the Gender Equality and Social Inclusion (GESI) Index • Academic and research applications, including empirical analysis of green growth performance and dynamics
Regional	OECS, Central Asia, Africa LDCs	• Inform regional development roadmaps and strategies • Peer-group benchmarking among structurally similar countries • Support for regional dialogue and cooperation (e.g., climate diplomacy)
National	Zambia, Kenya, Ghana, Togo, Lao PDR, Angola*	• Guide National Green Growth Strategies • Inform indicator frameworks for National Development Plans • Support development of green project pipelines • Link with the green growth simulation of SDG co-benefits • Capacity building to design, interpret, and apply the Green Growth Index for policy and planning

applications support peer-group comparison and regional dialogue; and national applications focus on informing country-specific strategies, planning frameworks, and capacity building. This section explains the rationale for applying the Index at different scales and clarifies its boundaries, including the distinction between analytical assessment and policy decision-making.

4.2.1. Global-Level Applications

At the global level, the Green Growth Index is used as a comparative analytical tool to assess and track green growth performance across indicators, pillars, dimensions, and index scores over time. Since 2019, the Global Green Growth Index has been published annually, providing a consistent and evolving evidence base for monitoring progress across countries. With coverage of over 150 countries, the global index supports multiple types of applications, including (1) integration in Country Planning Frameworks (CPFs), (2) use by GGGI member countries to review and compare scores and rankings with peer-countries, (3) groundwork for developing other sustainability indices, and (4) academic and research analysis (Table 5). In addition, the global application provides a platform for extended analytical features introduced under the Green Growth Index 2.0, including assessments of potential and pathways.
These different applications are summarized in Table 5 and are further elaborated in the paragraphs that follow.

A key global-level application of the Global Green Growth Index is its use in GGGI Members' Country Planning Frameworks (CPFs). CPFs are medium-term strategic documents that guide GGGI's engagement with member countries by aligning national development priorities with green growth objectives and GGGI's institutional strategy. The Index provides a standardized analytical foundation for CPFs by offering an evidence-based assessment of a country's green growth performance across the four dimensions of the Index. Index results are used to identify relative strengths, gaps, and priority areas, supporting a structured diagnosis of green growth challenges and opportunities at the outset of the planning process. Within CPFs, the Green Growth Index serves as a diagnostic and prioritization tool, rather than a prescriptive policy instrument. Index scores and comparative insights inform the selection of thematic focus areas, help frame discussions

with government counterparts, and support alignment between national priorities and GGGI's programmatic solutions. Through its application in CPFs, the Global Green Growth Index strengthens coherence across GGGI's country programs by ensuring the consistent use of indicators and benchmarks across GGGI member countries.

GGGI Member Countries use the Global Green Growth Index to review their scores and rankings, and to **compare their performance with that of peer countries**. The Index provides a consistent reference for assessing relative performance across the overall index, dimensions, and pillars, and for observing how performance changes over time. Comparing results with peer countries helps highlight areas of relative strength and weakness and places national performance within broader global and regional patterns. Index scores serve as a basis for GGGI member countries to discuss potential green projects that could be implemented to improve performance in specific areas. In addition, the results encourage closer examination and tracking of data availability, particularly where low scores may reflect data gaps rather than underlying performance. This use of the Index remains analytical and diagnostic, supporting learning, dialogue, and informed reflection rather than policy prescription.

The Global Green Growth Index also provides analytical and methodological **groundwork for developing complementary sustainability indices**, including the Gender Equality and Social Inclusion (GESI) Index. The GESI Index builds on the Green Growth Index framework by retaining its core analytical principles, indicator-based structure, and emphasis on cross-country comparability, while deepening analysis within the social inclusion dimension. By drawing on the four-dimensional structure of the Green Growth Index and its globally validated methods, the GESI Index extends measurement to capture gender equality, disability inclusion, and intergenerational equity in the context of climate and green growth transitions. In practice, the GESI Index has been applied to support the integration of GESI assessment into Rwanda's Nationally Determined Contribution (NDC),16 demonstrating how the Green Growth Index framework can be extended to inform inclusive climate planning and monitoring. This approach ensures coherence across GGGI's measurement tools and enables integrated analysis across economic, environmental, and social dimensions within a shared analytical framework.

The Global Green Growth Index is also widely used for **academic and research applications**, supporting empirical analysis of green growth performance and dynamics across countries and over time. The availability of open-access databases, together with publicly accessible models and source codes hosted on GGGI's GitHub repositories, enables researchers to download and reuse data, replicate results, and conduct independent analysis. On average, about 30 unique users per month download the datasets and analytical resources associated with the Global Green Growth Index, reflecting sustained interest from the research community. The Index is regularly cited in academic theses, peer-reviewed international journals, and technical reports, where it is used to examine cross-country patterns, assess relationships between green growth and development outcomes, and explore transition dynamics. Through these applications, the Global Green Growth Index advances research on sustainable development and provides a transparent, reproducible evidence base for academic inquiry.
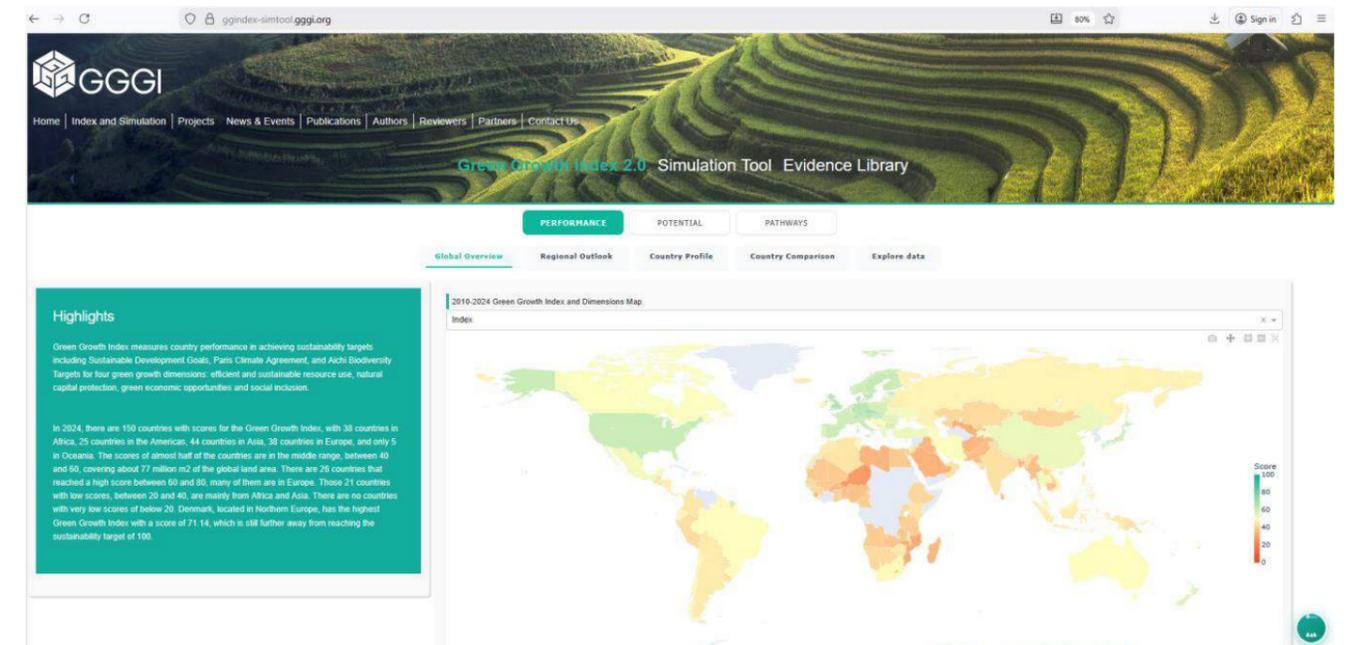
Overall, global-level applications of the Green Growth Index are further strengthened through the introduction of potential and pathways assessment under the Green Growth Index 2.0. This extension is designed to complement existing uses of the Index by adding a forward-looking analytical perspective to performance assessment. The enhanced Index is supported by an interactive online dashboard that brings together core index scores, time-series trends, comparative rankings, and the extended potential and pathways analysis within a single analytical interface. As illustrated in the online dashboard (Figure 9), users can explore country profiles, regional comparisons, dimension- and pillar-level performance, and indicative transition pathways derived from observed performance dynamics. For the CPFs, the enhanced dashboard allows planners to combine performance assessment with insights on transition potential, supporting a more informed strategic diagnosis at the outset of

country engagement. For GGGI member countries, integrating scores, rankings, and potential analysis into the dashboard strengthens comparative review with peer countries and facilitates deeper interpretation of performance dynamics over time. The expanded analytical architecture also reinforces the role of the Green Growth Index as groundwork for developing complementary sustainability indices, enabling thematic extensions, such as the GESI Index, to build on a richer and more integrated global evidence base. Finally, for academic and research applications, the combination of enhanced analytical features and transparent access via the online dashboard expands opportunities for empirical analysis, enabling researchers to examine both observed performance and indicative transition dynamics within a consistent, reproducible global framework.

4.2.2. Regional and Peer-Group Applications

Regional and peer-group applications of the Green Growth Index complement global benchmarking by providing a more context-specific analytical perspective. By focusing on countries that share geographic, structural, or development characteristics, these applications enable more meaningful comparison and interpretation of green growth performance within omparable contexts. Regional and peer-group analyses are designed to support analytical learning, peer exchange, and regional dialogue, rather than harmonized policy formulation. Regions and peer groups are defined using transparent and analytically grounded criteria. Examples include the Organisation of Eastern Caribbean States (OECS), which brings together small island developing states (SIDs) with shared vulnerabilities and development constraints; Central Asia, defined by geographic proximity and economic interlinkages; and the African Least Developed Countries (LDCs), which constitute a peer group based on development status (Table 5). While the

Figure 9. Online Dashboard for the Global Green Growth Index

national context and data availability. While international data sources are used where possible to maintain comparability, national applications place greater emphasis on national statistical and administrative data, including the use of proxy indicators where international coverage is limited. This approach allows the Index to capture country-specific conditions more accurately while remaining aligned with the core framework and methodological rules.

At the national level, the Green Growth Index is applied to support a range of policy-relevant analytical uses, including informing the development and review of National Green Growth Strategies, structuring indicator frameworks for National Development Plans, and identifying priority areas for green investment and project pipeline development (Table 5). Interpretation of national results is conducted through intensive participatory processes, typically involving multi-day technical workshops with national government experts and technical partners. These engagements focus on examining the plausibility of index scores, understanding sector-specific drivers of performance, and identifying key challenges and opportunities for green growth transitions. Interpretation remains confined to the analytical phase, supporting validation and contextual understanding rather than making policy decisions.

National applications also contribute to capacity building and institutional strengthening by enhancing government officers' understanding of green growth concepts, indicator-based assessment, and performance analysis. Through participation in index development and interpretation, government institutions strengthen cross-sectoral coordination, improve awareness of data gaps and monitoring needs, and develop a more coherent analytical foundation for planning and review. While national-level applications are closely linked to policy processes, clear boundaries are maintained between analytical assessment and policy decision-making. The Green Growth Index informs discussion, prioritization, and monitoring, but does not prescribe policy choices or investment decisions. Responsibility for policy formulation and implementation remains with national governments, with GGGI acting as a technical partner supporting analysis, interpretation, and capacity development.

grouping criteria differ, all regional and peer-group applications retain alignment with the global Green Growth Index framework, ensuring consistency in conceptual scope and analytical structure.

The scope of regional and peer-group analysis builds on the core Green Growth Index framework and globally validated methods. Applications cover all four dimensions of the Index, with analytical emphasis adjusted to reflect region-specific priorities, data availability, and structural conditions. Indicator selection and treatment remain consistent with the global framework to preserve comparability within the group, while allowing limited refinement to enhance relevance where justified by regional context and data constraints. In the OECS application, additional blue economy–related indicators were included to reflect the specific SIDs context, where marine resources play a central role in economic development, resilience, and sustainability.

Regional and peer-group outputs include comparative scorecards, regional profiles, and analytical summaries that highlight performance variation across participating countries. These outputs are used to identify shared strengths, common challenges, and patterns that may not be visible in global analysis alone. For example, regional applications have highlighted issues related to climate vulnerability and resilience in OECS countries, structural transformation and resource efficiency in Central Asia, and development and inclusion challenges among African LDCs. Such insights support a more nuanced understanding of green growth dynamics within comparable settings. Regional and peer-group applications provide a standard analytical reference for discussing shared challenges and opportunities and for identifying areas where cooperation or further analysis may be

beneficial. At the same time, clear boundaries are maintained: regional results do not prescribe regional policies, and policy application remains the responsibility of national governments. Positioned between global benchmarking and national-level analysis, regional and peer-group applications help translate global insights into a more context-specific understanding. They retain complete alignment with the globally validated framework and methods and do not involve separate methodological validation. At this stage, the extended potential and pathways assessments introduced under the Green Growth Index 2.0 are not applied in regional and peer-group analyses. Any future application of these extended assessments at the regional level will depend on analytical readiness and the expressed demand of regional institutions and government partners. Instead, regional and peer-group applications provide an intermediate level of analysis that supports comparison, relevance, and dialogue among countries with shared characteristics, while remaining consistent with the Green Growth Index's performance measurement.

4.2.3. National-Level Policy Applications

National-level applications of the Green Growth Index are developed to support country-specific analysis that aligns global and regional insights with national development priorities and policy processes. These applications translate the common Green Growth Index framework into a nationally relevant analytical tool, while preserving consistency with the globally validated concepts and methods. The scope of national analysis is anchored in the four dimensions of the Green Growth Index, with indicator selection and data inputs adapted to reflect

CHALLENGES AND ADDRESSING LIMITATIONS

This chapter synthesizes key challenges associated with the development and application of the Green Growth Index. It explains how these are addressed through the design choices, validation procedures, stakeholder engagement processes, and responsible use principles described in earlier sections of this guideline. While many limitations are inherent to composite indices and cross-country analysis, the Green Growth Index addresses these challenges through transparent methods, structured validation, and precise analytical boundaries. Remaining limitations are acknowledged to support appropriate interpretation and use of results.

Data availability and quality:
A central challenge in constructing the Green Growth Index is the uneven availability and quality of data across countries, indicators, and time. International datasets vary in coverage, update frequency, and methodological consistency, and in some cases, proxy indicators are required to ensure broad comparability. Time lags are particularly relevant for social and environmental indicators, which may not be updated annually. These challenges are addressed through indicator screening and data availability assessment during the design process (Section 4.1), ensuring that only indicators that meet minimum data coverage and quality criteria are included. Data preparation and validation procedures, including outlier detection, consistency checks, and expert review, are applied systematically (Section 3). Confidence levels and transparent documentation are used to communicate data

limitations and gaps in index outputs. Despite these measures, a remaining limitation is the continued dependence on international datasets with different update cycles. This constraint is explicitly acknowledged through the transparent presentation of yearly database updates, highlighting where significant data divergence and gaps exist for specific indicators and countries.

Comparability and aggregation:
Cross-country comparability and aggregation present inherent challenges in composite index construction. Differences in country structure, scale, and development pathways can complicate direct comparison, while normalization, weighting, and aggregation choices influence composite scores and rankings. The Green Growth Index addresses these challenges through consistent normalization and aggregation rules applied across all Index editions, combined with robustness checks and sensitivity analysis (Section 3). Peer-group validation and comparative diagnostics are used to assess whether observed patterns are analytically plausible within structurally similar groups. Geometric aggregation is applied to limit full compensability across dimensions and reduce the risk that strong performance in one area masks weaknesses in others. A remaining limitation is the interpretation of small score or rank differences, particularly among countries with similar performance profiles. Rankings are therefore treated as secondary analytical outputs and should be interpreted alongside score distributions,

confidence levels, and contextual analysis that are provided in the technical report.

Interpretation and use of results:
Another key challenge is the risk of over-interpreting index scores, rankings, and pathways, or treating them as precise measures or policy prescriptions. Composite indices necessarily simplify complex realities and cannot capture all dimensions of national circumstances or policy contexts. This challenge is addressed through design-stage interpretation and participatory validation (Section 4.1), which support contextual understanding of results, and through explicit principles for responsible use articulated in Section 4.3. Graphical diagnostics, narrative analysis, and structured interpretation workshops further support appropriate use of results across global, regional, and national applications. The reliance on user judgment and contextual knowledge is therefore central to interpreting the results. Analytical outputs cannot substitute for sectoral analysis, qualitative assessment, or policy deliberation, and their responsible use depends on informed interpretation by users. Hence, the interpretation of Index scores by national experts with in-depth knowledge of national conditions and policy contexts is a critical part of developing national Green Growth Index applications, ensuring that analytical results meaningfully inform policy dialogue and planning processes.

Forward-looking analysis and pathways:
The introduction of forward-looking pathways analysis under the Green Growth Index 2.0 brings additional analytical challenges related to uncertainty and sensitivity to assumptions. Pathways are derived from observed performance dynamics and structural relationships and are influenced by data structure, modelling choices, and historical patterns. These challenges are addressed by limiting pathways analysis to the global level, where data availability and comparability are strongest, and by explicitly framing pathways as indicative and non-prescriptive (Section 4.3). Validation of growth dynamics through smoothing, peer-relative comparison, and expert review further supports analytical robustness (Section 3). A remaining limitation is the sensitivity of pathways to underlying assumptions and data structures, underscoring the need for cautious interpretation and complementary qualitative analysis. Any future extension of pathways analysis at the regional and national levels will require careful consideration of analytical readiness and stakeholder demand.

Institutional and capacity constraints:
Finally, the practical interpretation and use of Green Growth Index results depend on institutional and technical capacity, which varies across countries and regions. Differences in data systems, analytical resources, and coordination mechanisms can affect how results are understood and applied. These constraints are addressed through national-level applications and capacity-building processes (Section 4.2.3), including participatory interpretation workshops, technical training, and support for indicator frameworks and monitoring systems. Open access to data, methods, and documentation further supports transparency and learning.Nonetheless, resource and institutional constraints may limit sustained analytical use in some contexts. This reinforces the importance of phased development of the Index, alignment of indicator choices with national priorities and institutional realities, and continued capacity building.

6

CONCLUSION AND RECOMMENDATIONS

Framework Scope and Interpretability Across Scales:
This technical guideline sets out the conceptual foundations, methodological design, and application logic of the Green Growth Index, with a particular focus on the enhancements introduced in Green Growth Index 2.0. Building on the framework established since 2019, the guideline documents how the Index integrates performance assessment with an extended analysis of green growth potential and pathways. While performance captures observed outcomes, potential reflects countries' relative capacity and readiness for green growth transition, and pathways provide an indicative, forward-looking perspective on transition dynamics. These complementary analytical components strengthen the Index's relevance for both policy-oriented and academic applications while remaining grounded in validated methods, structured stakeholder engagement, and transparent documentation. The Green Growth Index remains an indicator-based analytical tool designed to support comparability, consistency, and analytical rigor across countries and over time.

Across its global, regional, and national applications, the Green Growth Index demonstrates the value of a multi-level analytical framework that allows results to be interpreted within different contexts while maintaining a common conceptual and methodological foundation. Global benchmarking provides a consistent reference for comparative assessment and trend analysis; regional and peer-group applications enable more context-specific comparisons among countries with shared characteristics; and national applications translate these insights into country-level analytical evidence. These applications illustrate how a single framework can support differentiated analysis without compromising coherence or comparability.

Stakeholder Engagement and Analytical Robustness:
A central strength of the Green Growth Index lies in its multi-stakeholder approach, which integrates diverse forms of expertise into the design, validation, and interpretation of the Index. Continuous engagement of international expert groups, regional institutions, national government experts, technical partners, and scientific and thematic experts ensures that the Index reflects both global analytical standards and country-specific knowledge. This diversity of inputs enhances conceptual robustness, improves indicator relevance, and strengthens the credibility of results. By systematically incorporating expert judgment at key stages of the design cycle, the Green Growth Index balances analytical rigor with practical relevance, while maintaining transparency and accountability in design decisions.

Iterative Design and Methodological Integrity:
The Green Growth Index also benefits from a structured, iterative design process that provides a clear framework for integrating data, methods, and expert inputs over time. The use of defined design stages, validation procedures, and feedback loops supports consistency across the Index editions and applications, while allowing for incremental refinement in response to new data and analytical insights. This structured approach reduces ad hoc decision-making, ensures traceability of methodological choices, and strengthens comparability across countries and over time. By embedding iteration within a disciplined design framework, the Green Growth Index can evolve analytically without compromising stability, coherence, or methodological integrity.

Finally, the guideline has highlighted that the robustness of the Green Growth Index depends not only on its methods, but also on clear analytical boundaries and responsible use. The index results, rankings, potential assessments, and pathways are designed to inform analysis and dialogue, not to prescribe policy choices. Challenges related to data availability, comparability, interpretation, and forward-looking analysis are explicitly acknowledged and addressed through validation procedures, stakeholder engagement, and transparent documentation. Through this combination of methodological discipline, inclusive design, and clear safeguards, the Green Growth Index is positioned as a credible and adaptable analytical framework for assessing and understanding green growth transitions over time.

Implications for Future Updates of the Index:
The Technical Guideline also provides a foundation for the ongoing evolution of the Green Growth Index. By anchoring the framework in stable conceptual pillars and transparent methodological choices, the Index can be updated as data availability improves and new analytical priorities emerge, without compromising comparability across countries or over time. This modular structure allows for refinement at the indicator level while preserving the integrity of the overall framework, ensuring that future iterations remain analytically consistent with earlier editions. As global and national data systems expand, future updates may incorporate longer time series, broader coverage of emerging green-economy dimensions, and more refined representations of structural change. The validation procedures and documentation standards outlined in this guideline are intended to support such updates in a disciplined and transparent manner, enabling the Index to adapt analytically while maintaining its role as a stable reference for assessing green growth transitions.

Guidance for Application and Use
For practitioners and analysts, the Green Growth Index 2.0 is designed to support interpretation, comparison, and dialogue rather than to prescribe specific policy actions. Performance, potential, and pathways should be interpreted jointly, with careful attention to national context, peer-group dynamics, and data limitations. National applications can build on the global framework by aligning indicator selection and benchmarking approaches with country-specific priorities while retaining consistency with the Index's underlying structure. The guideline emphasizes responsible use of results, particularly where forward-looking analysis is involved. Growth-based indicators and pathway classifications are intended to inform understanding of transition dynamics, not to generate forecasts or normative judgments. When used alongside qualitative evidence, stakeholder input, and complementary analytical tools, the Index provides a robust basis for evidence-informed discussion and peer learning.
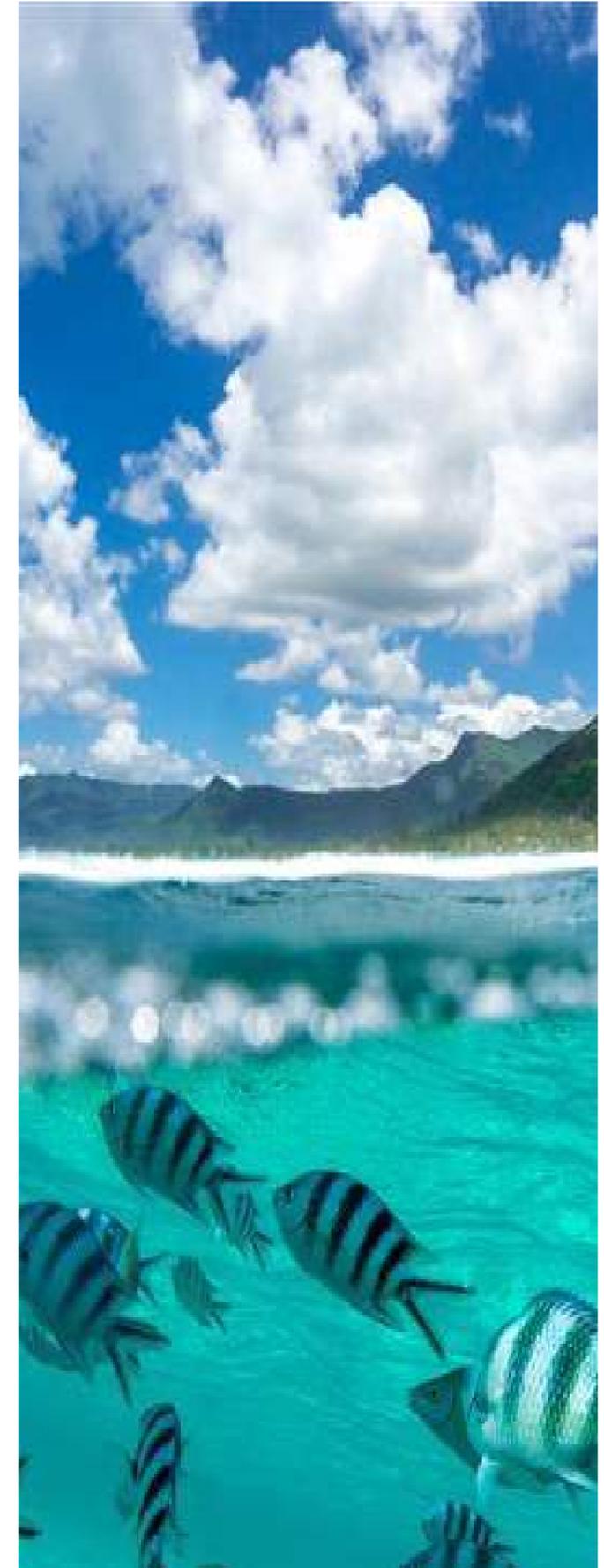
ANNEXES

Annex 1: Evolution of the Indicator Framework of the Green Growth Index (2019–2025)

Green Growth Indicators*		2019	2020	2021	2022	2023	2024	2025
Efficient and sustainable resource use								
EE1	Ratio of total primary energy supply to GDP	✓	✓	✓	✓	✓	✓	✓
EE2	Share of renewable to total final energy consumption	✓	✓	✓	✓	✓	✓	✓
EE3	Logistics performance, efficiency in sustainable transport			✓	✓	✓	✓	✓
EW1	Water use efficiency	✓	✓	✓	✓	✓	✓	✓
EW2	Share of freshwater withdrawal to available freshwater resources	✓	✓	✓	✓	✓	✓	✓
EW3	Sustainable fisheries as a proportion of GDP			✓	✓	✓	✓	✓
SL1	Nutrient balance per unit area[1]			✓	✓	✓	✓	✓
SL2	Share of organic agriculture to total agriculture land area	✓	✓	✓	✓	✓	✓	✓
SL3	Share of ruminant livestock population to agricultural area			✓	✓	✓	✓	✓
ME1	Domestic material consumption per unit of GDP	✓	✓	✓	✓	✓	✓	✓
ME2	Total material footprint per capita	✓	✓	✓	✓	✓	✓	✓
ME3	Average of food loss to production and food waste to consumption			✓	✓	✓	✓	✓
Natural capital protection								
EQ1	PM2.5 air pollution, mean annual populationweighted exposure	✓	✓	✓	✓	✓	✓	✓
EQ2	DALY rate due to unsafe water sources	✓	✓	✓	✓	✓	✓	✓
EQ3	Municipal waste collected per urban population[2]							✓
GE1	Ratio of CO_2 emissions to population, including AFOLU	✓	✓	✓	✓	✓	✓	✓
GE2	Ratio of nonCO_2 (CH_4, N_2O, and Fgas) emissions to population, excluding AFOLU	✓	✓	✓	✓	✓	✓	✓
GE3	Ratio of nonCO_2 (CH_4, N_2O, and Fgas) emissions in agriculture to population	✓	✓	✓	✓	✓	✓	✓
BE1	Average proportion of Key Biodiversity Areas covered by protected areas	✓	✓	✓	✓	✓	✓	✓
BE2	Share of forest area to total land area	✓	✓	✓	✓	✓	✓	✓
BE3	Aboveground biomass in forest[3]		✓	✓	✓	✓	✓	✓
CV1	Red List Index	✓	✓	✓	✓	✓	✓	✓
CV2	Tourism and recreation in coastal and marine areas	✓	✓	✓	✓	✓	✓	✓
CV3	Share of terrestrial and marine protected areas to total territorial areas	✓	✓	✓	✓	✓	✓	✓
Green Economic Opportunities								
GV1	Public Investments in Renewable Energy[4]							✓
GV2	Environmental Protection Expenditures[5]							✓
GV3	Total amount of funding to promote environmentally sound technologies per GDP					✓	✓	✓

Green Growth Indicators*		2019	2020	2021	2022	2023	2024	2025
GT1	Share of export of environmental goods to total export	✓	✓	✓	✓	✓	✓	✓
GT2	CO2 emissions embedded in trade					✓	✓	✓
GT3	Water virtual trade flows					✓	✓	✓
GJ1	Share of green manufacturing employment in total manufacturing employment	✓	✓	✓	✓	✓	✓	✓
GJ2	Ratio of renewable energy employment to renewable energy production					✓	✓	✓
GJ3	Employment in water and waste collection, treatment and disposal activities, and materials recovery[6]							✓
GN1	Development of environmentrelated technologies, share of patents[7]							✓
GN2	Universityindustry collaboration in Research & Development					✓	✓	✓
GN3	Installed renewable energygenerating capacity					✓	✓	✓
Social Inclusion								
AB1	Population with access to basic services, i.e., water, sanitation, and electricity	✓	✓	✓	✓	✓	✓	✓
AB2	Prevalence of undernourishment[8]			✓	✓	✓	✓	✓
AB3	Proportion of population with primary reliance on clean fuels and technology[9]							✓
GB1	Proportion of seats held by women in national parliaments	✓	✓	✓	✓	✓	✓	✓
GB2	Gender ratio of an account at a financial institution or mobilemoneyservice provider	✓	✓	✓	✓	✓	✓	✓
GB3	Getting paid, covering laws and regulations for equal gender pay	✓	✓	✓	✓	✓	✓	✓
SE1	Inequality in income based on Palma ratio[10]		✓	✓	✓	✓	✓	✓
SE2	Population with access to basic services by urban/rural, i.e., electricity	✓	✓	✓	✓	✓	✓	✓
SE3	Share of youth (aged 1524 years) not in education, employment, or training	✓	✓	✓		✓	✓	✓
SP1	Proportion of population above statutory pensionable age receiving pension	✓	✓	✓	✓	✓	✓	✓
SP2	Universal health coverage (UHC) service coverage	✓	✓	✓	✓	✓	✓	✓
SP3	Proportion of urban population living in slums	✓	✓	✓	✓	✓	✓	✓

Notes: *The table lists the green growth indicators that were used in the 2025 Edition of the Green Growth Index.
[1] The previous indicator was the average soil organic carbon content, a proxy variable used from 2019 to 2020.
[2] The previous indicator was municipal solid waste (MSW) generation per capita, a proxy variable used from 2019 to 2024.
[3] The previous indicator was the soil biodiversity potential level of diversity living in soils, a proxy variable used in 2019.
[4] The previous indicator was adjusted net savings minus natural resources and pollution damages, a proxy variable used from 2019 to 2024.
[5] The previous indicator was the degree of integrated water resources management implementation, financing, used from 2023 to 2024. It was replaced due to insufficient data.
[6] The previous indicator was the employed population below international poverty line, a proxy variable used from 2023 to 2024.
[7] The previous indicator was 5-year rolling average, patents on environment technologies, used from 2019 to 2024. It was replaced with a similar indicator with a better database.
[8] The previous indicator was population with access to electricity and clean fuels/technology, used from 2019 to 2020. It was combined with AB1 to add an indicator of access to food.
[9] The previous indicator was universal access to sustainable transport, a proxy variable used from 2019 to 2021, and the proportion of the population with convenient access to public transport from 2022 to 2024. The latter was replaced due to insufficient data.
[10] The previous indicator was inequality in income based on Atkinson, used from 2019 to 2020. It was replaced with Palma ratio, which is a better indicator for income inequality.

Annex 2: Illustration of divergences in databases for selected indicators and countries

The raw data for all indicators for the 2023 and 2024 Green Growth Index were compared to identify any divergences that could affect the scores. Generally, there are differences in the data reported in online databases from year to year. The diagrams below show indicators with significant divergences between databases for selected countries. In the 2024 Edition of the Green Growth Index, 23 indicators out of 48 represent data divergence for some countries. The data sources for the indicators were the same, except for AB3 and GT1 for the 2023 and 2024 Green Growth Index.

EE1: Energy intensity level of primary energy (MJ per $2011 PPP GDP)
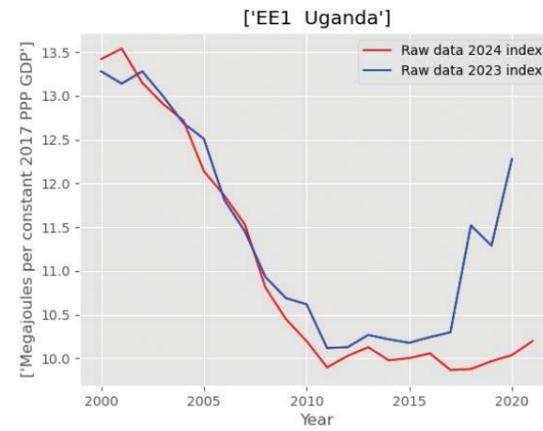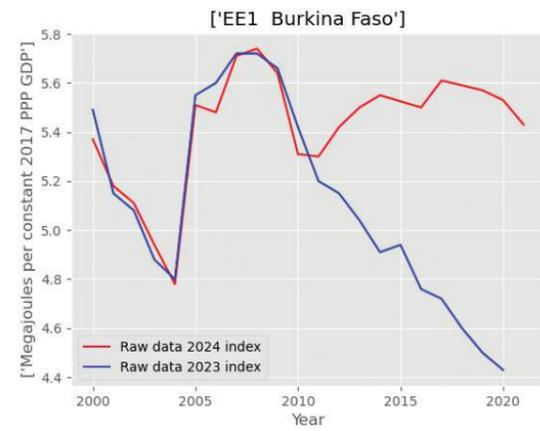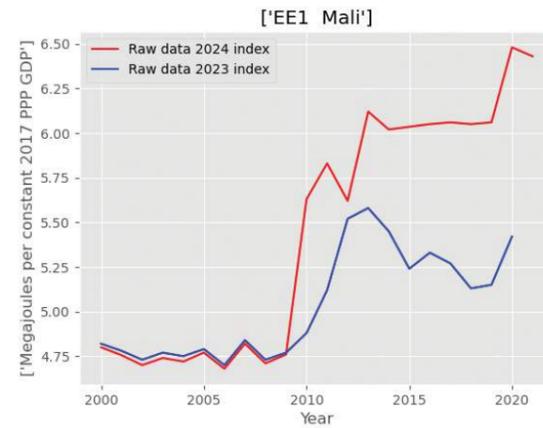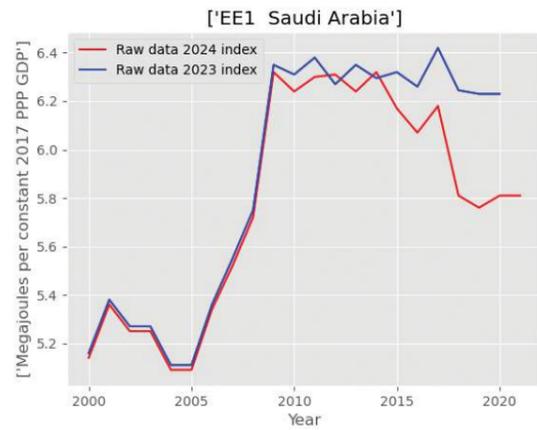
EE1: Share renewable to total final energy consumption (Percent)
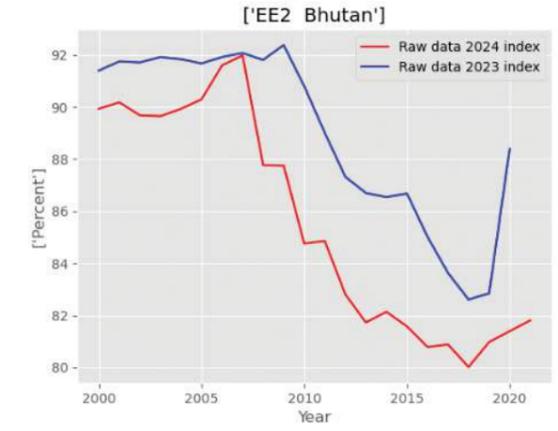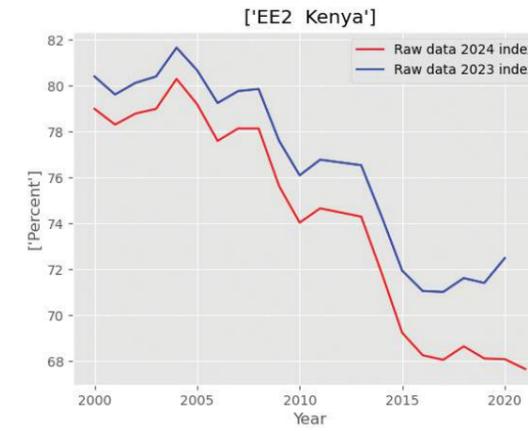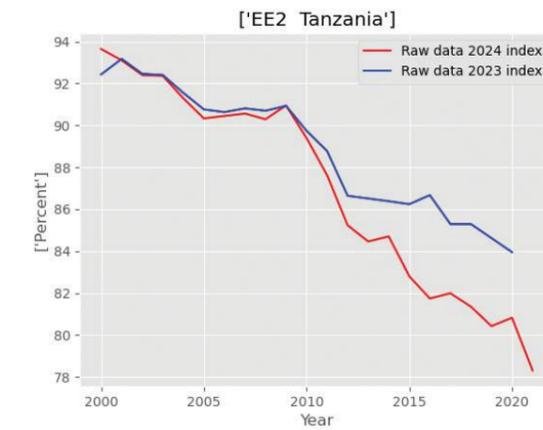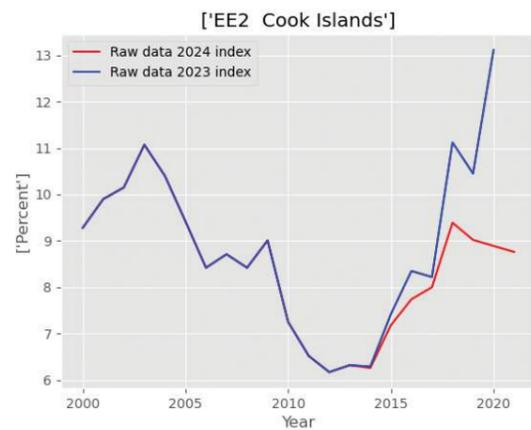
EW2: Level of water stress: freshwater withdrawal as a proportion of available freshwater resources
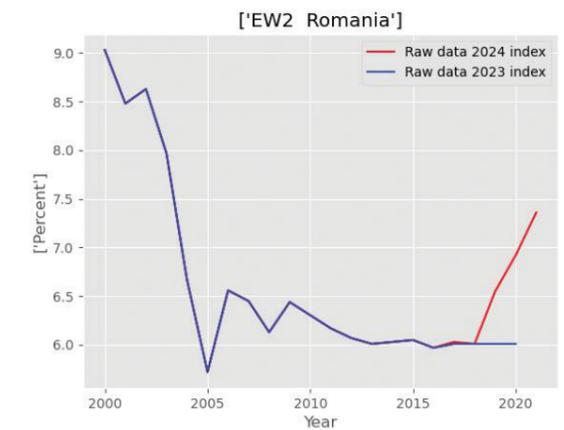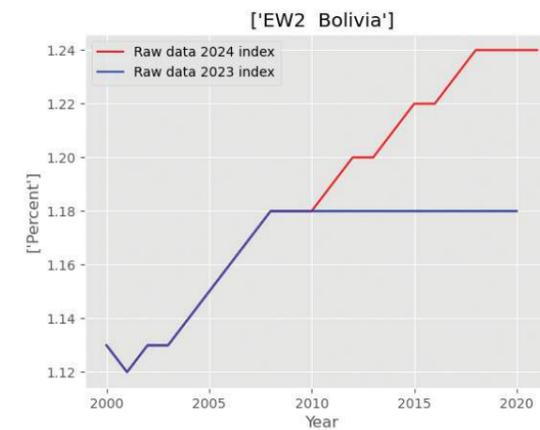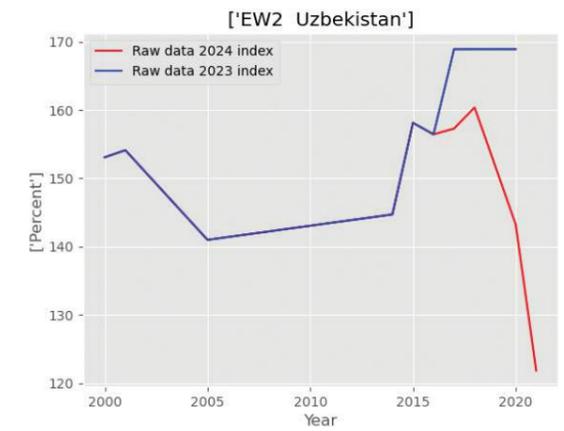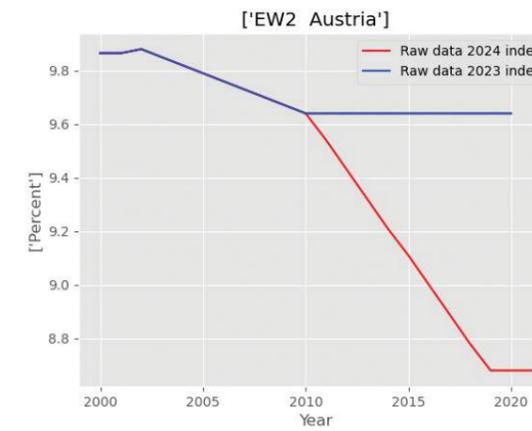
SL3: Share of ruminant livestock population to agricultural area (Livestock units per hectare)
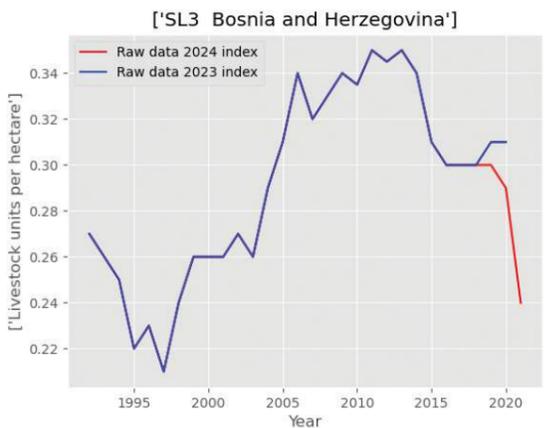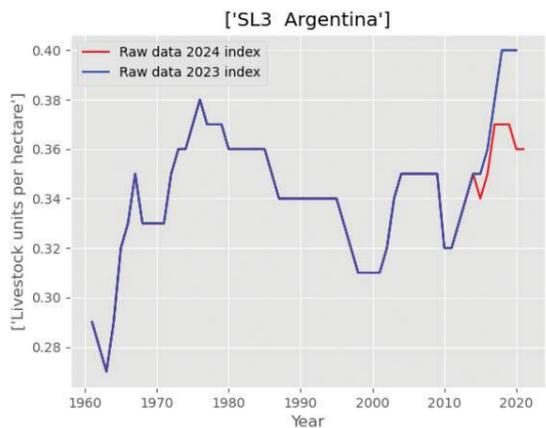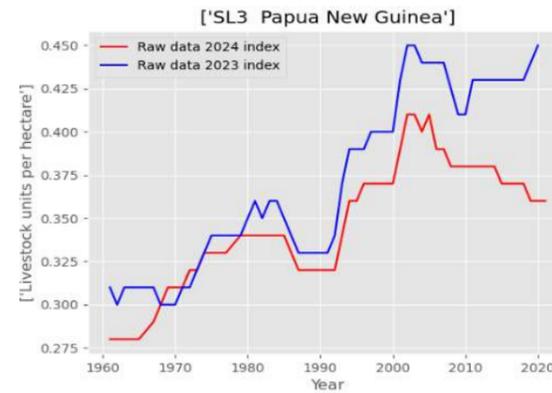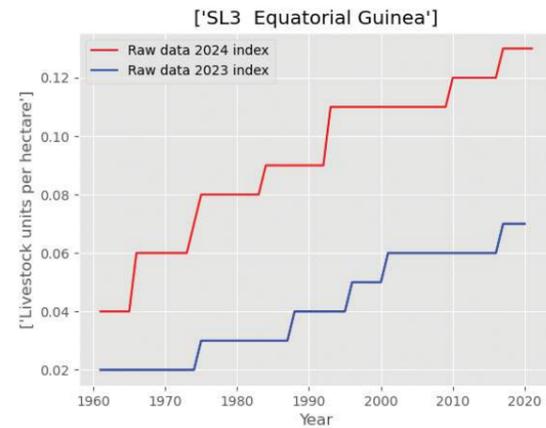
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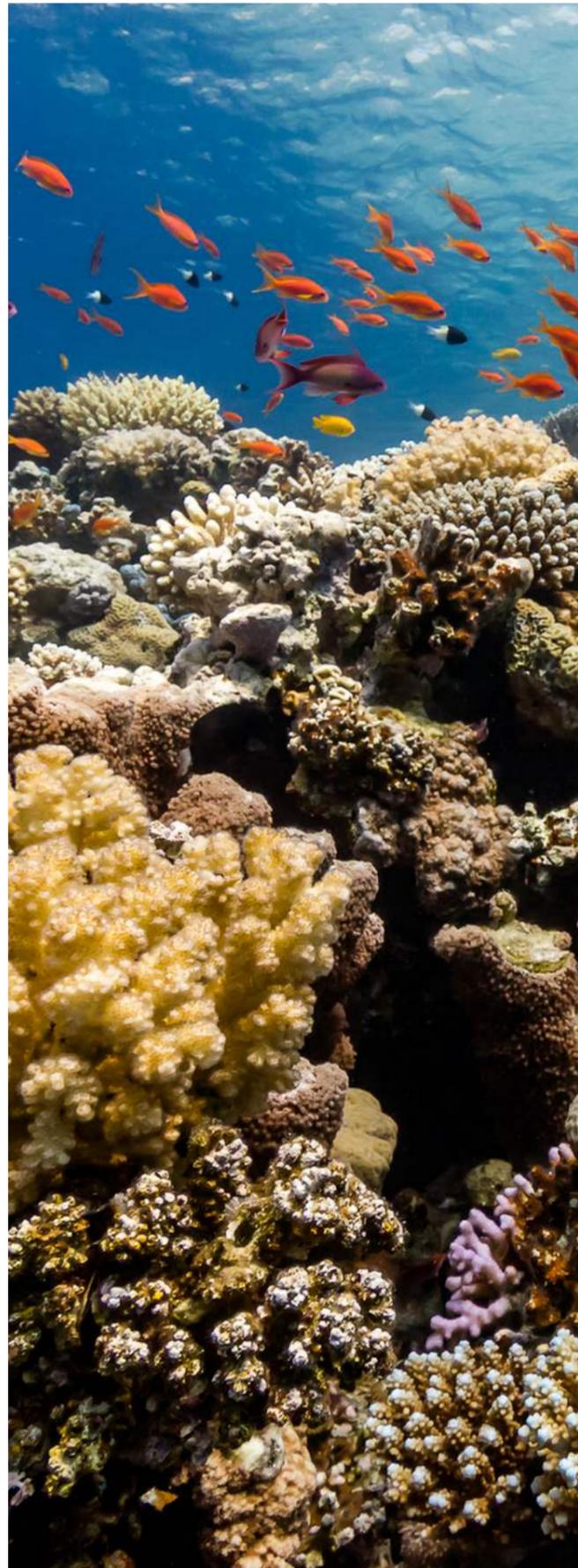
Annex 4 Example of an online survey questionnaire used for expert engagement and consultation

Annex 5 Examples of real-time structured polling on experts' analysis of index scores

Which of the four green growth dimensions offers the best opportunity for Kenya to further improve its green growth performance?

- Efficient and Sustainable Resource Use: 20
- Natural Capital Protection: 0
- Green Economic Opportunities: 3
- Social Inclusion: 0

GEO (final): Which of the four GEO pillars offers the best opportunity for Kenya to further improve its green growth performance?

- Green investment (GV): 17
- Green trade (GT): 0
- Green employment (GJ): 1
- Green innovation (GN): 2

ESRU (final): Which of the four ESRU pillars offers the best opportunity for Kenya to further improve its green growth performance?

- Efficient and sustainable energy (EE): 12
- Efficient and sustainable water use (EW): 8
- Sustainable land use (SL): 0
- Material use efficiency and waste (ME): 1

SI (final): Which of the four SI pillars offers the best opportunity for Kenya to further improve its green growth performance?

- Access to basic services and resources (AB): 17
- Gender balance (GB): 3
- Social equity (SE): 0
- Social protection (SP): 1

NCP (final): Which of the four NCP pillars offers the best opportunity for Kenya to further improve its green growth performance?

- Environmental quality (EQ): 11
- Greenhouse gas emission reduction (GE): 2
- Biodiversity and ecosystem protection (BE): 10
- Cultural and social value (CV): 0

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