A climate change adaptation index for financial risk assessment

by

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Client: Ortec Finance

April 25, 2025

Masters project submitted in partial fulfillment of the requirements for the Master of Environmental Management degree in the Nicholas School of the Environment of Duke University

EXECUTIVE SUMMARY

As the impacts of climate change intensify, communities are experiencing more extreme weather events that amount to billions of dollars in damages. Climate adaptation is the process of adjusting to current and future climate impacts. Governments—from national to local levels—have laid out climate adaptation strategies and have begun implementing measures to mitigate the impacts of climate change within their communities. Additionally, private institutions—such as banks, asset managers, and insurance companies—are recognizing the role of climate risk and related adaptation measures on their assets. These trends indicate that the ability to assess and quantify climate adaptation is becoming increasingly important, both for governments tracking their adaptation progress and private institutions making strategic decisions.

Our team worked with Ortec Finance, a financial risk and return management firm. Ortec manages a broad array of financial risks, including those related to climate change, and utilizes a proprietary climate model called ClimatePREDICT to estimate future risk associated with extreme, acute climate events. Ortec approached our team to help improve the model's performance by developing a climate adaptation index that can be integrated into ClimatePREDICT. Our team hoped to strengthen the model's capacity to estimate future GDP losses associated with extreme events by more holistically estimating countries' current and future adaptation capacity.

The methodology for our index was informed by a review of literature and existing indices. The literature review directed our team to several climate adaptation, climate risk, and sustainable infrastructure indices that helped us populate and structure a new index, focused specifically on adaptation. As climate adaptation spans a vast array of sectors, the index was structured using tiered layers, groups, indicators, sub-indicators, and specific metrics. Additionally, the forward-looking characteristics of climate adaptation and the current issues regarding the climate crisis led to the development of a three-layer structure: an adaptation plan, a current adaptation, and a government credibility layer. This enables assessment of a country's future intended action, present-day resilience level, and the ability of its government to achieve its adaptation goals, respectively.

In addition to this novel index structure, our team developed several other key innovations to strengthen our index calculations. We created a credibility multiplier mechanism to generate final index scores that reflected the likelihood of implementation of a country's national adaptation plan based on their financial capacity and quality of governance. Our second significant contribution was the development of a three-tiered data quality framework to address data availability and quality concerns. The framework quantitatively evaluates each metric against six quality dimensions, applies hierarchical classification to data sources, and incorporates a layer completeness calculation that accounts for missing data, resulting in a lower overall index score if the adaptation evaluation was based on less robust data.

Complementing the national-level index, we developed a regional/local adaptation index version to allow for more customizable, hazard-specific assessments of adaptation initiatives in countries that extend across large geographic areas and allow for a closer analysis of adaptation actions by local jurisdictions. Both the national-level and regional/local indices produce an assessment value from the scale of zero to one, with one representing a highly adapted region and zero representing low adaptation.

We assessed adaptation across eight countries based on an Ortec-provided list of countries essential to their clients' portfolios: Germany, France, Spain, the United Kingdom, China, Japan, Canada, and the United States. Across the eight countries, the United Kingdom scored highest while the United States scored lowest. The results of our index ranked the countries in the following order from highest to lowest scores: the United Kingdom, Germany, France, Japan, Spain, Canada, China, and the United States. Furthermore, we applied the regional/local adaptation index to London, UK and California, demonstrating the ability to evaluate adaptation at a city and state level. Finally, our team explored whether time spent implementing adaptation measures or GDP per capita were drivers of the final index scores and found no correlation between those variables and our scores.

While Ortec still needs to refine their method of incorporating the adaptation index values into ClimatePREDICT, these indices present a novel, customizable, and replicable approach for evaluating climate adaptation at multiple scales.

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INTRODUCTION

1.1 Climate Change Impacts and Adaptation

Since 1880, the average global temperature has increased by at least 1.1° Celsius, driven primarily by human activities.[1] This anthropogenic alteration in temperature has disrupted global weather patterns, leading to unprecedented changes in extreme weather events. Heat waves, droughts, heavy precipitation events, and hurricanes have become more frequent and intense.[2] These climate-related disturbances impose pressures on the infrastructure and economies of global communities, as previously developed infrastructure and response procedures are slow to adapt to the new conditions.

In the past two decades, 185 extreme weather events have incurred an estimated cost of $2.86 trillion. More than half of these events, accounting for $260.80 billion worth in damages, are ascribed to climate change.[3] These physical hazards and resulting losses are also linked to sharp contractions in GDP. The cost of inaction to curtail emissions will continue to climb with rising emissions; the National Bureau of Economic Research estimates every 1°C warming reduces world GDP by 12%.[4] Notably, climatological events, like droughts or forest fires, have the most pronounced effect on per-capita GDP, potentially leading to cumulative decreases of up to 10% in per capita growth.[5]

Climate risk is a function of exposure to hazards and vulnerability of the affected region. The degree of vulnerability and exposure is influenced by social and physical factors like infrastructure, geography, and income.[6] Officials seek to decrease risk through actions that help adapt to the impacts of climate change and build resilience within the communities and systems most vulnerable to those impacts. Adaptation is thus defined as "the process of adjustment to actual or expected climate and its effects" while resilience is the "capacity or ability to anticipate and cope with shock".[7]

Implementing adaptation and resilience is essential to prevent the worst harms of climate change and can mitigate some of the economic risks of climate change by increasing the anticipatory, adaptive, and absorptive capacity of communities.[8] Since the ability to reduce exposure to and cope with each event is essential to protecting the long-term health of the economy as climate change-driven disasters become more frequent and severe, countries or communities with more effective plans may be better protected, suffer less damages, and recover more quickly after these disasters.

1.2 National Adaptation Planning

As the social and financial costs of climate change have increased, governments and private enterprises have recognized the importance of climate adaptation to protect communities, infrastructure, and other assets. $76 billion in adaptation finance was mobilized in 2022, the majority of which came from the public sector.[9]

Adaptation is essential to mitigate risk to growing climate threats and countries across the world have responded with ambitious national adaptation plans (NAPs), setting goals for adaptation in the coming years and decades. Indeed, five out of six Parties to the United Nations Framework Convention on Climate Change (UNFCCC) have developed at least one NAP since the inception of the NAP process under the 2010 UNFCCC Convention of Parties in Cancun.[10,11]

The UNFCCC states that the intended goals of the NAP process is to "reduce vulnerability to the impacts of climate change, by building adaptive capacity and resilience; and to facilitate the integration of climate change adaptation, in a coherent manner, into relevant new and existing policies, programmes and activities, in particular development planning processes and strategies, within all relevant sectors and at different levels, as appropriate".[12] Formalization of the NAP process followed the implementation of National Adaptation Programs of Action (NAPA) by the UNFCCC in 2001, which focused on adaptation in least developed countries and particularly on the most vulnerable communities within those countries.

By 2005, developed countries also began to write and implement adaptation strategies. Evaluation of NAPAs revealed that these plans often focused on distinct sectors and failed to integrate with broader national strategic planning. Recognizing the growing importance of adaptation planning to developed and developing nations, the NAP process was introduced to improve the coherence of adaptation planning with national development strategies and to build capacity for planning, implementation and monitoring of adaptation action. [13, 12]

The efficacy of these plans depends on governance, financial resources, and institutional capacity for implementation.[11] Effective governance plays a critical role in translating plans into action, making governance and regulatory quality a key factor in assessing adaptation potential. An assessment of the drivers of national adaptation found that good governance was the strongest predictor of adaptation action.[14] This study also found that population size—as a proxy for economic capacity—was positively correlated with adaptation action but only in countries with higher-than-average governance measures.

Monitoring and evaluation frameworks are also essential to track progress and ensure accountability in adaptation efforts.[11] NAPs often lack implementation guidelines or comprehensive monitoring and evaluation guidelines, which may affect the likelihood of executing adaptation plans.[15, 12] Particularly glaring is the failure to include information about cost or funding needs and sources in NAP.[16] Developed countries more frequently view adaptation planning as an opportunity to develop long-term strategies rather than plans for specific projects with explicit cost estimates and guidelines for implementation.[12]

1.3 Variation in Climate Adaptation Action

There is wide variation across countries in how climate adaptation is implemented, reflecting differences in climate change impacts, available adaptation actions, and the broader context in which adaptation occurs. Unique geographical locations and socio-economic conditions influence a country's exposure and vulnerability to hazards, while distinct governance and financial structures shape how nations respond to current and future climate change impacts.[16] The capacity to implement adaptation action also varies by available economic resources. Countries with more scarce economic resources prioritize immediate needs over the mitigation of future risk, which pertains to climate adaptation's objective.[11]

1.4 Evaluating Climate Adaptation

Evaluating the potential outcomes of climate adaptation is a challenging endeavor because of the consideration of multiple dimensions that interact across time and space.[17] Climate risk considers exposure (the spatial organization of people and infrastructure) and vulnerability (degree of adaptive capacity) in the context of the probability of hazardous events. Adaptation plans tend to be developed *in response* to climate risk assessments, attempting to reduce exposure and vulnerability. As a result, a more robust evaluation of climate adaptation would consider the adaptation measure's scope of impact, duration of impact, and depth of impact. This implies going beyond the mere existence of a climate adaptation initiative, such as the implementation of permeable urban surfaces to reduce flooding, to evaluating metrics such as the percentage change in permeable surfaces, the longevity of the measure (e.g., lifespan of vegetation), the cost of implementation and maintenance, and the efficiency of the measure (e.g., using plants and trees versus porous pavement).

However, such holistic analysis at the national scale requires subject-matter expertise that goes beyond the capabilities of the student team and even sector-specific experts. Adaptation is a broad topic that spans infrastructure engineering, government programs, social justice, disaster relief, agricultural operations, and much more. Furthermore, robust analysis also involves copious amounts of data that require extensive research. It is also highly unlikely that the parties implementing adaptation—be it governments or private groups—have the capacity to collect and publish these ex-post outcomes.

Unsurprisingly, current national assessments of climate adaptation and resilience often rely on proxies of adaptive capacity to measure adaptation. The Notre Dame Global Adaptation Initiative defines adaptive capacity as "the ability of society and its supporting sectors to adjust to reduce potential damage and to respond to the negative consequences of climate events."[16] Adaptive capacity can be measured across various sectors and includes actions as diverse as improving transportation networks and protecting terrestrial biomes. Although not an exact assessment of climate adaptation's direct impacts, adaptive capacity provides a means for relative comparison across countries and regions.

1.5 Climate change and financial risk

Financial institutions and investors are increasingly considering current and potential future climate change-driven losses, as the effects of climate change and climate mitigation strategies introduce new complexity and risks in investment portfolios.[18,19,20] Furthermore, reporting legislation such as the EU Corporate Sustainability Reporting Directive (CSRD) and California SB 261 are requiring certain companies to report on material environmental risks, climate impact, or climate mitigation strategies.[21,22] Climate scenario analysis provides a way to identify climate change-related risks and opportunities within their portfolio.[23]

Beyond financial risk, there are also discussions regarding climate resilience as an investment theme.[24] These conversations imply financial institutions and investors expect increasing demand for resilience-related products and services and see value in cross-sector resilience solutions. As climate finance continues to evolve, the ability to assess and quantify climate adaptation status for regions, sectors, and portfolios will become more important.

OBJECTIVES

2.1 Client Overview: Ortec Finance

Ortec Finance—a leading global provider of technology and solutions for risk and return management—assists institutional investors in understanding climate risk and incorporating that risk into their portfolios. Using proprietary climate scenario analyses, Ortec Finance builds future climate risk into financial models to understand how global assets will fare in the coming years, estimating losses and disruptions due to climate change.

Ortec Finance has tasked a team of Nicholas School of Environment graduate students with understanding how climate adaptation action has and will mitigate the loss of GDP as a result of climate change for countries essential to their clients.

2.2 Project Scope

This project identifies and assesses the effectiveness of national climate adaptation across developed countries by constructing a climate adaptation index. The product is intended to aid in the evaluation of the monetary benefit of these adaptation and resilience plans. The index will be used by Ortec Finance within their proprietary climate model—ClimatePREDICT—to the effect of discounting or offsetting the projected GDP loss of extreme climatological and hydrological events, improving the predicted costs of these events within their model.

METHODOLOGY

A review of existing adaptation indices was conducted. The team reviewed client-provided proprietary literature, recommended literature, and existing indices. This was followed by a review of existing climate adaptation and vulnerability indices, which produced many examples—as detailed below—from reputable institutions and university research groups. The team reviewed the indicators and methodologies behind 55 indices.

The project team deliberately selected indicators based on established conceptual frameworks of the economic, social, and governance sectors, and measures of environmental quality essential to climate change adaptation. One such framework incorporated in this study comes from Climate ADAPT, a European climate adaptation platform developed by the European Commission and the European Environment Agency. Climate ADAPT measures adaptation activity across various economic sectors (e.g., energy, transport, cultural heritage, and water management), many of which were included as categories of indicators in both assessing current adaptation activity and adaptation planning in the project's index. Shaping the index around existing conceptual frameworks of adaptation ensured the index was aligned with real-world practice, rather than selecting largely subjective statistical measurements divorced from any context of current adaptation action.

As climate adaptation spans a vast array of sectors, the adaptation index was structured using layers, groups, indicators, sub-indicators, and specific metrics. Additionally, the forward-looking characteristics of climate adaptation and the current issues regarding the climate crisis led to the development of three layers: an adaptation plan, a current adaptation, and a government credibility layer. This enabled assessment of a country's future intended action, present-day resilience level, and the ability of its government to achieve its adaptation goals.

3.1 Existing Indices

Numerous climate risk and vulnerability indices have emerged in recent years. Indices and composite indicators have faced significant criticism, however, for oversimplifying complex, multidimensional issues, lacking objectivity, and requiring extensive data.[25,26] Despite these critiques, they have been applied widely to aid in comparison and drive behavioral changes in governments or agencies. Existing indices frequently cited in the literature and used in the development of this project's climate adaptation index are the Notre Dame Global Adaptation Initiative's (ND-GAIN) Country Index, Infrastructure for Good, WorldRiskIndex, and the European Commission's INFORM Risk Index. These indices also include measures of adaptive capacity and measure things besides adaptation that are already included in Ortec Finance's climate scenarios such as exposure and sensitivity to climate change impacts, which are outside the scope of project analysis. Given data availability challenges, lack of subject-matter expertise, and short timeline to complete the project, the team utilized existing indicators from these indices that were of particular relevance to adaptation. These indicators selected for analysis are discussed further in the methodology section.

ND-GAIN measures a country's vulnerability to climate change, as well as its "readiness to leverage private and public sector investment for adaptive actions".[17] Vulnerability is measured across six sectors (food, water, health, ecosystem services, human habitat and infrastructure) and is a composite measure of each sector's exposure, sensitivity, and adaptive capacity. Readiness is a measure of economic, governance, and social readiness to effectively implement adaptation actions. As Ortec Finance's climate scenario tools capture climate exposure and sensitivity, ND-GAIN's composite index cannot be used directly in tandem with Ortec Finance's models. Additionally, ND-GAIN uses the World Bank's Ease of Doing Business Index to measure economic readiness to mobilize private capital for adaptation. This index has not been updated since 2020, and so its continued use to measure economic readiness may not be appropriate. Given these challenges, the team pulled underlying data and country-level scores from indicators measuring adaptive capacity, governance readiness, and social readiness.

Infrastructure for Good—an index developed by Economist Impact in partnership with the Duke Nicholas Institute for Energy, Environment & Sustainability and Deloitte—assesses infrastructure ecosystems across 30 countries, evaluating their ability to provide high-quality, sustainable infrastructure while also examining how effectively they leverage infrastructure to bridge economic, social, and environmental gaps.[27] While focused on infrastructure, the index is broadly relevant to adaptation as it includes measures of governance and planning, sustainable finance and investment, social wellbeing, and environmental sustainability and resilience. Additionally, measures of infrastructure quality included in the index were included in the final adaptation index.

3.2 Data Quality Assurance

Although the goal of the index is to ensure consistent evaluation of a region's climate adaptation, challenges in data collection exist. For example, government agency publications may not be in English and existing databases are reporting data collected prior to 2020.

While standard statistical values derived from regionally specific, reputable sources may be more timely or accurate than international institutional data (e.g., a transportation agency's press article versus a United Nations report), the sheer quantity of indicators required for a comprehensive analysis and the complexity of the data search posed challenges for the student team. Furthermore, since the index products would be transferred to the client for future use, the client may lack the staff capacity to apply a massive index to other countries or cities.

The client expressed preference for data that is consistently and easily replicable, so that they may apply the index to more regions of interest. As a result, many indicators in the index utilize composite statistical values, such as indices from international institutions and nongovernmental organizations, as data inputs. These composite indices are compiled by subject-matter experts and achieve a more holistic analysis of an adaptation indicator. In contrast, the evaluation of transportation infrastructure quality is beyond the expertise of the student and client team.

As a result, there is a trade-off between data consistency (pulling from the same source across all desired countries) and data quality. This project's index contains a mix of standard statistical and composite statistical values, with a stronger emphasis on composite data for the country-level index and standard data for the city/regional-level index.

Despite the student team's best efforts to identify country-level data sources for use in the country index, it is possible that a future country of study lacks appropriate data. Furthermore, the city/regional-level index will require a more flexible data collection approach. As a result, index users should follow the data quality checklist and data hierarchy to maintain a rigorous, consistent approach to data collection. This framework can be found in Appendix 1a and 1b.

3.3 Indicator Selection

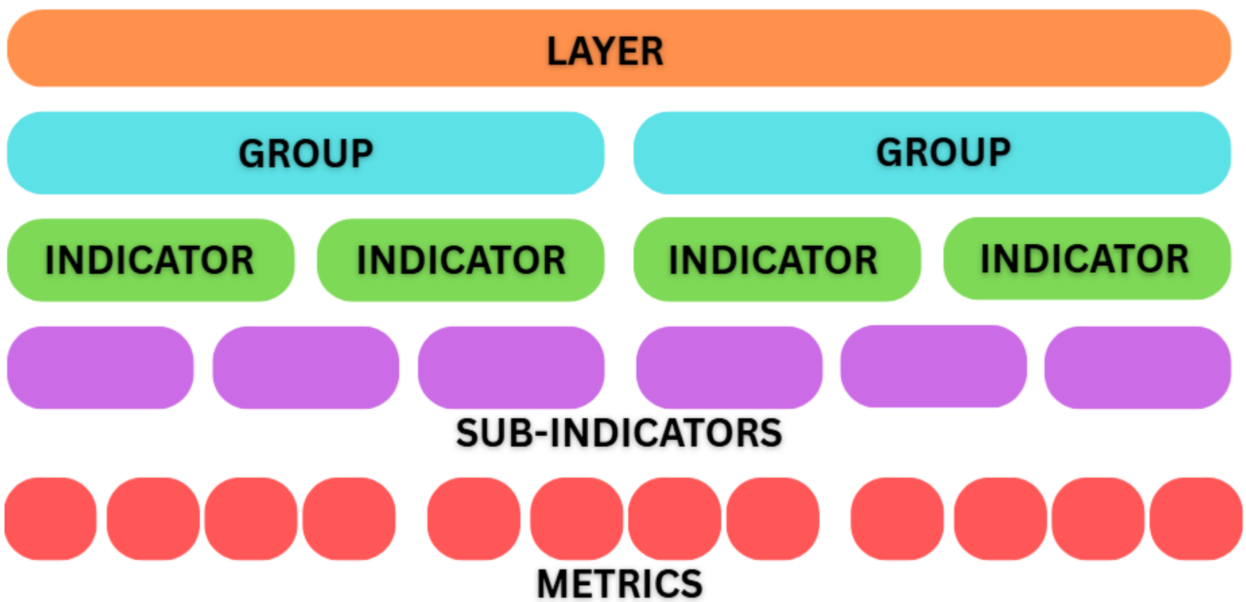

Figure 1: Each layer is subdivided into groups, indicators (corresponding to a group), sub-indicators (corresponding to an indicator), and metrics (corresponding to a sub-indicator).

Figure 2: An example of the categorization mechanism in Layer 1. There are two metrics under the Monitoring & Evaluation sub-indicator, which is under the Adaptation Plan indicator, which is under the Published Literature group.

Layer 1: Adaptation Planning

The first layer is used to assess the future resiliency of the country or region by evaluating the efficacy of the adaptation plan the country published. There are two groups in this layer: Published Literature and Adaptation Plan. For the national/federal-level index, this layer includes 26 indicators, as shown in Appendix 2a.

Layer 2: Adaptive Capacity

The second layer is used to assess the current resiliency of the country or region by evaluating the progress of current and past policies and initiatives. This layer is used to determine how resilient the country or region currently is through 13 indicators in the following groups: Environmental Quality and Management, Built Environment, Public Services, Communications Infrastructure, Disaster Risk Reduction, and Finance and Investment. The regional/city-level index has additional indicators that are hazard-specific and are customizable depending on the unique physical hazards of the region. Descriptions of these indicators are shown in Appendix 2b.

Layer 3: Credibility

The third layer is used to assess whether the national or regional government can credibly implement measures and policies needed to increase the adaptation and resilience of a country. Due to the salience of this assessment, the layer is used in the overall analysis twice. The layer's score is both applied to the first layer and added to the index as a whole. The section below describes this process in more detail. This layer encompasses three groups (Commitment to Environmental Action, Governance & Regulation, Financial Capacity) and includes six metrics, as shown in Appendix 2c.

3.4 Index-building: Data Cleaning

After inputting the data, the values were standardized to ensure comparability across different ranges. Binary questions (0 or 1) were left unchanged, while continuous values are standardized to a 0-1 scale. For example, a percentage value of 50% converts to 0.5, and a value of 80 on an index with a maximum value of 100 converts to 0.8. For most indicators, higher values reflect better outcomes and thus contribute to a higher score. However, two sub-indicators—economic inequality (measured by the percentage of people living below the poverty line) and economic diversity—are exceptions. For these, lower values indicate better performance, so the scores were inverted using the calculation of 1 minus the standardized values. Although there were no missing values for the five countries analyzed, the team recommends using average values to address potential missing data in future applications.

3.5 Index-building: Normalization

The team normalizes the data values by dividing them by the maximum values of each respective indicator. This normalization procedure is implemented to mitigate the inherent imbalance among the indices, as certain indices tend to cluster around higher values while others cluster around lower values. Without normalization, the direct application of weighting would disproportionately amplify the influence of indices with higher numerical ranges, thereby introducing bias into the analysis.

3.6 Index-building: Metric Weighting

Weighting plays a critical role in index construction, as it significantly influences the final scores. Recognizing that differing priorities and a lack of subject-matter expertise across multiple sectors can negatively affect metric-by-metric weighting, the team treated the metrics within a layer with equal importance. For example, the decision to weigh the publication of a climate risk assessment heavier than the publication of a climate adaptation plan, and vice versa, will depend on a country or index user's subjective values. Likewise, the decision to weigh a secure energy grid over a resilient water infrastructure system is also subjective. Index weighting is still addressed, but at the data quality and layer level, rather than at the "relative value of metrics" level.

3.7 Index-building: Data Quality Weighting

Faced with several data availability issues, the team developed a data quality framework that resulted in the assignment of a "data quality weighting" to each metric. The data quality framework consists of three parts: data dimensions per metric ("data dimensions"), data hierarchy per metric ("data hierarchy"), and completeness per layer ("layer completeness").

The team identified six data dimensions that encapsulate criteria that the metric's source should fulfill: consistency, accuracy, completeness, timeliness, accessibility, and reputation. For a full description of the criteria, see Appendix 1a. Each metric's source is evaluated based on the total number of data dimensions it fulfills, with a maximum value of six and a minimum value of zero. The maximum value of data dimension (per metric) is 1, the minimum value is 0.

$$Data\ dimensions_{per\ metric} = \frac{data\ dimensions\ fulfilled}{6}$$

There are nine levels in the data hierarchy, with "1—region-specific government regulations and publications" representing high-priority (more important) sources and "9—regional non-profit organization publications or websites" representing lower-priority sources. Each metric in the index is assigned a data hierarchy level. For example, an adaptation plan-related metric would be assigned "1" as the data would ideally be sourced from a government-published adaptation plan, and a transportation infrastructure metric would be assigned "5—existing indices" as the data would likely be sourced from the Sustainable Infrastructure Index. However, the actual research process may lead to the usage of different data sources from the index-provided sources. Each metric's *actual* source is labeled with a data hierarchy level—which could be the same as, or different from, the *assigned* level. For the full data hierarchy, see Appendix 1a. The maximum value of data hierarchy (per metric) is 1, the minimum value is 0.5. The "0.5" was arbitrarily set as the maximum deduction amount to ensure moderate penalization for lower-quality sources used, and may be adjusted in the future depending on how much priority the client may wish to place on the data hierarchy system.

$$Data\ hierarchy_{per\ metric} = 1 - 0.5 * \left(\frac{actual\ source\ hierarchy\ level - assigned\ hierarchy\ level}{9 - assigned\ hierarchy\ level}\right)$$

The layer completeness is the ratio of answered metrics versus total metrics within each layer. In a scenario where data cannot be found for certain metrics, it is crucial to not "overweight" layers based on data availability. For example, as the implementation credibility layer has the fewest number of metrics, missing data for just two of the seven metrics would make the remaining five metrics hold greater "weight" in the implementation credibility score and overall index score. The layer completeness ratio therefore acts as an adjustment to the metric's layer-level contribution, reducing the possibility of inadvertently attributing higher total index weight to incomplete layers.

$$Data\ completeness_{Layer\ n} = \frac{total\ number\ of\ metrics\ answered}{total\ number\ of\ metrics\ in\ layer}$$

Each metric's data quality weighting was therefore calculated by multiplying all three parts of the data quality framework together (data quality weight per metric is capped at "1"):

$$\begin{aligned}Data\ quality\ weight_{per\ metric} &= data\ dimensions_{per\ metric} * data\ hierarchy_{per\ metric} \\ &* data\ completeness_{Layer\ n}\end{aligned}$$

For each metric, the data value is multiplied against the data quality weight. In a scenario where all data quality dimensions are fulfilled, the actual source data hierarchy aligns with the assigned source hierarchy level, and all layer metrics are answered, the data quality weight would equal "1" and index metric value discounting would not occur.

$$\boldsymbol{Index\ metric\ value = metric\ data * \ data\ quality\ weight_{per\ metric}}$$

3.8 Index-building: Calculating Final Index Values

The most straightforward approach to calculating the final score is to add up the weighted scores of all questions.

$$\begin{aligned}Index\ value_{simple} &= Layer_1 * weight_{Layer\ 1} + Layer_2 * weight_{Layer\ 2} + Layer_3 * weight_{Layer\ 3}\end{aligned}$$

However, to enhance the robustness of the index, a multiplicative adjustment was introduced. Specifically, the Layer 1 (adaptation plans) score was multiplied by a credibility multiplier derived from Layer 3 (government credibility). This multiplier was calculated by dividing a country's Layer 3 score by its maximum possible score (i.e., Layer 3's total weight). The adjusted Layer 1 score is then added to the scores of Layer 2 (current adaptation) and Layer 3 to produce the final index score.

$$\begin{aligned}Index\ value_{credibility-weighted} &= Layer_1 * \frac{Layer_3\ actual\ score}{Layer_3\ \max score} weight_{Layer\ 1} + Layer_2 * weight_{Layer\ 2} \\ &+ Layer_3 * weight_{Layer\ 3}\end{aligned}$$

To further enhance the robustness of the index, a data quality weighting was applied to each metric. The summation of weighted metric scores for each layer was multiplied by the layer's data completeness percentile. These layers, now adjusted according to the quality of their data values, are applied to the government credibility-multiplicative equation for calculating the final index value.

$$Layer_n = \sum (index\ metric\ values)$$

$$Index\ value_{data\ quality\ weighted} = Layer_1 * \frac{Layer_3\ actual\ score}{Layer_3 \max score} weight_{Layer\ 1} + Layer_2 * weight_{Layer\ 2} + Layer_3 * weight_{Layer\ 3}$$

3.9 Index-building: Scenario Testing and Layer Weighting

Given the inherently subjective nature of weight choices, the team explored how changes in layer weights affect the final scores. This is important because weight choices can be subjective and scenario analysis on them helps ensure the results are robust and not overly dependent on a single weighting scheme.

The team kept the weight of layer 1 constant at 0.3 and adjusted the weights of layer 2 and layer 3 between 0.3 and 0.4, creating three scenarios:

1. Scenario 1: Weighting = 0.3 (Layer 1), 0.3 (Layer 2), 0.4 (Layer 3)
2. Scenario 2: Weighting = 0.3 (Layer 1), 0.35 (Layer 2), 0.35 (Layer 3)
3. Scenario 3: Weighting = 0.3 (Layer 1), 0.4 (Layer 2), 0.3 (Layer 3)

3.10 Further Index-building Considerations

While the assignment of weights is an attempt to balance the contribution of questions within each layer, an inherent imbalance remains. Binary questions, where most countries score 1 in Layer 1, tend to contribute more to the final score than continuous-value questions, whose scores typically range between 0 and 1, even when assigned the same weight. Furthermore, within continuous-value questions that range between 0 and 1, values cluster differently. Some indicators, such as the energy security indicator, cluster around higher values (e.g., 0.6-0.8), while others, like the poverty indicator, cluster around much lower values (e.g., 0-0.2). Still, others exhibit a more even distribution across the 0-1 range. This discrepancy highlights the need for careful consideration of question types and their relative impacts in future repetitions of the index.

RESULTS

4.1 Product A: National-level Index

The national-level index is used to assess adaptation initiatives at the national level. This includes the infrastructure projects and resilience programs that are either facilitated by federal governmental bodies and federal agencies or have national coverage in scope of implementation.

Indicator scores were classified by percentile rank. Scores within Layer 2 that fell in the highest or lowest 25% for each indicator were labeled ‘High Adaptive Capacity’ or ‘Low Adaptive Capacity’, respectively. Scores with Layer 3 were similarly categorized as ‘High Credibility’ or ‘Low Credibility’ depending on their relative score.

4.2 Product B: Regional/city-level Index

The regional/city-level index is used to assess adaptation initiatives at the local level. While the boundaries of the national/federal-level index are clearly delineating the country’s borders, the boundaries of the regional/city-level index can range from state to county, to greater municipal regions, or to central municipal scales. This index allows for a closer analysis of adaptation initiatives under local jurisdiction. Additionally, for countries that encompass vast geographical areas facing various physical climate risks, this index allows for more customizable, hazard-specific assessment of adaptation initiatives.

The methodology for assessing adaptation at the regional level builds on the process discussed above but is different due to the shift in geographic and governing scope. Not only does the regional index have slightly different metrics, but it also seeks to evaluate the coverage of the adaptation measure. The regional index methodology can be found in the Appendix (TBD).

4.3 Index results: Country Overall Rank, “Implementation Credibility-Weighted” Approach

Table 1. Overall country scores for Credibility-Weighted Index

Implementation Credibility-Weighted Index	
UK	0.875
Germany	0.863
France	0.846
Japan	0.828
Spain	0.804
Canada	0.782
China	0.739
USA	0.655

4.4 Index results: Country Layer Scores, "Implementation Credibility-Weighted" Approach

The results shown in the table below are the output for the Implementation Credibility-Weighted Index under a 0.3, 0.35,0.35 weighting scenario. The following discussion section will focus on the results from this weighting scenario to compare the country layer scores.

Table 2. Country layer and overall scores, organized according to overall score. The upper 75th percentile are highlighted in green, the middle 50th are in yellow, and the lower 25th are in orange.

Layer	UK	Germany	France	Japan	Spain	Canada	China	USA
Plan	0.300	0.285	0.300	0.257	0.271	0.286	0.286	0.107
Capacity	0.278	0.287	0.267	0.294	0.274	0.271	0.260	0.259
Credibility	0.322	0.317	0.312	0.308	0.299	0.281	0.264	0.303

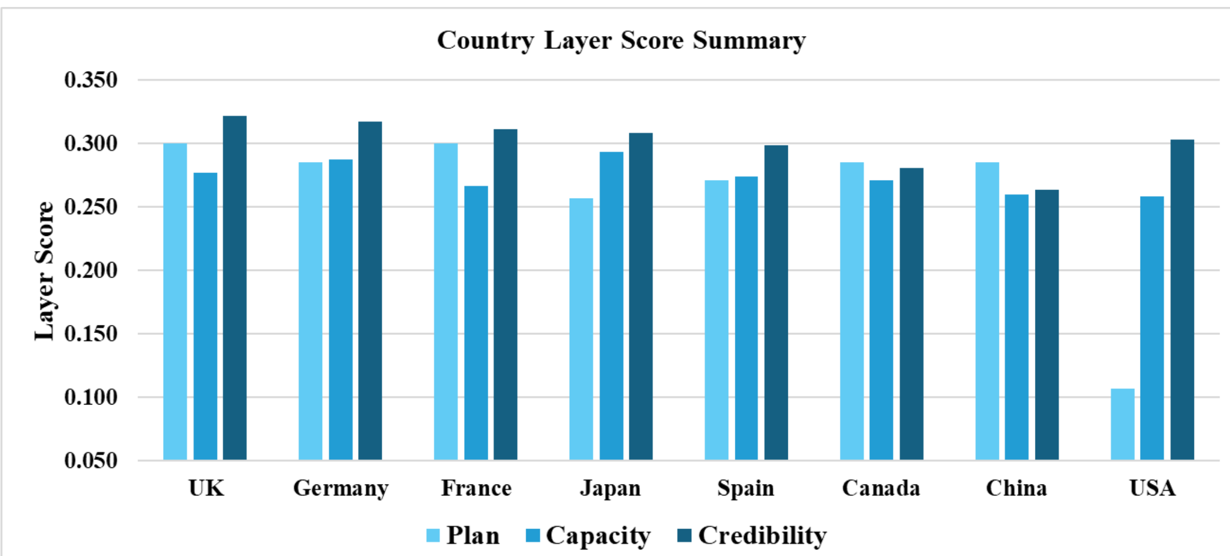

Figure 3. Country Layer Score Summary, Layer Scores from Layer 1 "Plan", Layer 2 "Capacity", and Layer 3 "Credibility".

4.5 Country Overview: The United Kingdom

Layer 1 - Adaptation Planning

The United Kingdom's first national adaptation plan was implemented in 2013[28]. Since then, the country has published two more adaptation plans, concluding with the *Third National Adaptation Plan* that outlines measures intended to be implemented from 2024 to 2028.[29] The U.K.'s Layer 1 scores are based on the NAP3. The United Kingdom received a perfect score Layer

1, equal to France, receiving a ‘Yes’ for all indicators, showing that the U.K. has a very robust adaptation plan.

Layer 2 - Adaptive Capacity

The United Kingdom’s score for Layer 2 falls in the middle 50th percentile. The UK did not have any indicators with particularly poor scores, generally performing similarly to the other countries. It did, however, have the highest score for ‘Adherence to Sendai/Hyogo Frameworks’ showing the country’s strong ability to reduce the risk of natural disasters through quality infrastructure.

Layer 3 - Credibility

The U.K. performed the highest for Layer 3. The U.K. has particularly high ‘Economic Diversity’, ‘Commitment to Climate Action’, and ‘Regulatory Quality’ scores. These results show that the U.K. economy is particularly diverse, has historically implemented climate policies, and has the ability to implement policies.

Overall

The U.K. has the highest overall score because it has a particularly robust adaptation plan, has a strong credibility score, and does not have any big gaps in policy inhibiting its adaptive capacity. This combination suggests that the U..K has been historically committed to adaptation and resilience and has strong plans for the future.

4.6 Country Overview: Germany

Layer 1 - Adaptation Planning

Germany’s *Strategy for Adaptation to Climate Change* was first adopted in 2008, with multiple adaptation strategy updates and progress reports adopted since, making it a country with a strong history of adaptation awareness. The most current version, adopted in December 2024, contains 33 measurable targets for adaptation and over 180 implementation actions. Although Layer 1 was assessed based on the 2020 version (due to translation challenges), Germany’s adaptation planning still covered the majority of Layer 1’s measures. However, Germany’s adaptation planning lacked measures for utility and telecommunications infrastructure. Most measures were addressed in the *Strategy for Adaptation to Climate Change 2020,* but several adaptation measures were identified in other published literature, such as the National Water Strategy and Germany Recovery and Resilience Plan.

Layer 2 - Adaptive Capacity

Germany’s current adaptive capacity is more robust than that of other project scope countries. In particular, Germany’s proportion of protected terrestrial ecosystems, rigor of environmental regulation, closing of the infrastructure gap, and green bond/loan financing stand out compared to other project scope countries. However, Germany is ranked lower than other project scope countries in the preparedness of its infrastructure against natural disasters (Infrastructure for Good) and security of its energy system (WEF Energy Index - Security).

Layer 3 - Credibility

Germany’s government credibility across index measures remains competitive with that of other project scope countries, with high data values across government effectiveness and economy metrics. Germany has the strongest rating in its ability to stay on track for its Paris Agreement greenhouse gas commitments (Climate Change Performance Indicator), implying its government is successful in facilitating climate action and mitigation initiatives.

Overall

Germany is ranked second highest in overall country adaptation index scoring. It’s history of setting forth adaptation plans, and more robust adaptive capacity establish a foundation for future adaptation planning. The ability of Germany’s states (Lander) and federal government to collaborate and drive change in their respective jurisdictions will continue to play a role in its climate adaptation journey.

4.7 Country Overview: France

Layer 1 - Adaptation Planning

France’s *National Strategy for Adaptation to Climate Change* was first published in 2006. Since then, France has published several national adaptation plans[30]. The most recent was published in March of 2025, entitled *3rd National Climate Change Adaptation Plan (PNACC)*. France’s scores for Layer 1 are based on this plan[31].

France received one of the highest scores in this analysis, receiving a 0.30, only equal to the United Kingdom. France received a ‘Yes’ for all indicators, demonstrating that France has a robust adaptation plan.

Layer 2 - Adaptive Capacity

France's score falls in the middle 50th percentile range, receiving a 0.247, but had the lowest score compared to the UK and other EU countries. France had particularly low scores for ‘Environmental Impact Assessments’ and ‘Financing for Social Good’ compared to the other countries. This suggests that France might not have as stringent environmental assessment requirements, nor promotes sustainable finance to the degree of other countries.

France had the highest indicator scores for ‘Access to public infrastructure and utilities’ and ‘Information Communication Technology Infrastructure’. These high scores suggest that France has particularly strong access to public utilities and broad-band or internet connectivity.

Layer 3 - Credibility

France ranked relatively high in the credibility layer, only being outranked by Germany and the UK. That said, France scored slightly lower for ‘Regulatory Quality’, and ‘Economic Diversity’. The low ‘Regulatory Quality’ score, measuring the perception of the government’s ability to implement sound policies, indicates that France may have difficulty implementing some of the measures outlined in the adaptation plan. The low ‘Financial Capacity’ score indicates that the French citizenry may not have the financial means necessary to adapt to new policies or climate change, inhibiting overall resilience.

Overall

France’s score is at the top of the middle 50th percentile, preceded by the UK and Germany. While France has a very robust adaptation plan, the overall score was reduced by the Layer 2 and Layer 3 scores. In summation, while France has strong adaptation plans, they might have difficulty implementing those plans to the fullest degree in the near term.

4.8 Country Overview: Japan

Layer 1 - Adaptive Planning

Japan has a relatively low score for Layer 1, falling in the lower 25th percentile. It did not receive a ‘Yes’ for ‘Funding’, ‘Telecommunications Infrastructure’, and ‘Environmental Justice’.

Layer 2 - Adaptive Capacity

Japan received the highest score for Layer 2, outperforming the other countries for indicators like ‘Environmental Impact Assessments', ‘Adherence to Sendai/Hyogo’, and ‘Economic Inequality’. These high scores reflect that Japan has strong assessment policies, has quality infrastructure that can withstand natural disasters, and has a relatively low percentage of the population living below the poverty line.

Layer 3 - Credibility

Japan’s score for Layer 3 falls within the 50th percentile. The country received a low score for ‘Commitment to Climate Action’, showing that Japan has historically not performed as well as the other countries in terms of instituting climate policies. Japan received high scores for ‘Economic Inequality’ and ‘Government Effectiveness’, showing that Japan has a low percentage of the population living in poverty and has a strong ability to implement policies.

Overall

Japan's overall score falls in the bottom of the 50th percentile range. While Japan has a high adaptive capacity and ability to implement policies, it does not have relatively robust plans to address adaptation or resilience in the coming years.

4.9 Country Overview: Spain

Layer 1 - Adaptation Planning

Spain has a high Adaptation Planning score relative to other countries within the Index, receiving a 'Yes' for all indicators other than 'Funding' and 'Telecommunications Infrastructure'.

Layer 2 - Adaptive Capacity

Spain has a Layer 2 score of 0.254, falling in the central range of the layer. The country scores poorly for adaptive capacity indicators including 'Environmental Impact Assessments', 'WEF Energy Transition Index - Secure Indicator', and 'Gross Fixed Capital Formation'. The country has a high 'WEF Energy Transition Index - Sustainability Indicator', second only to the UK.

Layer 3 - Credibility

Spain's Layer 3 score also falls in the central range of the layer among other countries in the index. The country was found to have low 'Government Effectiveness' and 'Regulatory Quality' scores, as well as a low score for the 'Financial Market Depth & Health' indicator. These low scores are indicative of poor governance and lack of robust financial markets.

Overall

Spain ranked fifth among countries included in the index. Despite having a strong national adaptation plan, many of its key indicators that reflect development were relatively low. These low indicators scores are indicative of poor infrastructure, governance, and financial institutions relative to other countries in the index.

4.10 Country Overview: Canada

Layer 1 - Adaptation Planning

Canada launched its first national adaptation plan in 2023, entitled *National Adaptation Strategy*[32]. The Layer 1 scores are based on this plan. Canada has one of the top scores for this layer, receiving a 'Yes' for almost all indicators. It did not receive a 'Yes' for 'Does the Adaptation Plan intend to improve the energy grid?'. This indicator was not discussed in Canada's adaptation plan. Given growing concerns in the stability of Canada's energy grid, this may be a gap in policy if not addressed elsewhere.[33]

Layer 2 - Adaptive Capacity

Canada falls in the middle 50th percentile for this layer, scoring similarly to China and France. Canada scored lowest in comparison to the other countries for 'Protection of Terrestrial Biome', 'WEF Transition Index-Sustainable Indicator', and 'Commitment to Climate Action'. Canada had the highest scores for 'Environmental Impact Assessments', reflecting the country's strong assessment requirements.

Layer 3 - Credibility

Canada had the lowest credibility score compared to all other countries, largely due to its significantly lower scores for 'Commitment to Climate Action' and 'Economic Diversity'. The low 'Commitment to Climate Action' score, which assesses historical trends in climate policy and GHG emission reduction, indicates that Canada has not been as committed to implementing climate policy as other countries. The low 'Economic Diversity' score suggests Canada's economy is not particularly diversified. Canada scored particularly high for 'Economic Inequality', showing that Canada has a relatively lower percentage of the population living in poverty.

Overall

Canada fell in the lowest 25th percentile, despite its robust adaptation plan. This is due to its low 'Credibility' score, which indicates Canada might struggle to implement its adaptation plans. Secondly, its average 'Adaptive Capacity' score shows that the country may currently be faced with challenges resulting from a few policy gaps (as discussed above), reducing the overall resilience of the country.

4.11 Country Overview: China

Layer 1 - Adaptation Planning

China performed similarly to most countries in the index within Layer 1, receiving a score of 0.286. The only indicator for which China did not receive a 'Yes' within the layer was for the Environmental Justice indicator, as the country's NAP does not state an intention to 'implement solutions that address distributive, procedural, or social justice'. The UNFCCC NAP Technical Guidelines explicitly articulates that it does not aim to be prescriptive, but does include suggestions to consider historical social disadvantages, such as those based on gender (UNFCCC, 2012).

Layer 2 - Adaptive Capacity

China received a Layer 2 score of 0.26, the second lowest score among the countries in the index. Indicators for which China received Low Adaptive Capacity scores include Ecosystem Health and Conservation, Access to Public Infrastructure and Utilities, Information Communication Technology (ICT) Infrastructure, Infrastructure Gap, and Gross Fixed Capital Formation. These low scores likely reflect China's development status, characterized as an upper-middle income nation by the World Bank. China's economic growth rate has slowed relative to its rapid growth since opening its economy in the late 1970s, however the country saw a robust 5.2% increase in GDP in 2023. Infrastructure investment will likely increase as China continues to develop.

China had High Adaptive Capacity scores for Network Connectivity, Adherence to Sendai/Hyogo Frameworks, and Financing for Social Good. These scores reflect China's investment in transportation infrastructure, disaster preparedness, and the prevalence of sustainable or impact financial instruments.

Layer 3 - Credibility

As in the previous layer, China ranked second to last among all countries in the index in Layer 3, receiving a score of 0.281. Indicators driving this low score include Climate Action, Government Effectiveness, Regulatory Quality, Economic Inequality, and Financial Market Depth & Health. The country ranks highest for measures of Economic Diversity, however, along with Germany.

Overall

China ranked the second lowest in all countries, despite its robust adaptation plan. This is due to its low Capacity and Credibility scores, which indicates China has historically been lagging on climate adaptation actions and its relatively low government credibility might hinder its ability to implement the ambitious adaptation plans.

4.12 Country Overview: The United States of America

Layer 1 - Adaptation Planning

The United States does not have a country-wide national adaptation plan. Rather, federal agencies have been individually tasked with creating Federal Agency Adaptation Plans to address current impacts and future risks of climate change within the scope of each agency's administrative management responsibilities.[34] The first agency adaptation plans were published in 2014, with subsequent plans released in 2021 and 2024, the latter of which are effective through 2027. The mission of each U.S. federal agency is distinct and specific, ranging from communication to housing and environmental protection. As such, their adaptation plans are narrower in their scope and are specific to the agency's operations and regulatory responsibilities and so do not individually meet the criteria selected in the development of the index (e.g., the U.S. Environmental Protection Agency Adaptation Plan does not intend to improve telecommunications infrastructure). In a review of 38 national adaptation plans, multi-agency authorship was found to be the strongest positive correlation for overall adaptation plan quality.[11]

Given the lack of centralization and coordination of adaptation planning, the U.S. were given a score of 0.5 for each indicator that was assigned a 'Yes' in the 'Yes/No' structure of Layer 1 indicators. If each indicator within Layer 1 for which the U.S. meets the criteria received a score of 1.0 rather than the discounted 0.5 value, the country would receive a Layer 1 score of 0.22 using equal weights for each index layer.

Layer 2 - Adaptive Capacity

The U.S. ranks last among all countries within both Layer 1 and Layer 2. Several indicators can help explain this low score relative to other countries in the index. Indicators and sub-indicators for which the U.S. scored lowest or among the lowest in Layer 2 include: Ecosystem Health and Conservation, WEF Energy Transition Index - Sustainable Indicator, Infrastructure for Good 2.1.1 - Infrastructure Gap, and Infrastructure for Good 2.2 Financing for Social Good. Three of these indicators are measures of infrastructure development, investment, and finance. There has been particular focus in the U.S. on reducing the infrastructure gap, measured as the difference between current infrastructure needs and investment trends, and in 2017 the American Society of Civil Engineers estimated that the infrastructure gap for 2020-2030 was $2.6 trillion.[35] The other infrastructure-focused indicators for which the U.S. scores poorly reflect relatively weak investment in sustainable energy infrastructure and insufficient environmental and social-linked financing. Indicators in Layer 2 for which the U.S. scores highly include WEF Energy Transition Index - Secure Indicator and Access to Public Infrastructure and Utilities.

Layer 3 - Credibility

The index indicates that the U.S. has a relatively high financial and institutional credibility score. second to Germany. Indicators which are driving this strong credibility score include: Regulatory Quality and Government Effectiveness (measures of good governance collected by the World Bank), and Financial Market Depth and Health, which aggregates measures of the cost of capital, marketable debt risk, and health of local banks. The U.S. scores poorly, however, on the Climate Action indicator, a result of high greenhouse gas emissions relative to the country's commitments under the UNFCCC Paris Climate Agreement.

Overall

The United States ranked last among all countries, driven by its low Adaptation Planning and Adaptive Capacity scores. As discussed above, the Layer 1 score was particularly low because of its lack of a country-wide NAP, lowering its score significantly relative to the other countries included in the index.

4.13 Case Study: California

Layer 1 - Adaptation Planning

California produces a statewide adaptation strategy every three years. This assessment was based on the 2021 adaptation strategy, as the 2024 adaptation strategy is still being finalized. California's adaptation strategy is fairly robust with its layer score of 0.252 out of 0.300, but has not fulfilled metrics for climate spending disclosure and meteorological-related adaptation measures. Data quality-weighted layer score is 0.236 out of 0.300, which suggests data quality for Layer 1 is strong.

Layer 2 - Adaptive Capacity

California's current adaptive capacity is relatively robust with its layer score of 0.240 out of 0.350. California's top hazard categories are meteorological and climatological events. Out of these two categories, adaptive capacity for meteorological events (storms) remains low. Little to no information was found for event drills/simulations, ecosystem management or public-facing programs, and insurance market coverage associated with meteorological events. Data quality-weighted layer score is 0.230 out of 0.350, which suggests data quality for Layer 2 is strong.

Layer 3 - Implementation Credibility

California's state government possesses a fairly robust level of adaptation implementation credibility, with a score of 0.255 out of 0.350. Its current governor, Gavin Newsom, supports climate action and both chambers of its state legislature are controlled by the Democratic Party, which supports more environmental protection and climate action than the opposition party.[36, 37] The California Natural Resources Agency oversees the coordination of the Climate Adaptation Strategy, though individual measures are undertaken by state agencies and local governments. This suggests cross-sectoral collaboration is present in California's climate adaptation efforts. California's implementation credibility dropped due to challenges in understanding total climate adaptation expenditures. While Governor Newsom has committed billions of dollars to climate action in prior years, future cuts to that initial value have not only decreased the total amount of spending, but also eroded confidence in government commitments. Data quality-weighted layer score is 0.227 out of 0.350, which suggests data quality for Layer 3 is moderate.

4.14 Case Study: London, United Kingdom

Layer 1 - Adaptation Planning

London's first Climate Adaptation Strategy dates back to 2011, but since then, multiple city-level plans have included some form of climate adaptation strategy. For example, the City of London Corporation's Resilience Strategy, the 2021 London Plan, the Thames Estuary 2100 Plan, the Transport for London's Climate Adaptation Plan, and more. London's climate adaptation planning is fairly robust with its layer score of 0.255 out of 0.300, but could improve more on specific measures addressing its top hazards, which are meteorological and climatological hazards. Data quality-weighted layer score is 0.237 out of 0.300, which suggests data quality for Layer 1 is strong.

Layer 2 - Adaptive Capacity

London's current adaptive capacity is relatively robust with its layer score of 0.264 out of 0.350. Several areas of weakness include health, transportation, energy, and private sector involvement. Although there are discussions to embed climate's impacts into health inequities in the UK Health Security Agency, the healthcare system does not have a record of being informed of how climate change can impact health and how practitioners can address these issues. Furthermore, for a city heavily dependent on public transportation, there is a lack of data on how extreme weather has impacted transportation systems for residents. Due to London's reliance on the country's National Grid, determining London-specific adaptive capacity of the grid has also been challenging. Finally, as a global hub for finance and other economic activity, there is a lack of private-sector involvement in funding or supporting local adaptation measures. Data quality-weighted layer score is 0.225 out of 0.350, which suggests data quality for Layer 2 needs improvement.

Layer 3 - Implementation Credibility

London's government is fairly complex. There are 32 boroughs in London, each governed by local borough authorities, and the City of London Corporation, which governs the historic center of the city. The Greater London Authority, which includes the mayor of London and the London Assembly, has regional governance across the 33 smaller authorities. The implementation credibility layer's evaluation focused more broadly on the Greater London Authority and received a score of 0.291 out of 0.350, which is strong. Characteristics include dominant political party motivation for addressing climate change and interdisciplinary collaboration. London's implementation credibility score could benefit from improved adaptation fund budgeting. Data quality-weighted layer score is 0.265 out of 0.350, which suggests data quality for Layer 3 needs improvement.

DISCUSSION

5.1 Discussion of Overall Results and Potential Explanations

The United Kingdom scored the highest of the eight countries evaluated in this report. In other words, the United Kingdom is, and likely will be, better adapted than the other countries, especially when compared to the United States which scored the lowest. The team explored whether time spent implementing adaptation measures and GDP per capita were drivers of these scores.

To explore whether scores correlate to the duration the country has been implementing adaptation measures, the team examined the connection between the date of the country's first adaptation plan and their score. There was no apparent correlation. For example, Spain, whose score is roughly the median, published their first national adaptation plan in 2006.[38] In comparison, the United Kingdom, which scored the highest, published their first adaptation plan in 2013.[39] In short, the United Kingdom did not score the highest because they have been implementing adaptation measures for longer.

GDP per capita also does not correlate to the scores. For example, in 2023, the United States had a GDP per capita of 82,769.40 USD, while the United Kingdom's GDP per capita was 49, 463.90 USD.[40] While the United States had a greater GDP per capital than the United Kingdom, it still scored the worst of all eight countries.

In conclusion, country adaptation is driven by many factors and is not immediately dependent on the country's GDP nor its history in this space.

5.2 Contribution to Climate Adaptation Assessment

The goal of this project was to develop an index focused specifically on climate adaptation, without duplicating measures of risk already captured by Ortec's ClimatePREDICT model. As discussed previously, the team used existing indices—such as ND-GAIN, Economist Impact's Infrastructure for Good, ASCOR, the WorldRiskIndex, and the INFORM Risk Index—to inform the structure and content of the model. However, the Climate Adaptation Index that was developed is distinct in that it includes only measures or proxies of adaptation, excluding direct measures of risk or vulnerability.

To evaluate national-level adaptation, the team reviewed and scored national adaptation plans based on their completeness and efficacy. All indicators in Layer 2 estimated the current adaptive capacity of countries, using proxies aligned with criteria essential for national adaptation. Layer 3, Government Credibility, assessed the likelihood that adaptation plans would be implemented. This structure, combined with the project's government credibility multiplier framework for final score calculation, represents a novel approach to assessing country-level adaptation.

The team's first methodological innovation, the government credibility multiplier, addresses a critical gap in climate adaptation evaluation—the disconnection between policy planning and implementation. Recognizing that ambitious adaptation plans hold discounted value without execution capacity, the team developed the credibility multiplier mechanism. This approach applies a credibility adjustment to a nation's adaptation plan score (Layer 1) by multiplying it with a normalized credibility coefficient derived from the ratio of the nation's governance credibility score (Layer 3) to the maximum possible Layer 3 score. This produces the enhanced Credibility Index, which provides several analytical advantages over conventional additive indices. First, it explicitly accounts for implementation probabilities rather than treating all plans as equally viable. Second, it reveals cases where strong institutional capacity might compensate for less comprehensive planning. The multiplier approach aligns with established political economy literature emphasizing the centrality of governance quality in policy outcomes,[17] which provides a quantifiable method to integrate this insight into adaptation metrics.

The second major contribution, data quality assurance framework, addresses data challenges in climate adaptation research through a novel three-tiered quality assessment framework. The system evaluates each datapoint against six quality dimensions, applies hierarchical classification to data sources and incorporates a layer completeness calculation that accounts for missing data. This rigorous process generates a Data Quality Index that serves multiple functions. First, it identifies countries (such as Canada) where rankings are particularly sensitive to data quality issues. Second, it provides quality weights and highlights priority areas for data improvement. While the team maintains the Credibility Index as the primary analytical index, the Data Quality Index offers crucial information about measurement uncertainty. The framework particularly advances adaptation assessment by making implicit data quality judgments explicit, reproducible, and adjustable to different user priorities.

The index was tailored to meet Ortec's specific needs: it focuses on countries critical to Ortec's client portfolio, relies on reproducible data sources, and is structured to allow for integration with the ClimatePREDICT model. The index can be applied either as a pre- or post-model multiplier, or modularly by integrating individual layers, as discussed below. By enhancing specificity for ClimatePREDICT and ensuring flexibility in model integration, the team aimed to improve ClimatePREDICT's ability to account for differences in adaptation capacity across countries.

5.3 How Ortec can use the index

There are two general approaches for applying the adaptation index to Ortec's ClimatePREDICT model.

The first approach applies the index value as a multiplier to post-PREDICT model results. Ortec trialed this approach against the Munich Reinsurance Group's NatCatSERVICE natural disasters database, using all eight countries within this project scope. Although the results of the initiative are proprietary and cannot be included in this report, they varied noticeably across the eight countries. This suggests that, instead of a straightforward multiplication of index values against PREDICT results, a post-model multiplier approach may require the index values to be adjusted through functions or factors, which complicates the approach.

The second approach is an integrated method. Ortec may apply the adaptation index as discount or amplification factor at an earlier step of the PREDICT model. As the adaptation index consists of three layers, Ortec may also dissect the index and apply the layers to different PREDICT model components, which would be a modular approach. These approaches and their outcomes have not been explored yet, as the student team does not have access to the PREDICT model.

5.4 Limitations

Data availability was a significant challenge, as discussed previously. For example, it was only recently (2020) that the European Environment Agency began systematically collecting and comparing the results of climate and energy policies, as noted in Germany's National Energy and Climate Plan. Adaptation practices should be ingrained across all sectors, but the lack of a centralized national database for climate adaptation poses an obstacle for research. Furthermore, certain measures such as building code upgrades and water infrastructure planning may fall under "climate adaptation" but are not necessarily tagged as "climate adaptation" in publications.

Although the use of existing indices provides the project's adaptation index with the added credibility of subject-matter expertise and literature-cited adaptation findings, these existing indices are only proxies for adaptation and may not be updated frequently. The data quality framework and weighting process provides structure for research and discounts the relevance of lower quality data sources in the index; however, the equations are still not perfect.

There is unavoidable subjectivity in the selection of indicators within the adaptation index. Adaptation to climate change at the national scale is complex and successful climate adaptation and adaptation planning is context dependent. Factors that determine successful adaptation such as good governance, sound financial institutions, and healthy ecosystems are also complex and often cannot be measured directly.[41] Rather, they are assessed using latent variables, variables that cannot be directly measured but rather are estimated using a series of other indicators or proxies.[42]

For example, the World Bank's Worldwide Governance Indicators (WGI) are frequently applied to assess the quality of national governance and compare governance across nations. Because 'governance' cannot be directly measured, the WGI uses proxies such as regulatory quality, rule of law, and control of corruption to capture the complexity of governance in indicators within their conceptual framework of what makes for good governance. Similarly, for the adaptation index the project team selected indicators within team members' conceptual framework of adaptation. It is certain, however, that the team did not select all variables that would comprehensively estimate national adaptation.

Another challenge present in the development of the index was the use of composite indicators developed by existing indices, as previously discussed. Indicator scores, including those measuring adaptation in the energy and finance sectors, as well as disaster risk reduction within the climate adaptation framework, were calculated using composite indicators. These indicators employ multiple proxy variables to create a single score reflecting a complex phenomenon. For instance, the World Economic Forum's Energy Transition Index—Secure Indicator includes measures of diversification of import counterparts, diversity of total energy supply, net energy imports, diversity of electricity supply, flexibility in electricity system, gas supply resilience, system average interruption duration and frequency, and electric power transmission and distribution losses. While this measure may be comprehensive, reporting a single score hides the underlying complexity of the indicator. Indicators often lack transparency in the methodology of how the data is weighed as well. By obscuring the complexity in a single score, comparison across countries can become difficult. Two countries may have similar scores for a given compound indicator but could have very different metrics that drive that score.

Adaptation is time-sensitive, meaning that the benefits associated with adaptation measures shift over time and will require maintenance or replacement at some point. For example, an adaptation goal of increasing street trees to counter the urban heat island effect takes time to fully implement. Several years will elapse before the planted trees can achieve sufficient growth and provide benefits. Benefits of existing street trees may also decrease over time as trees age and die. Another example is the construction of a levee to protect against coastal flooding. By a certain year, the sea level rise projections may nullify the levee's protective effects. Rather than taking the temporal aspect of adaptation measures into account, this project's index serves more as a static checklist. Adaptation measures that were implemented six years ago, for example, are treated the same as adaptation measures that were implemented the prior year.

Beyond the year-over-year, time series potential that remains unachieved, the static nature of the index also poses an issue for not being nimble enough to reflect current events. The United States's implementation credibility layer is 0.303 out of 0.350 but will likely fall in the coming year due to the shift in the current administration's priorities and beliefs. Because this index's metrics rely on proxies and prior year data, the implementation credibility layer lacks a nuanced analysis of the political and social landscape - a set of conditions that shift on a cyclical basis.

5.5 Future applications of the indices and implications

The indices can be applied to various countries and regions. Ortec's services cover roughly 30 countries, which range from high income to middle income economies. As the index is applied to more middle-income countries, the team expects existing values (values from the eight countries in this project scope) to shift slightly, as metric data points are normalized against each other.

Assessing climate adaptation measures across eight countries has underscored the reality that climate change adaptation is highly interdisciplinary, and its assessment requires holistic analysis across multiple sectors. Beyond its direct relevance to protecting communities and ensuring resilience, climate adaptation is a growing area of interest for financial institutions.

APPENDIX

Appendix 1a: Data Dimensions

Dimension	Criteria
Consistency	• Data should be in a format that aligns with the indicator's data type (percentage (of GDP), real number (of years), yes or no)
Accuracy	• Data values (for a country) should be collected in a similar fashion compared to other data values (other countries' values) from the same source • If the data (for a country) was interpolated using proximate values, while other data values within the source set were not, the data point does not fulfill accuracy standards ○ An alternative source may thus be more accurate
Completeness	• Data should address the indicator's question (avoid additional analysis or lack of analysis)
Timeliness	• Data collected post-2020 (within 5 years) is acceptable • Preference should be given to the most recently updated data source, assuming other dimensions hold constant
Accessibility	• Data should ideally be publicly accessible and not behind a paywall or subscription service
Reputation	• Data source should possess a reputation for rigorous assessment, fact-checking practices, or be peer-reviewed

Appendix 1b: Data Hierarchy

1. **Region-specific government regulations and publications |** standard statistical values
    a. National, state, or city-level
        i. Regulation texts, binding documentation, agency reports, etc.
2. **Region-specific government websites |** standard statistical values
    a. National, state, city
        i. Official statements, press releases, etc.
3. **Academia and academic research institutions |** standard statistical values
    a. Peer-reviewed journal articles, field-based case studies, etc.
        i. Examples: Duke University, Stockholm Resilience Centre
4. **International institutions |** standard OR composite statistical values
    a. Examples: World Bank, United Nations, World Economic Forum, Red Cross
5. **Existing indices |** standard OR composite statistical values
    a. Examples: Infrastructure for Good, ND-GAIN, Global Social Progress Index
6. **Corporate/research center analytics or gray literature |** standard OR composite statistical values
    a. Case studies, risk ratings, program analysis articles, press releases, etc.
7. **Non-profit research institutions and platforms**
    a. Examples: World Resources Institute, Climate Action Tracker
8. **Reputable news articles |** standard statistical values
    a. International or local (city) journalism
9. **Regional non-profit organization publications |** standard statistical values
    a. Case studies, program analysis articles, press releases, etc.

Appendix 2a: Layer 1 “Adaptation Planning” Indicators

Layer 1: Metric 1 “Does the country have a national adaptation plan?”	
<u>Rationale for the Selection of the Metric</u> This metric determines whether the county has a national adaptation plan, which the remainder of Layer 1 is concerned with. If the country does not have a national adaptation plan, but does have individual agency adaptation plans, they are awarded 0.5 for this metric and the following metrics in this layer when applicable. They do not receive full scores for agency plans, because organized, inter-agency collaboration is essential for implementation. Without a national plan that addresses inter-agency and cross-sector concerns, the country is likely to encounter challenges to implementation.	<u>Location in the Index</u> Group: Published Literature Indicator: Adaptation Plan Sub-Indicator: Adaptation Plan Excel Row: 2
<u>Basis of Scoring</u> Score of 0-1 0 = “No”; 1 = “Yes”	<u>Where to find the data</u> The country’s adaptation plan

Layer 1: Metric 2 “Does the plan have measurable targets related to social and environmental outcomes?”	
<u>Rationale for the Selection of the Metric</u> Specific goals or measurable targets allow the country to specifically identify prominent issues and enables progress evaluations. Indistinct or ambiguous plans are more difficult to implement.	<u>Location in the Index</u> Group: Published Literature Indicator: Adaptation Plan Sub-Indicator: Adaptation Plan Excel Row: 3
<u>Basis of Scoring</u> Score of 0-1 0 = “No”; 1 = “Yes”	<u>Where to find the data</u> The country’s adaptation plan

Layer 1: Metric 3 "Have they made a plan in the last 5 years?"	
<u>Rationale for the Selection of the Metric</u> Adaptation is affected by changes in weather patterns, the economy, politics, legislation, technological innovations, and more. Adaptation policies therefore need to be regularly updated to be effective.	<u>Location in the Index</u> Group: Published Literature Indicator: Adaptation Plan Sub-Indicator: Relevance Excel Row: 4
<u>Basis of Scoring</u> Score of 0-1 0 = "No"; 1 = "Yes"	<u>Where to find the data</u> The country's adaptation plan

Layer 1: Metric 4 "Has the country published a monitoring and evaluation report on the progress made?"	
<u>Rationale for the Selection of the Metric</u> Monitoring progress of the implementation of an adaptation plan is integral for a) establishing the country is seeking to achieve adaptation goals, and b) identifying where future efforts need to be focused.	<u>Location in the Index</u> Group: Published Literature Indicator: Adaptation Plan Sub-Indicator: Monitoring and Evaluation Excel Row: 5
<u>Basis of Scoring</u> Score of 0-1 0 = "No"; 1 = "Yes"	<u>Where to find the data</u> The country's adaptation plan

Layer 1: Metric 5 "Is there a dedicated cross-sector coordinating body that oversees the strategies and actions made by the plan?"	
<u>Rationale for the Selection of the Metric</u> Cross-sector collaboration is essential, as adaptation is intricately linked to many different sectors. Without a designated body that organizes and collaborates with adaptation efforts, the country will likely encounter implementation challenges.	<u>Location in the Index</u> Group: Published Literature Indicator: Adaptation Plan Sub-Indicator: Monitoring and Evaluation Excel Row: 6
<u>Basis of Scoring</u> Score of 0-1 0 = "No"; 1 = "Yes"	<u>Where to find the data</u> The country's adaptation plan

Layer 1: Metric 6 “Does the country regularly publish climate risk assessments?”	
Rationale for the Selection of the Metric Understanding which climate risks are most salient for a country is essential for adaptation planning. Regular assessment provides update information and ensure the country is able to accurately respond to those climate risks.	Location in the Index Group: Published Literature Indicator: Climate Risk Assessment Sub-Indicator: Climate Risk Assessment Excel Row: 7
Basis of Scoring Score of 0-1 0 = “No”; 1 = “Yes”	Where to find the data The country’s adaptation plan

Layer 1: Metric 7 “Does the adaptation plan discuss funding mechanisms for its proposed strategies?”	
Rationale for the Selection of the Metric If the country has pre-established funding mechanisms dedicated for the adaptation plan’s goals, and therefore has identified how to fund those goals, they have a better chance of realizing those targets.	Location in the Index Group: Published Literature Indicator: Funding Sub-Indicator: Funding Excel Row: 8
Basis of Scoring Score of 0-1 0 = “No”; 1 = “Yes”	Where to find the data The country’s adaptation plan

Layer 1: Metric 8 “Does the adaptation plan intend to address climate change related health impacts, develop climate-resilient health services, or reduce climate-related morbidity and mortality?”	
<u>Rationale for the Selection of the Metric</u> Climate change has multiplicative human health effects. If the adaptation plan includes measures to improve health impacts, then the country will be more resilient and healthier in the long term.	<u>Location in the Index</u> Group: Adaptation Plan Indicator: Adaptation Plan Sub-Indicator: Health Services Excel Row: 9
<u>Basis of Scoring</u> Score of 0-1 0 = “No”; 1 = “Yes”	<u>Where to find the data</u> The country’s adaptation plan

Layer 1: Metric 9 “Does the adaptation plan intend to build structural measures?”	
<u>Rationale for the Selection of the Metric</u> This metric includes examples of infrastructure the adaptation plan might list, including, dams, flood levees, ocean wave barriers, and earthquake-resistant construction and evacuation shelters. These types of infrastructure can preventatively prepare the country to withstand climate related hazards, increasing the resiliency of the country.	<u>Location in the Index</u> Group: Adaptation Plan Indicator: Adaptation Plan Sub-Indicator: Environmental Infrastructure Excel Row: 10
<u>Basis of Scoring</u> Score of 0-1 0 = “No”; 1 = “Yes”	<u>Where to find the data</u> The country’s adaptation plan

Layer 1: Metric 10 "Does the adaptation plan intend to improve infrastructure of roads and the transportation system?"	
<u>Rationale for the Selection of the Metric</u> While the country likely has measures to improve its transportation infrastructure in other policies or plans, if the country intends to specifically improve transportation to adapt to future climatic conditions, their transportation infrastructure will likely be more resilient. Second, the infrastructure is essential for other public services: quickly evacuating for hazards, transporting supplies, allowing people to move, etc.	<u>Location in the Index</u> Group: Adaptation Plan Indicator: Adaptation Plan Sub-Indicator: Transportation Infrastructure Excel Row: 11
<u>Basis of Scoring</u> Score of 0-1 0 = "No"; 1 = "Yes"	<u>Where to find the data</u> The country's adaptation plan

Layer 1: Metric 11 "Does the adaptation plan intend to enhance building resilience?"	
<u>Rationale for the Selection of the Metric</u> Building codes and buildings will likely need to be adjusted to account for new climatic conditions, and perhaps, to reduce the carbon footprint of those buildings.	<u>Location in the Index</u> Group: Adaptation Plan Indicator: Adaptation Plan Sub-Indicator: Building Infrastructure Excel Row: 12
<u>Basis of Scoring</u> Score of 0-1 0 = "No"; 1 = "Yes"	<u>Where to find the data</u> The country's adaptation plan

Layer 1: Metric 12 "Does the adaptation plan intend to improve utility infrastructure (sewage system, etc.)?"	
<u>Rationale for the Selection of the Metric</u> Updating the utilities—which are essential for daily life—to better withstand future hydrological or climatic conditions will better prepare the economy. These measures can include water recycling programs or efficiency measures, new reservoirs, etc.	<u>Location in the Index</u> Group: Adaptation Plan Indicator: Adaptation Plan Sub-Indicator: Utility Infrastructure Excel Row: 13
<u>Basis of Scoring</u> Score of 0-1 0 = "No"; 1 = "Yes"	<u>Where to find the data</u> The country's adaptation plan

Layer 1: Metric 13 "Does the adaptation plan intend to improve telecommunication infrastructure?"	
<u>Rationale for the Selection of the Metric</u> Communication is important during hazardous events and in general. If a country has a more publicly accessible, updated, resilient telecommunications system, they are more resilient.	<u>Location in the Index</u> Group: Adaptation Plan Indicator: Adaptation Plan Sub-Indicator: Telecommunications Infrastructure Excel Row: 14
<u>Basis of Scoring</u> Score of 0-1 0 = "No"; 1 = "Yes"	<u>Where to find the data</u> The country's adaptation plan

Layer 1: Metric 14 "Does the adaptation plan intend to improve the energy grid?"	
<u>Rationale for the Selection of the Metric</u> Energy is the lifeblood of the country and to the economy. A more resilient energy grid will ensure the country is able to operate as normal.	<u>Location in the Index</u> Group: Adaptation Plan Indicator: Adaptation Plan Sub-Indicator: Energy Grid Excel Row: 15
<u>Basis of Scoring</u> Score of 0-1 0 = "No"; 1 = "Yes"	<u>Where to find the data</u> The country's adaptation plan

Layer 1: Metric 15 “Does the adaptation plan intend to enhance climate resilient food and agriculture production, supply, and distribution?”	
<u>Rationale for the Selection of the Metric</u> Food production is especially vulnerable to climate change. Addressing this vulnerability and taking steps to mitigate impacts is essential to properly prepare the country.	<u>Location in the Index</u> Group: Adaptation Plan Indicator: Adaptation Plan Sub-Indicator: Food and Agriculture Excel Row: 16
<u>Basis of Scoring</u> Score of 0-1 0 = “No”; 1 = “Yes”	<u>Where to find the data</u> The country’s adaptation plan

Layer 1: Metric 16 “Does the adaptation plan intend to reduce climate-induced water scarcity and attain climate-resilient water supply?”	
<u>Rationale for the Selection of the Metric</u> Like energy, water is an essential part of life. Instituting water efficiency, management, and resiliency mechanisms will allow the country to be more resilient.	<u>Location in the Index</u> Group: Adaptation Plan Indicator: Adaptation Plan Sub-Indicator: Water Management Excel Row: 17
<u>Basis of Scoring</u> Score of 0-1 0 = “No”; 1 = “Yes”	<u>Where to find the data</u> The country’s adaptation plan

Layer 1: Metric 17 “Does the adaptation plan intend to invest in natural infrastructure?”	
<u>Rationale for the Selection of the Metric</u> “Natural infrastructure” includes wetlands, natural coastal barriers, forests, and more. Natural infrastructure is an innovative way to both preserve natural ecosystem services and to prepare the country for climate change impacts.	<u>Location in the Index</u> Group: Adaptation Plan Indicator: Adaptation Plan Sub-Indicator: Ecosystem Excel Row: 18
<u>Basis of Scoring</u> Score of 0-1 0 = “No”; 1 = “Yes”	<u>Where to find the data</u> The country’s adaptation plan

Layer 1: Metric 18 "Does the adaptation plan intend to take actions to protect ecosystems and biodiversity?"	
<u>Rationale for the Selection of the Metric</u> Conservation and preservation of ecosystems and biodiversity will preserve ecosystem services and the ecological health of the country, making the country more resilient.	<u>Location in the Index</u> Group: Adaptation Plan Indicator: Adaptation Plan Sub-Indicator: Ecosystem Excel Row: 19
<u>Basis of Scoring</u> Score of 0-1 0 = "No"; 1 = "Yes"	<u>Where to find the data</u> The country's adaptation plan

Layer 1: Metric 19 "Does the adaptation plan intend to consider nature-based solutions?"	
<u>Rationale for the Selection of the Metric</u> Nature-based solutions are a method to protect and sustainably manage natural or modified ecosystems while also addressing societal challenges. This allows the country to increase overall resilience from both a human and environmental perspective.	<u>Location in the Index</u> Group: Adaptation Plan Indicator: Adaptation Plan Sub-Indicator: Nature-based Solution Excel Row: 20
<u>Basis of Scoring</u> Score of 0-1 0 = "No"; 1 = "Yes"	<u>Where to find the data</u> The country's adaptation plan

Layer 1: Metric 20 "Does the adaptation plan intend to implement solutions that address distributive, procedural, or social justice?"	
<u>Rationale for the Selection of the Metric</u> According to the <u>United Nations</u>, distributive or social inequalities make communities or populations more vulnerable to climate change impacts, as their ability to adapt is inhibited by systemic barriers. Addressing these inequalities makes a country more resilient in the long term.	<u>Location in the Index</u> Group: Adaptation Plan Indicator: Adaptation Plan Sub-Indicator: Environmental Justice Excel Row: 21
<u>Basis of Scoring</u> Score of 0-1 0 = "No"; 1 = "Yes"	<u>Where to find the data</u> The country's adaptation plan

<table>
<tr><th colspan="2">Layer 1: Metric 21 “Does the adaptation plan intend to protect cultural heritage from the impacts of climate-related risks by developing adaptive strategies for preserving cultural practices and heritage sites and by designing climate-resilient infrastructure?”</th></tr>
<tr><td><u>Rationale for the Selection of the Metric</u>

Cultural heritage is important for the community pride and mental health of a nation. Preserving these sites can help to maintain the country's pride and community resilience.</td><td><u>Location in the Index</u>

Group: Adaptation Plan
Indicator: Adaptation Plan
Sub-Indicator: Cultural Heritage
Excel Row: 22</td></tr>
<tr><td><u>Basis of Scoring</u>
Score of 0-1
0 = “No”; 1 = “Yes”</td><td><u>Where to find the data</u>
The country’s adaptation plan</td></tr>
</table>

Appendix 2b: Layer 2 "Adaptative Capacity" Indicators

Layer 2: Metric 22 "What proportion of terrestrial biomes is protected/restricted from natural resources extraction?"	
Rationale for the Selection of the Metric If the country has already taken measures to protect the integrity of their connected, integral ecosystems and natural resources, they have better ecological health and more natural ecosystem services to build upon.	Location in the Index Group: Environmental Quality and Management Indicator: Ecosystem health and conservation Sub-Indicator: Protection of Terrestrial Biomes Excel Row: 23
Basis of Scoring Data Source Format: 0-100, 100 is the best The score is transformed to the index by dividing the score by 100 to get a value between 0-1, 1 being the best score.	Where to find the data **EPI Yale Index | Terrestrial biome protection (global weights)** Last Updated: 2024 Updated every two years About the Data Source The EPI Yale Index evaluates the state of sustainability around the world. The Terrestrial Biome Protection Indicator (global weights) is a weighed percentage of the proportion of each biome in a country that lies within a protected area. A score of 100 indicates that the country protects at least 17% of each type of biome within the country.

<table>
<tr><th colspan="2">Layer 2: Metric 23 “Impartial regulation, publication requirement, published methodology, post-project audits, mechanisms to ensure influence”</th></tr>
<tr><td><u>Rationale for the Selection of the Metric</u>

Strong environmental assessments enable the mitigation and management of environmental impacts from projects by identifying the potential impacts. Without the assessments, projects would negatively impact the integrity of the country’s ecosystems without stakeholders’ knowledge.</td><td><u>Location in the Index</u>

Group: Built environment
Indicator: Buildings
Sub-Indicator: Environmentally Sustainable and climate-resilient Infrastructure
Excel Row: 25</td></tr>
<tr><td rowspan="2"><u>Basis of Scoring</u>

Data Source Format: 0-100, 100 is the best

The score is transformed to the index by dividing the score by 100 to get a value between 0-1, 1 being the best score.</td><td><u>Where to find the data</u>

<u>Infrastructure for Good | 5.1.2 Environmental Impact Assessment</u>

Last Updated: 2023</td></tr>
<tr><td><u>About the Data Source</u>

Infrastructure for Good evaluates the ability of the country to deliver quality, sustainable infrastructure. This indicator evaluates whether the country’s environmental assessments are effective and transparent.</td></tr>
</table>

Layer 2: Metric 24 "Enabling conditions; planning; project prioritization and appraisal; green capital budgeting and infrastructure financing; monitoring environmental and climate impact throughout life cycle"	
Rationale for the Selection of the Metric The governance and financing of infrastructure, including buildings, is essential to understanding the capacity of governments to implement the infrastructure necessary to adapt to the impacts of climate change.	Location in the Index Group: Built environment Indicator: Buildings Sub-Indicator: Environmentally Sustainable and climate-resilient Infrastructure Excel Row: 25
Basis of Scoring Data Source Format: 0-100, 100 is the best The score is transformed to the index by dividing the score by 100 to get a value between 0-1, 1 being the best score.	Where to find the data **OECD Infrastructure Governance Indicators** About the Data Source The OECD Governance Indicators evaluates how well a country enables climate resilient conditions through financing and environmental impact monitoring.

<table>
<tr><th colspan="2">Layer 2: Metric 25 “Energy intensity, energy consumption per capita, CO2 emissions per capita, CO2 intensity of total energy supply, CH4 intensity of energy production, share of clean energy in the final energy consumption”</th></tr>
<tr><td>Rationale for the Selection of the Metric

Energy efficiency, consumption, and associated carbon emissions all determine a) how much energy is being consumed, and b) the impact that energy consumption has on the climate. If a country is more energy efficient or has a lower GHG intensity production of energy, than that country will have a lower carbon footprint and will contribute less to climate change, which will help to mitigate the progression of climate change and its impacts.</td><td>Location in the Index

Group: Built environment
Indicator: Energy
Sub-Indicator: WEF Energy Transition Index - Sustainable Indicator
Excel Row: 26</td></tr>
<tr><td rowspan="2">Basis of Scoring

Data Source Format: 0-100, 100 is the best

The score is transformed to the index by dividing the score by 100 to get a value between 0-1, 1 being the best score.</td><td>Where to find the data

World Economic Forum Energy Transition Index (Sustainable)

Last Updated: 2024
Updated annually</td></tr>
<tr><td>About the Data Source

The Energy Transition Index evaluates a country’s performance and “readiness” to enable a transition to a sustainable and secure future. The indicator explores assesses measures that reduce GHG intensity in energy supply, the proportion of clean energy, and energy efficiency.</td></tr>
</table>

Layer 2: Metric 26 "Diversification of import counterparts, diversity of total energy supply, net energy imports, diversity of electricity supply, flexibility in electricity system, gas supply resilience, system average interruption duration and frequency, electric power T&D losses"	
<u>Rationale for the Selection of the Metric</u> A secure supply of energy is essential for a country to function properly.	<u>Location in the Index</u> Group: Built environment Indicator: Energy Sub-Indicator: WEF Energy Transition Index - Secure Indicator Excel Row: 27
<u>Basis of Scoring</u> Data Source Format: 0-100, 100 is the best The score is transformed to the index by dividing the score by 100 to get a value between 0-1, 1 being the best score.	<u>Where to find the data</u> **World Economic Forum Energy Transition Index** **(Sustainable)** Last Updated: 2024 Updated annually
	<u>About the Data Source</u> The Energy Transition Index evaluates a country's performance and "readiness" to enable a transition to a sustainable and secure future. The indicator explores how secure energy supply is through the supply mix, energy trade partners, and more.

<table>
<tr><th colspan="2">Layer 2: Metric 27 “How easily can people move around the country? How well can supplies move around the country? Etc."</th></tr>
<tr><td><u>Rationale for the Selection of the Metric</u>

Mobility plays a critical role in resilience and adaptation by strengthening community connections and enabling evacuation during climate-related emergencies. Investing in transportation infrastructure is essential to support mobility and promote economic wellbeing.</td><td><u>Location in the Index</u>

Group: Built environment
Indicator: Transport
Sub-Indicator: Network Connectivity
Excel Row: 28</td></tr>
<tr><td rowspan="2"><u>Basis of Scoring</u>

Data Source Format: 0-100, 100 is the best

The score is transformed to the index by dividing the score by 100 to get a value between 0-1, 1 being the best score.</td><td><u>Where to find the data</u>

World Bank | Transport investment per capita

Last Updated: 2023</td></tr>
<tr><td><u>About the Data Source</u>

The dataset analyzes investment in infrastructure.</td></tr>
</table>

Layer 2: Metric 28 "Access to social infrastructure, access to electricity and clean energy, and access to water and sanitation services"	
Rationale for the Selection of the Metric As access to public infrastructure and utilities improve, quality of life improves, and residents become less vulnerable to external stressors. Countries with a better social infrastructure, access to energy, and access to water and sanitation services are less vulnerable and more resilient to extreme events.	Location in the Index Group: Public Services Indicator: Access to public infrastructure and utilities Sub-Indicator: Access to public infrastructure and utilities Excel Row: 29
Basis of Scoring Data Source Format: 0-100, 100 is the best The score is transformed to the index by dividing the score by 100 to get a value between 0-1, 1 being the best score.	Where to find the data Infrastructure for Good | 3.4 Last Updated: 2023
	About the Data Source Infrastructure for Good evaluates the ability of the country to deliver quality, sustainable infrastructure. The indicator evaluates how much access citizens have to social infrastructure, energy, and sanitation services.

Layer 2: Metric 29 "What is the country's capacity to prepare for pandemics and epidemics?"	
<u>Rationale for the Selection of the Metric</u> Human health will be impacted by climate change in a variety of ways, from extreme event mortalities to chronic health morbidities. Increasing temperatures have been linked to the rise in infectious diseases–especially from mosquito vectors–and a country's health system's ability to address these diseases is a strong proxy of the robustness of its health system.	<u>Location in the Index</u> Group: Public Services Indicator: Health Sub-Indicator: Health Excel Row: 30
<u>Basis of Scoring</u> Data Source Format: 0-100, 100 is the best The score is used in the index as is.	<u>Where to find the data</u> **Global Health Security Index** Last Updated: 2021 <u>About the Data Source</u> The GHS Index is the first comprehensive assessment and benchmarking of health security across 195 countries that make up the States Parties to the International Health Regulations. The GHS Index addresses the capacities of countries to prepare for epidemics and pandemics.

<table>
<tr><th colspan="2">Layer 2: Metric 30 “Access to and the use of ICT infrastructure: mobile phone subscription per 100 persons, fixed phone subscription per 100 persons, fixed broad-band subscription per 100 persons, and percent of individuals using the internet.”</th></tr>
<tr><td><u>Rationale for the Selection of the Metric</u>

ICT infrastructure enables education, hazard warning notification, and can strengthen communication and therefore the ability to manage extreme events.</td><td><u>Location in the Index</u>

Group: Communications Infrastructure
Indicator: ICT
Sub-Indicator: Information Communication Technology (ICT) Infrastructure
Excel Row: 31</td></tr>
<tr><td rowspan="2"><u>Basis of Scoring</u>

Data Source Format: 0-1, 1 is the best

The score is used in the index as is.</td><td><u>Where to find the data</u>

<u>ND-GAIN</u>

Last Updated: 2024</td></tr>
<tr><td><u>About the Data Source</u>

The ND-GAIN Country Index explores a country’s vulnerability to climate change and its ability to increase its resilience. The ICT indicator evaluates the proportion of citizens with access to ICT infrastructure, such as broad band.</td></tr>
</table>

Layer 2: Metric 31 "Does a catastrophe or hazard insurance market exist?"	
Rationale for the Selection of the Metric Hazard insurance allows residents and companies to more quickly financially recover from extreme weather events, therefore increasing the long-term resiliency of a country.	Location in the Index Group: Disaster Risk Reduction Indicator: Insurance Sub-Indicator: Insurance Excel Row: 32
Basis of Scoring Score of 0-1 0 = "No"; 1 = "Yes"	Where to find the data Potential Data Sources: IAIS Members EIOPA If not listed on those sources, you will likely need to independently find another reference to answer this question.

Layer 2: Metric 32 "Are there alternative (such as parametric insurance) insurance models being considered for natural disasters?"	
Rationale for the Selection of the Metric Parametric insurances offers solutions for lapses in insurance coverage to enhance overall financial resilience of the residents after extreme weather events or other climate impacts.	Location in the Index Group: Disaster Risk Reduction Indicator: Insurance Sub-Indicator: Insurance Excel Row: 33
Basis of Scoring Score of 0-1 0 = "No"; 1 = "Yes"	Where to find the data Independent Online Research

Layer 2: Metric 33 "How prepared is the country to reduce the risk of natural disasters?"	
Rationale for the Selection of the Metric Countries that are better prepared for disasters are more resilient in the long term. The Sendai Framework outlines best practices in this area.	Location in the Index Group: Disaster Risk Reduction Indicator: Adherence to Sendai/Hyogo Frameworks Sub-Indicator: Adherence to Sendai/Hyogo Frameworks Excel Row: 34
Basis of Scoring Data source format: score of 0-1, 1 = most prepared This score is included in the index as is.	Where to find the data **Infrastructure for Good | 5.4.2b Disaster Preparedness** Last Updated: 2023
	About the Data Source Infrastructure for Good evaluates the ability of the country to deliver quality, sustainable infrastructure. The indicator measures how prepared a country is to reduce the risk natural disasters according to the country's adherence to the Sendai Framework for Disaster Risk Reduction.

<table>
<tr><th colspan="2">Layer 2: Metric 34 “What is the country's estimated infrastructure gap?</th></tr>
<tr><td><u>Rationale for the Selection of the Metric</u>

Infrastructure is an integral aspect of resilience; better infrastructure will be more resilient to extreme weather events or other external issues caused by climate change. If a country has a large infrastructure gap, they are not investing enough in infrastructure and likely have some infrastructural weaknesses.</td><td><u>Location in the Index</u>

Group: Finance and Investment
Indicator: Infrastructure Gap
Sub-Indicator: Infrastructure Gap
Excel Row: 35</td></tr>
<tr><td rowspan="2"><u>Basis of Scoring</u>

Data source format: percentage, 100% = best

The score is transformed to the index by diving by 100 to convert the percent to a score between 0-1, 1 being the best.</td><td><u>Where to find the data</u>

<u>Infrastructure for Good | 2.1.1 Infrastructure Gap</u>

Last Updated: 2023</td></tr>
<tr><td><u>About the Data Source</u>

Infrastructure for Good evaluates the ability of the country to deliver quality, sustainable infrastructure. Infrastructure gap is measured as the difference between infrastructure needs and investment as a percentage of GDP.</td></tr>
</table>

<table>
<tr><td colspan="2">Layer 2: Metric 35 “Sum of the percent of project financed using sustainably-linked bonds or loans and percent of projects financed using green bonds or loans”</td></tr>
<tr><td><u>Rationale for the Selection of the Metric</u>

Sustainability-linked or green finance connects financing conditions with the project’s social or sustainability outcomes. These types of measures incentivize sustainable projects, leading to greater resilience.</td><td><u>Location in the Index</u>

Group: Finance and Investment
Indicator: Financing for Social Good
Sub-Indicator: Financing for Social Good
Excel Row: 36</td></tr>
<tr><td rowspan="2"><u>Basis of Scoring</u>

Data Source Format: 0-100, 100 is the best

The score is transformed to the index by dividing the score by 100 to get a value between 0-1, 1 being the best score.</td><td><u>Where to find the data</u>

<u>Infrastructure for Good | 2.2 Financing for Social Good</u>

Last Updated: 2023</td></tr>
<tr><td><u>About the Data Source</u>

Infrastructure for Good evaluates the ability of the country to deliver quality, sustainable infrastructure. This indicator is a composite score measuring the percent of projects using sustainable or “green” finance.</td></tr>
</table>

<table>
<tr><td colspan="2">Layer 2: Metric 36 “Gross fixed capital formation (formerly gross domestic fixed investment) includes land improvements (fences, ditches, drains, and so on); plant, machinery, and equipment purchases; and the construction of roads, railways, and the like, including schools, offices, hospitals, private residential dwellings, and commercial and industrial buildings.”</td></tr>
<tr><td><u>Rationale for the Selection of the Metric</u>

Gross-fixed capital formation can be directed towards building climate-resilient infrastructure, developing new technologies for adaptation, and investing in natural infrastructure such as reforestation and wetland restoration.</td><td><u>Location in the Index</u>

Group: Finance and Investment
Indicator: Gross Fixed Capital Formation
Sub-Indicator: Gross Fixed Capital Formation
Excel Row: 37</td></tr>
<tr><td rowspan="2"><u>Basis of Scoring</u>

Data source format: percentage, 100% = best

The score is transformed to the index by diving by 100 to convert the percent to a score between 0-1, 1 being the best.</td><td><u>Where to find the data</u>

<u>World Bank | Gross fixed capital formation</u>

Last Updated: 2023
Updated Annually</td></tr>
<tr><td><u>About the Data Source</u>

The dataset evaluates a country’s gross fixed capital formation, or gross additions to national wealth.</td></tr>
</table>

Appendix 2c: Layer 3 "Credibility" Indicators

Layer 3: Metric 37 "Is the country committed to climate action?	
Rationale for the Selection of the Metric This index evaluates whether the country has been historically committed to climate action by assessing their trends in policy, current state of renewables, and GHG emissions trends (among other metrics). By evaluating their progress in these areas, this index can help inform Ortec's Index on whether the country has historically taken measures to address climate change.	Location in the Index Group: Commitment to Environmental Action Indicator: Climate Action Sub-Indicator: Commitment to Climate Action Excel Row: 38
Basis of Scoring Data Source Format: 0-100, 100 is the best The score is transformed to the index by dividing the score by 100 to get a value between 0-1, 1 being the best score.	Where to find the data The Climate Change Performance Index = Last Updated: 2025 Updated whenever NDCs are submitted, typically every 5 years
	About the Data Source The (CCPI) assesses the climate performance of a country through the evaluation of four categories: GHG Emissions, Renewable Energy, Energy Use and Climate Policy.

<table>
<tr><th colspan="2">Layer 3: Metric 38 “Perceived perceptions of the government's ability to implement policy”</th></tr>
<tr><td>Rationale for the Selection of the Metric
By analyzing whether the government is able to provide quality public services and the perceptions of whether the government is credible, this indicator helps us understand whether the government can be trusted to implement policies to achieve its climate goals.</td><td>Location in the Index
Group: Governance and Regulation
Indicator: Government Effectiveness
Sub-Indicator: Government Effectiveness
Excel Row: 39</td></tr>
<tr><td rowspan="2">Basis of Scoring

Data source format: Percentage 0-100% , 100% = best

The score is transformed to the index by diving by 100 to convert the percent to a score between 0-1, 1 being the best.</td><td>Where to find the data

World Bank | Government Effectiveness

Last Updated: 2024
Updated annually</td></tr>
<tr><td>About the Data Source

The World Bank’s Government Effectiveness indicator captures perceptions of public services, policy formation, and the government’s commitment to policies.</td></tr>
</table>

Layer 3: Metric 39 "Perceived perception of the government's ability to formulate and implement sound policies and regulations that permit and promote private sector development."	
Rationale for the Selection of the Metric This indicator assesses whether a government and country enforce a favorable regulatory environment for private sector development. Adaptation and resilience measures require significant investment. If the private sector is inhibited from developing and investing in the infrastructure and initiatives necessary to adapt to climate in a timely manner, then the country will be more vulnerable.	Location in the Index Group: Governance and Regulation Indicator: Government Effectiveness Sub-Indicator: Regulatory Quality Excel Row: 40
Basis of Scoring Data source format: percentage 0-100% , 100% = best The score is transformed to the index by diving by 100 to convert the percent to a score between 0-1, 1 being the best.	Where to find the data **World Bank | Regulatory Quality** Last Updated: 2024 Updated Annually
	About the Data Source The dataset represents perceptions of the country's ability to create and implement policies that promote private sector development.

Layer 3: Metric 40 “Is the government collaborating across sectors and agencies to approach climate issues?”	
<u>Rationale for the Selection of the Metric</u> The consequences of climate change will affect virtually every sector and every aspect of public life. As such, inter-agency collaboration is necessary to determine whether a government is equipped to deal with the combined consequences and threats of climate change. For example, an extreme weather event can have consequences for public health, infrastructure, transportation, and more.	<u>Location in the Index</u> Group: Governance and Regulation Indicator: Government Effectiveness Sub-Indicator: Interdisciplinary collaboration Excel Row: 41
<u>Basis of Scoring</u> Score of 0-1 0 = “No”; 1 = “Yes”	<u>Where to find the data</u> Online research. This metric is qualitatively assessed by the individual assessor. To determine whether this question should be answered in the affirmative or not, consider a) whether the country has an inter-agency body or group committed to climate issues, or b) if there are news reports of this type of collaboration. If either is answered affirmatively, then this question can be given a “Yes”.

<table>
<tr><th colspan="2">Layer 3: Metric 41 “How much of the population is living below societal poverty line?”</th></tr>
<tr><td>Rationale for the Selection of the Metric

People living below the poverty line are more vulnerable to climate change, as they do not have the financial resources needed to move, or possibly, adapt to new ecological conditions. Therefore, countries with a higher percentage of people living below the poverty line are therefore more vulnerable as a whole and are less likely to have the ability to properly finance, or implement, climate adaptation measures.</td><td>Location in the Index

Group: Financial Capacity
Indicator: Economy
Sub-Indicator: Economic Inequality
Excel Row: 42</td></tr>
<tr><td rowspan="2">Basis of Scoring
Data source format: percentage 0-100% , 100% = best

The score is transformed to the index by diving by 100 to convert the percent to a score between 0-1, 1 being the best.</td><td>Where to find the data

World Bank | Poverty headcount ratio at societal poverty line (% of population)

Last Updated: Depends on the country

Updated Annually</td></tr>
<tr><td>About the Data Source
The dataset estimates the percent of the population at national poverty lines.</td></tr>
</table>

<table>
<tr><th colspan="2">Layer 3: Metric 42 “How diversified and robust is the economy?”</th></tr>
<tr><td><u>Rationale for the Selection of the Metric</u>

This metric measures economic diversity. If a country is more diversified, it is more likely able to withstand shocks to the economy from negative climatic effects, and therefore will be more resilient and better able to finance resilience policies in the future.</td><td><u>Location in the Index</u>

Group: Financial Capacity
Indicator: Economy
Sub-Indicator: Economic Diversity
Excel Row: 43</td></tr>
<tr><td rowspan="2"><u>Basis of Scoring</u>
Scores of 0-1
0 = least diversified; 1 = most diversified

The score is used in the index as is.</td><td><u>Where to find the data</u>

World Integrated Trade Solution Hirschman Herfindahl Index.

Last Updated: 2022
Updated Annually</td></tr>
<tr><td><u>About the Data Source</u>
Hirschman Herfindahl Index measures how diversified the country’s trade is. A country with trade (export or import) concentrated in very few markets will have an index value close to 1. Similarly, a country with a perfectly diversified trade portfolio will have an index close to zero.</td></tr>
</table>

<table>
<tr><th colspan="2">Layer 3: Metric 43 “Is the financial market healthy?</th></tr>
<tr><td><u>Rationale for the Selection of the Metric</u>

The financial market health of the country impacts the country’s ability to invest in adaptation measures.</td><td><u>Location in the Index</u>

Group: Financial Capacity
Indicator: Financial Market Depth and Health
Sub-Indicator: Financial Market Depth and Health
Excel Row: 44</td></tr>
<tr><td rowspan="2"><u>Basis of Scoring</u>
Data Source Format: 0-100, 100 is the best

The score is transformed to the index by dividing the score by 100 to get a value between 0-1, 1 being the best score.</td><td><u>Where to find the data</u>

Infrastructure for Good | 2.1.3 Financial Market Depth and Health

Last Updated: 2023</td></tr>
<tr><td><u>About the Data Source</u>
Infrastructure for Good evaluates the ability of the country to deliver quality, sustainable infrastructure. This indicator evaluates market health by measuring the average cost of capital, marketable debt risk, and health of local banks.</td></tr>
</table>

Appendix 3: Regional/local index methodology

The regional/local index builds upon the country index by adding more sub-indicators and adjusting metrics to evaluate at a lower level of government. There are some key differences to note:

- The regional/local index includes several metrics that trigger the inclusion of other metrics. For example, the "Relevance" sub-indicator under Layer 1: Adaptation Planning asks whether "the (adaptation plan/planning) is less than five years old". The data entered for that metric will trigger different metrics under the "Monitoring and Evaluation" sub-indicator: "if the plan is older than five years" or "if the plan has been published within the last five years"—only one of these two metrics will be relevant within the overall index. Coding within the Excel spreadsheet ensured index calculation accounted for the total number of relevant metrics under evaluation.
- Each metric is categorized as either "measure" or "depth". Measure metrics evaluate whether or not an action has been taken, or if an adaptation initiative exists. Depth metrics evaluate the extent to which an action has been taken or the degree to which a sector is being affected. For example, a "measure" metric asks whether or not the government disclosed how much it plans to spend on climate adaptation measures. The "depth" metric follow-up would ask "if the government discloses, how much?".
- A "Hazard Adaptation" group is included under Layer 2: Adaptive Capacity. This section addresses the region's top two natural hazard categories (or top two natural hazards) and will change depending on the region. Within this group, sub-indicators areas of evaluation for each natural hazard include risk assessment, capital projects, nature-based solutions, and management programs.

The default regional/local index contains 94 total metrics for evaluation. Layer 1 Adaptation Planning includes groups for published literature (10 metrics), climate finance (3 metrics), and adaptation plan (21 metrics). Layer 2 Adaptive Capacity includes groups for disaster preparedness (14 metrics), hazard adaptation (16 metrics, or 8 metrics per hazard), society (3 metrics), critical infrastructure (13 metrics), environment (3 metric), and economics and finance (3 metrics). Layer 3 Implementation Credibility includes groups for implementation of adaptation plan (3 metrics), climate action (1 metric), governance and regulation (3 metrics), and financial capacity (1 metric).

Like the country index, the regional/local index may be modified for bespoke analysis. Index users may refine or add metrics to more accurately assess adaptation for a specific region. This may be particularly important, as adaptation on a regional scale may vary due to unique governance structures, social demographics, and environmental characteristics.

Appendix 4: Review of deliverables

The team delivers the following materials to Ortec as final deliverables:

- **Final Research Report**: This comprehensive document presents the complete methodology and findings for the Climate Adaptation Index, detailing the research framework, indicator selection process, and scoring methodology. The report also discusses the main countries' results and insights derived from results. It serves as the primary reference, explaining the index's theoretical foundations while addressing limitations and improvement opportunities.
- **National Adaptation Index**
- **Regional/local Adaptation Index**
- **Indicator Handbook**: This is a practical guide detailing all metrics in the index framework, including selection rationale, measurement approaches, data sources, and scoring. It enables Ortec to modify the framework in the future application.
- **Coding Documents Folder:** This folder contains all code and data files needed to reproduce and update the index, including a Python script, raw data spreadsheet, and an output file. The well-documented data cleaning procedure allows for replicating analysis and expanding to new countries.
- **Source Documents Folder**: This folder collects all reference materials that the team investigated, including adaptation plans, academic literature, and policy documents.
- **MP Symposium Presentation Slide Deck:** This is the slide deck the team presented at Duke Nicholas School 2025 Spring Master Project Symposium.

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