Bridging the global stocktake gap of climate mitigation: Measuring political economy progress

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SUMMARY

The first Global Stocktake (GST), which serves as an important regular review process of the Paris Agreement, will take place in 2023. Yet important gaps need to be filled to advance collective mitigation ambition and action through the GST. Existing techno-economic information, which is broadly available, lays a concrete foundation for the GST. However, it does not sufficiently address political economy progress, which are critical for realizing transformative change and will determine how much additional gains can be made by the Parties. This paper sheds light on this important gap by providing an indicator framework for political economy progress. We identified 16 key indicators in five political economy dimensions and evaluated their measurability based on reviewed data sources. The goal of this paper is to highlight the potential for developing a more inclusive global stocktake. To that end, we outline an agenda for future research to better characterize climate mitigation progress and challenges.

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INTRODUCTION

The Global Stocktake (GST) is an integral part of the transparency framework of the Paris Agreement. It serves as a periodic review process on a five-year basis for the implementation of the Paris Agreement and for assessing the collective progress made by Parties and other non-Party actors. As one of the outcomes of COP24 at Katowice, Poland in 2018, Parties agrees that the GST shall cover three thematic areas: mitigation, adaptation, and means of implementation and support. Specifically, the first GST process, which spans from 2021 to 2023, consists of three key components: (1) Information collection and preparation, which is intended to gather, compile and synthesize information; (2) Technical assessment, which focuses on taking stock of the implementation of the Paris Agreement and assessing the collective progress based on the information collected; (3) Consideration of outputs, which aims to discuss the implications of the findings to inform Parties for enhancing future actions.

Information is therefore the foundation of the GST. The decisions of COP24 have listed the types and sources of information that should be used for the first GST. Specifically the information related to mitigation includes the state of greenhouse gas emissions, the mitigation efforts, the effect and the overall progress of the nationally determined contributions, good practices, experience and opportunities to enhance international cooperation [1]. However, important gaps remain to ensure an inclusive and robust GST despite that the formal technical assessment intend to incorporate more comprehensive and holistic information through three technical dialogues (TD), which convene Parties, experts and non-Party actors[2].Techno-economic information—such as for energy use and supply, economic costs and technical parameters—is broadly available for the GST, and for analyses of climate change mitigation progress in general. The UNFCCC, national governments, other international bodies like the International Energy Agency (IEA), and a number of independent organizations (e.g., Climate Action Tracker[3]) track this information and make it

widely available. These techno-economic indicators provide a robust basis for physical and economic assessment, laying a foundation for the GST by gauging the progress (or lack thereof) made by countries and other relevant actors.

However, these techno-economic indicators do not fully characterize the enabling societal and institutional conditions that will determine how much additional progress can be made. The Talanoa Dialogue of UNFCCC in 2018 proposed three fundamental questions for global and national climate actions: (1) Where are we? (2) Where do we want to go? (3) How do we get there? While these questions draw on scientific or technical considerations, fully answering them also depends on understanding the political and socio-economic factors that may facilitate or hinder the transition towards the global warming goals[4,5]. Yet the modeling and analysis of future pathways are used to answer the questions of "where do we want to go" and "how do we get there" is based on simplified modeling frameworks—valuable for their own purpose but limited in their ability to elucidate broader social or political issues.

The GST may be hindered if it is solely focused on aggregated techno-economic information[6], which often leads to partial conclusions about mitigation progress and may constrain our ability to identify future mitigation strategies. An inclusive stocktake of a broader set of indicators is needed to enhance ambition and action in diverse national and regional contexts, among other relevant organizational settings. The Intergovernmental Panel on Climate Change (IPCC) assessments have attempted to capture a broad picture of the national and subnational policies and institutions that bolster carbon emissions reduction[7,8]. Yet, the assessment reports only provide high level summaries of the attention needed on those societal elements. Information on mitigation progress beyond techno-economic data is still under-represented in GST conversations and is lack of systematic approach to track the progress.

In this paper, we first underscore the critical importance of incorporating political economy dimensions into the GST process and conversations. Secondly, we elaborate a set of such political economy dimensions and underlying indicators, introducing each by answering the following questions: (1) What sorts of issues or dynamics does the dimension represent?

(2) What are relevant indicators? (3) Why and how do these indicators link to progress? (4) How, and how well, can we measure the indicators? Thirdly, we evaluate the data availability of the indicators based on the data sources we have reviewed. We then provide a simplified illustrative example of the political economy assessments for the United States, China and India to show how the framework and indicators we proposed could potentially be applied. Finally, we present a discussion on limitations and the future application of the political economy dimensions we proposed in this paper (Figure1).

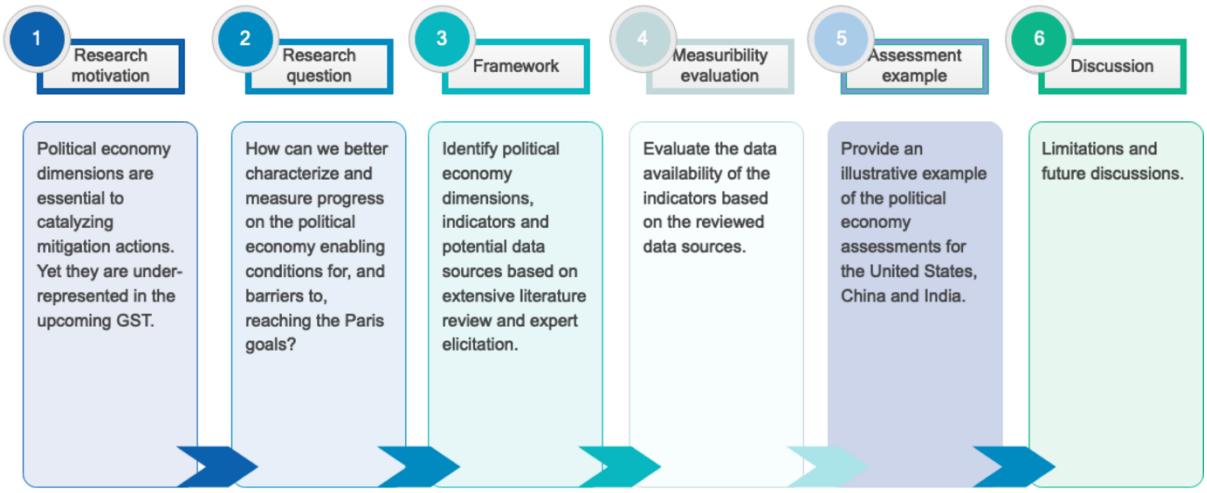

Figure 1. Research roadmap for incorporating political economy dimensions into the global stocktake.

THE NEED FOR INCORPORATING POLITICAL ECONOMY DIMENSIONS INTO THE GLOBAL STOCKTAKE

The transition to carbon neutrality requires systemic changes involving a wide range of actors[9], which inevitably create both winners and losers as well as costs and benefits[10]. Gaps between the Paris goals and current national policies will remain unless we can elucidate pathways to speed up implementation and increase ambition[11,12]. Therefore, political economy factors are critical determinants[13-15] that co-evolve with the techno-economic factors, jointly reflecting the pace and quality of climate mitigation efforts[16]. For example, political interests, such as interested industrial coalitions, can shape energy policies, such as renewable energy subsidies, which in turn influence the adoption of associated technologies and determine the extent to which capacity for such renewable energy sources can be

installed. On the other hand, the energy resource endowments of a country can significantly impact the political influence of various energy interest groups as well as the national climate ambition. Countries with abundant fossil fuel resources often experience stronger influence from the fossil fuel industry, which can create barriers to adopting more ambitious climate targets. In addition, individual support or opposition to specific energy sources can also impact the deployment of specific energy technologies. For instance, nuclear power has faced opposition from the general public in many countries.

Therefore, we need to address the political economy dimensions in order to answer the GST core questions: namely, are we doing enough—and given that we already know the answer to that will be "no", how can we do enough to keep 1.5 °C of warming within reach? Such indicators will then be a key to explaining why countries may have made progress or, conversely, why progress may have stalled.

Despite the critical importance of political economy factors, there has been little formal measurement because of their complexity and data limitations. Information on the political economy aspects of mitigation is therefore not as available or amenable for inclusion in the GST (compared to more-easily captured sociotechnical information). Additionally, this information is also more difficult to incorporate into processes associated with ambition-setting and developing action agendas. This lack of political economy information limits our ability to identify answers to the question of "how do we get there?". The question that motivates this paper is: How can we better characterize and measure progress on the political economy factors that enable or obstruct progress towards the Paris goals? In this paper, we identify 16 indicators associated with five political economy dimensions – national ambition; institutional arrangements; stakeholders and interests; policy effectiveness; and public opinion – that influence the ability to meet the Paris goals. We then discuss the current understanding of how to measure progress on each of these dimensions. We list potential data sources and existing literature (not limited to climate change research) that are useful for quantifying these indicators. Potential data sources include existing datasets (if any) and potential strategies to collect additional relevant information including social media, surveys,

documents (e.g. policy/government documents, newspaper/media articles, research articles) and qualitative interviews.

It is important to note that there is large heterogeneity among countries in terms of their political, socioeconomic and biophysical attributes and historical legacies of carbon emissions. Therefore, these political economy dimensions and indicators are not intended to be compared across countries. Instead, they should be used as benchmarks of countries' progresses relative to their avowed goals and responsibilities.

CHARACTERIZING THE POLITICAL ECONOMY DIMENSIONS OF MITIGATION PROGRESS

Any assessment of the political economy factors driving climate mitigation must wrestle first with the issue of what should and should not be included under the heading of "political economy". There are many factors that might be characterized as political economy factors and that influence a country's ability to reduce emissions, including rules and norms, stakeholders, and political systems [9,17-19]. The challenge for stocktaking is to navigate this complexity and identify a set of key indicators that relate to political economy and the ways to overcome associated barriers to progress.

There are many political and socioeconomic factors that shape a country's political economy, such as regime type, economic structure, and the level of development. These factors play a critical role in structuring climate mitigation strategies and vary across different countries. For example, democratic and authoritarian regimes have different strengths and weaknesses when it comes to climate action. Democratic regimes may be more politically decentralized and allow for diverse stakeholder engagement, but may face challenges in reconciling conflicting interests. Authoritarian regimes may be more efficient in implementing state-led actions, but may encounter difficulties in reversing anti-climate policies. However, these factors reflect the contexts in which a country's climate actions are embedded, rather than determinants of the country's political economy performance.

Therefore, we focus on indicators that are able to refract those contextual antecedents, and at the same time demonstrate progress over shorter periods of time[20].

Recognizing the importance of broad issues of definition and scope, we simplify an admittedly complex problem and literature in order to create a tractable approach. We do this by focusing on five dimensions that are particularly relevant for understanding political economy progress towards mitigation goals: national ambition; institutional arrangements; stakeholders and interests; policy effectiveness, and public opinion. These factors were chosen based on an extensive literature review and expert opinions, in which the inputs of 15 experts were collected in a roundtable organized by the authors in April 2021 (please see Method Clarification section for greater details).

We discuss the challenges and possibilities for the measurement of each of these five dimensions, and we propose potential indicators of progress for each. The five dimensions and the associated indicators are constructed with a practical rather than theoretical purpose: they are intended to provide information that the independent community of researchers and other civil society actors might use to better understand and document progress (Table 1).

Table 1. A political economy framework for assessing progress towards the Paris Agreement goals.

Dimension	Question Explored	Indicators of Progress
National ambition	Has this country offered strong goals and actions to combat climate change?	• Existing climate pledges • National commitments by heads of state or government
Institutional arrangements	Does this country have functioning institutions to support ambitious climate actions?	• Scales and scope of climate institutions • Robustness of climate institutions • Prevalence of institutional veto points
Stakeholders and interests	Has this country managed to coordinate stakeholders to reach a consensus on climate targets and actions?	• Stakeholder inclusiveness • Support from political elites • The political influence of interested coalitions • Number of co-benefits partnerships

Policy effectiveness	Has this country adopted and implemented effective policies to fulfill climate commitments and facilitate more ambitious actions?	• Effectiveness of policy adoption • Effectiveness of policy implementation • Policy coherence • Track record on previous climate commitments
Public opinion	How does the public perceive climate change and the potential strategies to address it?	• Climate awareness • Public support for climate actions • Heterogeneity in perception and specific interests

The framework highlights five dimensions by which progress might be assessed, the core question about progress that the dimension addresses, and possible indicators of progress along that dimension. Given the exploratory nature of this study, the scope of the indicators is intentionally kept broader than specific measurements. This approach is in line with similar research in the field, where indicators do not necessarily include measurement units[21].

However, we do not propose a generic "climate political economy" index. Rather, we recognize that there are complex interactions between the dimensions and indicators proposed, and that climate-related outcomes are often dependent on these causal chains. As illustrated in Figure 2, these dimensions follow a general causal relationship, and in many cases, overlap and combine in nonlinear ways to support national ambition. There may be ways to integrate these causal interactions into future assessment practices. For instance, assigning different weights to different dimensions or indicators can reflect their causal relationships. However, there is still much work needed to fully understand and clarify the linkages between all of the indicators. This is an area that requires further exploration and discussion.

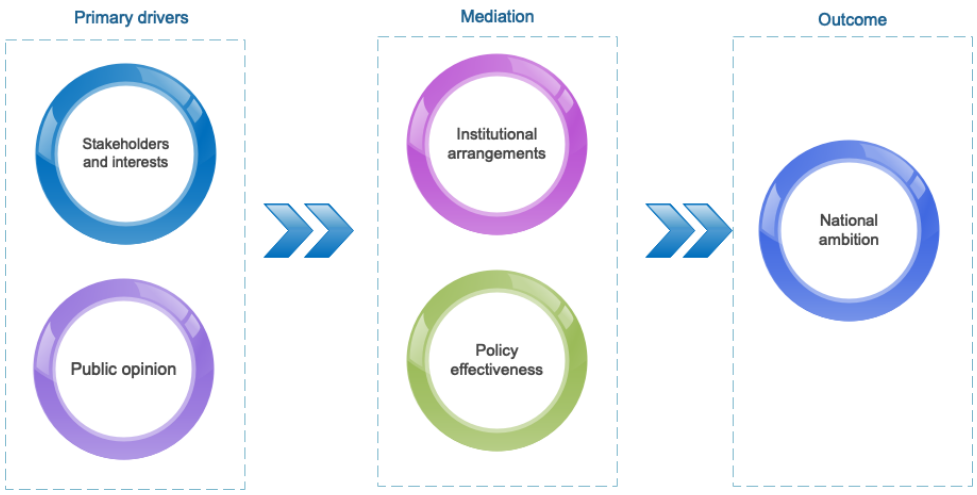

Figure 2. Directional relationship among the political economy dimensions. "Stakeholders and interests" and "public opinions" are the primary drivers of mitigation actions, and are mediated by "institutional arrangements" and "policy effectiveness". The level of national ambition towards the Paris goals results from this process.

Dimension 1: National ambition

National ambition explores how strongly a country has demonstrated its climate commitments. An ambitious stance establishes political foundations and leadership[22]. It also indicates the likelihood that a country (at least at the national level) will proactively engage in climate actions. Numerous studies have shown that current national policies and commitments fall well short of meeting the Paris warming goal, highlighting the need for national governments to increase their climate ambitions[11]. Indicators for this dimension include existing climate pledges of a country (e.g., NDCs, LTSs, net-zero pledges, and pledges from subnational and non-state actors within the country) and commitments that are publicly announced by the heads of state or government.

Table 2. Indicators and potential data sources for the national ambition dimension

Indicator	Linkage to the progress	Potential data sources	Literature
Existing climate pledges	The higher ambition current pledges demonstrate, the larger probability to act on climate change	○ *Climate Action Tracker*[3] ○ *Net Zero Tracker*[23] ○ *The CDP open data portal*[24] ○ *Non-State Actor Zone for Climate Action (NAZCA) database*[25] ○ *Climate Change Laws of the World*[26] ○ Text data sources (e.g. NDCs and LTSs from UNFCCC, research articles)	Giorgio et al. (2015)[27]; Höhne et al.(2018)[28], Hsu et al. (2016)[29]
National commitments by heads of state or government	The stronger commitments are, the more likely climate issues will be incorporated into the policy agenda.	○ Online and social media sources (e.g. *IISD Earth Negotiations Bulletin*[30]) ○ Text data sources (e.g., newspaper, government and administrative records such as *IISD Earth Negotiations Bulletin*[30])	N/A

Italicization indicates existing databases for the indicators

Existing climate pledges: This indicator examines the latest climate commitments a country has officially proposed. It helps us understand a country's determination to reduce emissions, and it implies forward planning to make progress towards the Paris goals. Relevant information is readily available from NDC and LTS submissions[31], laws, domestic policy documents, and official government announcements. Climate pledges from the subnational actors within a country can be also considered as a measure of national ambition even though it is less direct than the national pledges. However, it can also largely contribute to the mitigation progress of this country. Such data can be found in the *Non-State Actor Zone for Climate Action (NAZCA)* launched by UNFCCC in 2014[32] or the *CDP open data portal*[24]. In addition, the independent community has established several platforms for collecting and assessing pledges that already characterize these aspects, including but not limited to data and assessment platforms such as *Climate Action Tracker*[3]. In addition, the national commitments can be made much stronger if they are backed by laws. For example, 20 countries as of March 2023 have net-zero emission goals formalized in law, indicating stronger national ambition in these countries to tackle climate change. Such data can be collected from *Net Zero Tracker*[23].

National commitments by heads of state or government: This indicator captures commitments by national leaders such as presidents and prime ministers. The commitments complement formal climate pledges and can be a substitute when formal pledges are not available. These commitments demonstrate that climate change is an integral part of the country's political/policy agenda and show progress or retrogression in national ambition and leadership on climate change. Additionally, national decision-makers with positive attitudes towards mitigation can push to overcome barriers to progress [17]. Information on commitments of national leaders can be collected from existing platforms and sources including governments, UNFCCC, international institutions, research organizations, media/social media, and other documents.

Dimension 2: Institutional arrangements

Institutional arrangements reflect the readiness of a country's governance system to carry out emissions reductions. In particular, whether a country has well-developed climate institutions is essential to making progress toward global warming goals.

Climate institutions can be defined as rules, norms, routines, and organizational structures intentionally built to influence, as well as those incidentally contributing to, climate outcomes[33]. These institutions include the sets of governance procedures or mechanisms, such as government agencies (e.g. various government ministries), legislative process, legislations and corporate environmental responsibility, that the state and non-state actors can follow to address climate challenges. Climate institutions shape and are shaped by the politics within a country, translate emission targets into real actions by guiding policy design and implementation, and mediate political battles which are often challenges to effective climate actions[34,35]. Strong and well-designed climate institutions can accelerate a country's effort on climate change, while ill-designed institutions could also undermine the effectiveness of climate actions. For example, the relatively weak climate institutions in Australia are a result of a polarized political landscape and have led to erratic and unsustainable national climate policies and actions over the years[35].

The climate institutions of a country are not limited to the ones that were created intentionally for climate change mitigation (e.g., the Department of Climate Change within the Ministry of Ecology and Environment in China). Institutions whose primary objectives are not climate change mitigation, and which were not created for that purpose, but which nonetheless have a role to play in a country's climate change mitigation efforts also need to be taken into account[36]. For example, many government ministries of energy, agriculture and transport (e.g., the U.S. Department of Energy, the Brazil Ministry of Agriculture) can be treated as climate institutions since they have been granted responsibilities for climate change mitigation. The development of climate institutions in the United States, for example, has included adding new responsibilities to existing institutions[37] – a development common to many governments. In general, a good signal of institutional arrangements would be the

inclusion of climate units within key ministries. Based on this definition, we have identified three indicators for this dimension (Table 3).

Table 3. Indicators and potential data sources of the institutional arrangements dimension.

Indicator	Linkage to the progress	Potential data sources	Literature
Scales and scope of climate institutions	Progress is made by establishing national, subnational and non-state climate institutions that cover key sectors	○ *Climate Change Laws of the World*[26] ○ Text data sources (e.g. government records, research articles) ○ Fieldwork-based sources (e.g. small-scale surveys and interviews)	Heikkila and Weible, (2018)[38]; Mewhirter et al. (2018)[39]
Robustness of climate institutions	Progress is made by improving quality and maintaining stability of the climate institutions	○ *Climate Change Laws of the World*[26] ○ *Worldwide Governance Indicators*[40] ○ Text data sources (e.g. research articles, government and administrative records, and newspapers) ○ Fieldwork-based sources (e.g. small-scale surveys and interviews)	Averchenkova and Bassi (2016)[17]; Boin and Lodge (2016)[41]; Hochstetler (2021a)[42]
Prevalence of institutional veto points	The linkage can be either way. More veto points are more likely to create barriers for climate actions, but less likely to overturn adopted climate policies. Progress is made by neutralizing the influence of veto points on climate mitigation	○ *The Political Constraint Index (POLCON)*[43] ○ *CHECKS3 database*[44] ○ *The parliaments and governments database (ParlGov)*[45] ○ Text data sources (e.g. research articles, government and administrative records) ○ Fieldwork-based sources (e.g. small-scale surveys and interviews)	Madden (2014)[46]; Thürk et al. (2021)[47]; Henisz and Zelner (2006)[48]; Beck et al.(2001)[44]

Scales and scope of climate institutions: This indicator measures the extent to which a country's climate institutions cross governance levels (scales) and sectors (scope) (while we use "level" and "scale" interchangeably in this paper, because of the latter has become common terminology in the relevant, we recognize that in other contexts the they may refer to different biophysical and organizational definitions[49]) . Climate change is challenge to the earth system which is interactive and complex. To address the challenge inevitably requires to involve multi-level and multi-sector governance to cover the physical scales and spheres

impacted by, and contributing to, the global temperature rise[50]. Examples of governance levels include national, subnational, sub-state, and non-state. Examples of sectors include energy, building, and transport. The scales and scope of climate institutions can reflect a country's progress in climate change mitigation. There is a growing belief that a single, centralized national strategy or mechanism is necessary yet insufficient for effective climate change mitigation[51,52]. Sub-state and non-state actors, such as local authorities, businesses, and NGOs, can act to directly reduce emissions, and can support or hinder climate actions at all levels through political systems[53,54]. For instance, one study suggests that two-thirds of global greenhouse gas emissions are produced by less than one hundred companies[55]. Political scientists have argued that more decentralized and pluralistic institutions constituted by sub-state and non-state actors are more flexible and politically practicable in forging collective action on climate change[20,52,56]. Therefore, the more scales that climate institutions cross, the greater the impact they will likely have.

In addition, the scope of climate institutions should be expanded to cover key emission sectors and climate change issues. Evidence suggests that the implementation of climate plans is largely operationalized through sectoral actions[57]. The more sectors restructure their institutions based on climate change considerations, the greater actions will be taken in terms of greenhouse gas emissions reduction. For instance, climate actions institutionalized by the forest sector of Brazil have largely facilitated the climate change mitigation agenda of this country[57].

The indicator, given the lack of other relevant measures, could potentially be quantified by identifying and calculating the numbers of climate institutions within a country by different governance levels and sectors. In our analysis, we could find no existing databases that quantify this indicator directly and accurately. The *Climate Change Laws of the World* database [26] can be a data source to collect information on legislation for various sectors at the national level. Data for this indicator could potentially also be collected and coded from government documents and other official reports. Qualitative approaches such as surveys, interviews, and historic documents could also be used. A potentially necessary step for

quantifying this indicator is to narrow down the definition of "climate institutions", since it has been used to cover diverse topics and has diverse meanings in the academic literature.

Robustness of climate institutions: This indicator measures the capacity of domestic climate institutions to recover quickly from shocks such as changes in national political leadership, to be transformative, and to retain flexibility in changing conditions[41,42]. Climate institutions may face various challenges from political and socio-economic disturbances, which threaten their stability and existence. Robustness is crucial to guaranteeing institutional effectiveness, particularly with respect to transboundary crises and long-term challenges such as climate change. The domestic institutions needed to meet the Paris goals should be robust enough to avoid disruptions from anti-decarbonization interest groups and changes in domestic political leadership (e.g. presidential elections) and in the international system (e.g., breakdown of multilateral organizations and treaties, or heightened diplomatic tensions between countries). One relatively effective way to ensure the robustness of climate institution is to have a law that establishes a government agency in charge of coordinating and monitoring climate action. Climate mitigation efforts that solely depend on the executive branches of a country are not robust enough, as ministries or government departments can easily ignore the need for change without legal mandates.

The study of institutional robustness is in its infancy. Few data sources exist in terms of institutional robustness in the face of systemic stresses and shocks such as those of climate change. It is still uncertain whether this indicator is quantifiable. Existing databases on political risks and overall institutional environments could potentially be used to predict the institutional robustness of climate actions. The data from *Climate Change Laws of the World* could help to identify whether laws for more robust institutional arrangements have been enacted. However, they are still indirect to, or insufficient for, this indicator. In this regard, qualitative information such as those from documents and interviews could be of critical relevance.

Prevalence of institutional veto points: This indicator identifies the strength and prevalence of key veto points in a country's political institutions with respect to the Paris goals. Veto points are stages in the process of policymaking when actors or institutions can halt or impede passage[58]. Institutional veto points create major barriers to the adoption of new policies to address rising challenges, and they present obstacles to the alteration of pre-existing policies[59]. Scholars have identified the existence of institutional veto points as an obstacle to the adoption of effective climate change policies, including the "institutional prerequisites" of direct democracy[60]. This may include political orientations and policies that favor fossil fuel industries or other anti-decarbonization interests. For instance, based on empirical data of policies and legislation in OECD countries, Madden (2014)[46] concluded that the existence of veto points leads to lower rates of adoption of climate change actions, including those that may significantly benefit mitigation efforts. However, more veto points also mean that once a policy is adopted, it is more difficult to overturn.

There are varied approaches for the operationalization of institutional veto points in the existing literature. Types of government/political systems (e.g., federalism, bicameralism, and separately selected executive) are commonly coded to measure veto points. There are existing databases that quantify this indicator, such as the parliaments and governments database (*ParlGov*). In addition, Henisz and Zelner (2006)[48] provide an approach to quantify institutional veto points using the *POLCON*[43] and *CHECKS3*[44] databases. Such data could be collected and coded from questionnaires/surveys, interviews with key participants, and documents to identify veto points more accurately.

Dimension 3: Stakeholders and interests

The stakeholders and interests dimension assesses the extent to which different stakeholders and interests within a country align with the Paris goals. All actors in society have interests, incentives, and constraints. Transitions toward a carbon-neutral economy are largely determined by power struggles between alliances of collective actors, such as policymakers, industrial actors, companies, financial institutions and investors, NGOs, and others. Some

may support and benefit from a low-carbon transition while others may be negatively impacted[61-63]. The balance and evolution of these diverse groups, as well as who will pay for the costs and receive benefits, remains a fundamental question of this dimension[64]. This dimension is one of the most important elements in prevailing political economy research; therefore, it is also a key component of the framework proposed here. However, assessing the actions and impacts of stakeholders can be methodologically challenging due to a lack of data availability and standard quantification approaches.

Table 4. Indicators and potential data sources for the stakeholders and interests dimension

Indicator	Linkage to the progress	Potential data sources	Literature
Stakeholder inclusiveness	Stakeholder inclusiveness should be balanced between efficiency and equity of climate actions.	○ *NAZCA*[65] ○ *The CDP open data portal*[65] ○ Text data sources (e.g. research articles, government and administrative records, organization websites) ○ Fieldwork-based sources (e.g. small-scale surveys and interviews)	Averchenkova and Bassi (2016)[17]; Nachmany et al. (2015)[66]; Worker and Palmer (2020)[19], Data-Driven EnviroLab et al. (2022)[67]
Support from political elites	Progress is made by gaining more support from powerful political figures.	○ Online and social media sources ○ Text data sources (e.g. research articles, government and administrative records, organization websites) ○ Fieldwork-based sources (e.g. small-scale surveys and interviews)	Shehata and Hopmann (2012)[68]; Kousser and Tranter (2018)[69]
Political influence of interested coalitions	Progress is made by expanding pro-decarbonization coalitions and neutralizing anti-decarbonization ones	○ Economic databases associated with key sectors (e.g., *World Trade Organization databases*[70], *OECD Fossil fuel support data and Country Notes*[71]) ○ Databases on lobbyists (e.g., *Fossil Fuel* Lobbyist[72]) ○ Text data sources (e.g. research articles, government and administrative records, organization websites) ○ Fieldwork-based sources (e.g. small-scale surveys and interviews)	Hardy et al, (2013)[73]; Junk (2020)[74]; Rennkamp et al. (2017)[75]; Yackee and Yackee (2006)[76]

Number of co-benefits partnerships	Progress is made by discovering and engaging more interest groups that can benefit from climate actions.	○ Large-scale national/across national surveys and questionnaires ○ Text data sources (e.g. research articles, government and administrative records, organization websites) ○ Fieldwork-based sources (e.g. small-scale surveys and interviews)	Worker and Palmer (2020)[19]; Giordano et al. (2020)[77]

Stakeholder inclusiveness: This indicator measures the extent to which stakeholders, such as government organizations, business actors, media, and NGOs, have been identified and engaged in national climate pledges and actions. Its linkage to progress, however, is a "two-way street". On the one hand, interests are better represented by broadening the inclusiveness of stakeholders, thereby increasing the equity or fairness of climate actions. High stakeholder inclusiveness often indicates vigorous dynamics and resource mobility of climate change issues in policy agendas. It also helps to identify the absence of influential stakeholders. On the other hand, multi-stakeholder engagement does not necessarily lead to efficiency in climate actions due to the disparities of interests[78]. There is potential to refine or quantify this indicator as researchers could count the numbers of stakeholders engaged. The *CDP open portal*[65] on climate change and sustainability data reported by more than 1200 cities and regional governments can be a potential source to quantify this indicator. However, it is possible that in certain cases, more accurate or relevant data for this indicator could be collected through qualitative data sources, including government documents, interviews, and other text-based content.

Support from political elites: This indicator measures the level of pro-decarbonization gestures made by influential political leaders (e.g., key government officials, political party leaders, and leaders of large political groups) in public announcements, commitments, decisions, and other actions. Political elites are an integral part of a country's political system. They exercise the power to align political and policy agendas with their interests, values, and beliefs. In terms of climate change challenges, they can drive and frame political

issues in the media, influence public concerns, and determine what policies are chosen to solve problems[68,79,80]. For instance, research focusing on the influence of political elites in Australia found that voters respond to the position of political leaders on climate change policy, and voter polarization increases when leaders diverge[69]. Therefore, the higher level of support from these political elites for more ambitious climate actions, the more progress a country has made towards the Paris goals. We have found no existing databases to quantify this indicator.

However, party platforms, which comprise the set of goals, policies and principles of a political party to guide its action and inform the voters, are often shaped by the opinions of political elites[81]. Therefore, one potential proxy for this indicator could be the extent to which climate mitigation is included in party platforms of the political parties in a given country (e.g. the number of major opposition parties that integrate climate mitigation into their party platforms). In addition, data for this indicator could be collected from social media, policy documents, surveys, and interviews with key stakeholders.

Political influence of interested coalitions: This indicator measures the influence of pro- and/or anti-decarbonization coalitions (e.g., fossil fuel industries versus renewable energy industries or the cattle industry versus interests representing other sources of food) on a country's political and policy agendas of climate change mitigation. The outcomes of the competition between these two political forces advance or prevent carbon lock-in. In general, countries with stronger and more influential pro-decarbonization coalitions are more likely to take ambitious climate actions. Therefore, building winning coalitions for decarbonization contributes to the development of climate change mitigation initiatives[82,83]. Progress is made by empowering "winners" (particularly low-carbon niches) to support decarbonization while neutralizing "losers" by altering incentives[82].

Even though coalitions have been in the spotlight of the political economy discussions of climate change, measuring their political influence is challenging. In some countries, such as the United States, in which lobby is a legal practice, the indicator could potentially be

measured by comparing the number of lobbyists or lobbying expenditures between the fossil fuel sectors and the clean energy/pro-climate sectors if such data exists[72,84]. In addition, Averchenkova and Bassi (2016) uses the share of value added generated by carbon intensive industries and the mining sector over GDP to measure the size of the carbon intensive lobby or interest groups[17]. Qualitative methods such as case studies are more commonly used than quantitative approaches in coalition or interest group research due to data and method constraints[85,86]. For example, Aamodt and Stensdal (2017) evaluated and compared the policy influence of climate advocacy coalitions in China, Brazil and India through the Advocacy Coalition Framework (ACF)[87]. However, qualitative approaches can only apply to studies with small numbers of individuals or cases (i.e., small-N studies). There are potentially more objective measurements such as the size of coalitions, profiles of coalition participants, and economic data of related sectors (e.g., employment and export data, industrial subsidies and government funding[88]), yet the applicability of these measurements may be limited by the ambiguity of this indicator.

Other methods are also discussed in the existing literature, including attributed influence methods based on self-evaluation or expert assessment, and preference attainment approaches which link interest group or coalition influence with policy outputs[85]. The latter is more objective and can be applied to a larger number of cases, particularly by using quantitative text analysis[89]. In addition, Rennkamp and colleagues used network analysis to quantify this indicator. The study established a dataset of 560 coded statements in support or opposition of renewable energy from media articles, policy documents, and interviews. A network analysis using the dataset was conducted to quantify the political influence of the competing coalitions[75]. Similar data collection and analysis approaches could be a valuable line of future research.

Number of co-benefits partnerships: This indicator assesses the extent to which stakeholders/interests that receive co-benefits from climate mitigation are included in efforts to meet the Paris goals, such as air pollution control agencies, health, and agricultural sectors.

Climate co-benefits are described as linkages between mitigation and other key national priorities. Actions on carbon emissions reductions may positively impact other development challenges such as air pollution, health issues, and poverty. Addressing co-benefits helps to shape narratives around domestic climate change mitigation and to improve the political feasibility of climate actions[51,90]. For instance, energy security and air pollution were primary reasons for the promotion of renewable energy deployment in both India and China[90-92]. The progress of domestic climate actions can therefore be stimulated by engaging and building partnerships with these co-benefit interests[19]. This indicator focuses on stakeholder engagement rather than calculating co-benefits, as many policy- and economics-oriented studies have done[93,94]. An example would be the Partnership for Air Quality, Climate & Health (PACH) of Colorado State University.

The assessments of this indicator are largely driven by qualitative sources. We have found no existing databases that can be directly used to quantify this indicator. Data collected and coded from documents, interviews, and/or surveys could serve as measures of this indicator[19]. In particular, conducting interviews with "snowballing" or "referral sampling" technique can help with the identification of co-benefit partnership[77].

Dimension 4: Policy effectiveness

The policy effectiveness dimension investigates the extent to which policies are facilitating domestic climate change mitigation. For our purposes in this paper, we include laws, regulations, policy instruments, and anything a government chooses to do or not to do[95]. Effectiveness here is defined as "how well something works or whether it works as intended and meets the purposes for which it is designed"[96]. Four indicators are suggested, including the effectiveness of policy adoption, the effectiveness of policy implementation, policy coherence, and the track record of a country in delivering on its commitments.

Several additional questions arise in the measurement of policy effectiveness. One can simply ask yes-or-no or descriptive questions such as: "Has a given country adopted any regulations and laws to support climate actions?" or "How many climate regulations does a

country have?". Effectiveness, in reality, is much more complicated, since it can be difficult to demonstrate causal links between policies and desired outcomes. The gold standard for evaluating policy effectiveness is the experimental/quasi-experimental design which compares empirical observations with a control group. Such approaches are often costly and control groups are difficult to identify[97]. And they can be a poor match to the scale on which the policies need to operate.

Table 5. Indicators and potential data sources for the policy effectiveness dimension.

Indicator	Linkage to the progress	Potential data sources	Literature
Effectiveness of policy adoption	Progress is made by making and adopting climate policies that are capable of meeting the Paris goals	○ *Climate Policy Database*[98] ○ *Energy Policy Tracker*[99] ○ Large-scale national/across national surveys and questionnaires ○ (e.g., perceived effectiveness) ○ Text data sources (e.g. research articles, government and administrative records) ○ Fieldwork-based sources (e.g. small-scale surveys and interviews)	Nachmany et al. (2015)[66]; Roelfsema et al., (2020)[11], Nascimento et al. (2022)[100]
Effectiveness of policy implementation	Progress is made if effective climate policies are implemented successfully .	○ Energy or carbon emissions databases ○ Large-scale national/across national surveys and questionnaires ○ (e.g., perceived effectiveness) ○ Text data sources (e.g. research articles, government and administrative records) ○ Fieldwork-based sources (e.g. small-scale surveys and interviews)	Nicholson-Crotty and Carley (2016)[101]; Van Den Hoek et al. (2014)[102]; Allen et al. (2020)[103]; Proctor et al (2011)[104]; Lilliestam et al. (2020)[105]
Policy coherence	Progress is made if conflicts among policies are minimized	○ Text data sources (e.g. research articles, government and administrative records) ○ Fieldwork-based sources (e.g. small-scale surveys and interviews)	Gara et al. (2020)[106]; Jacob et al. (2019)[97]; Mallory (2016)[107]; OECD (2016)[108]; Worker and Palmer (2020)[19]; Scobie (2016)[109], iSDG[110]

Track record on previous climate commitments	Progress is made to keep taking actions towards committed climate targets. The better performance of previous records, the more credible to take future actions on climate change	○ *UNFCCC National Communication Submission*[111] and *Biennial Update Reports*[112] ○ *International Environmental Agreements (IEA) Database Project*[113] ○ *Climate Change Performance Index*[114] ○ *Climate Action Tracker*[3] ○ Text data sources (e.g. research articles, newspapers, government and administrative records)	Averchenkova and Bassi (2016)[17]; Dubash et al. (2013)[115]; Morel and Shishlov (2014)[116]; Höhne et al. (2012)[117]

Effectiveness of policy adoption: This indicator measures the extent to which policies that are capable of meeting the Paris goals have been designed, identified, and adopted[118] —i.e., whether or not the most effective climate policies for this country to reduce greenhouse gas emissions can be adopted successfully. For example, a country has to decide whether to choose carbon taxes or carbon markets for better mitigation results, and it needs to come up with the best design of the instrument it chooses.

It is practical to assess this indicator by using the types (e.g. regulations or market-based instruments) and numbers of current policies addressing climate change. Such data can be retrieved from multiple existing policy databases such as *Climate Policy Database*[98] and *Climate Change Laws of the World* [119]. For example, using various policy data sources, Nascimento et al. (2022)[100] tracked the mitigation policy coverage changes in G20 countries from 2000-2019 and evaluated the policy adoption gaps across sectors. Those gaps leave at least one-tenth of the G20's emissions uncovered. However, at this point, the policy databases are not sufficiently valid or accurate to measure this indicator. In interpreting the above collections of policies for analysis, it is standard to assume that the number of adopted policies indicates the level of effectiveness in terms of achieving the Paris goals. It is widely understood that this is not necessarily true. In many cases, identifying and adopting a single right policy can be more effective than making multiple policies that are poorly designed or even harmful to the mitigation progress. The quantity of policies does not necessarily reflect a country's ability to design and adopt the right policies. However, policy decision-making is difficult to assess since it often relates to political processes and the context of these

policies[120,121]. In this case, interviews, surveys on perceived effectiveness of the public or policymakers, and/or documents could potentially be used to understand this indicator more accurately.

Effectiveness of policy implementation: This indicator measures how well climate policies aimed at meeting the Paris goals have been implemented. Adopted policies are not necessarily effectively implemented, which may undermine the achievement of desired outcomes. For example, policies could be poorly implemented when the incentives of the implementers and the policymakers are not aligned. This indicator can be assessed by the degree to which a policy achieves its stated goals[118]. We have found no existing databases to quantify this indicator directly. However, in many cases, policy outputs are often used as a proxy of the effectiveness of policy implementation[101,102]. It makes output-oriented data such as carbon emissions or installed power capacity potential measures for implementation effectiveness. But such outputs are not always solely or directly caused by a certain policy. In addition, there have been attempts in both the academic research community and international organizations to evaluate policy effectiveness based on reviews and meta-analyses of empirical evidence[105,122-125]. Questionnaires/surveys and interviews with key participants may be suitable for assessing and quantifying this indicator, such as surveys on how people perceive the effectiveness of policy implementation[126].

Policy coherence: This indicator measures the extent to which domestic climate policies are consistent with each other and coherent at different levels of government, from national to local. The indicator aims to answer the question: are a country's climate policies consistent, or are they operating at cross-purposes? Policy coherence is the systematic promotion of mutually-reinforcing policies that can accumulate synergies to achieve objectives. This occurs when the balance of policies is aligned with a common goal or set of intentions[97]. Incoherent policies hinder policy effectiveness by creating negative spill-over effects[64,107,108,127]. For example, policies to promote renewable energies may conflict with

policies to preserve/increase carbon sinks such as forests and grasslands due to competition over land use[128].

Monitoring interactions among related policies is key to evaluating policy coherence. OECD (2016)[108] discusses methods and data sources for assessing policy coherence for the Sustainable Development Goals (SDGs). It introduces a simulation model called Integrated Sustainable Development Goals (iSDG) that monitors the interactions and coherence among various SDG policies[110]. However, few existing datasets can be used to quantify policy coherence in climate change mitigation directly. Policy documents are major sources to generate quantifiable data for this indicator. Interviews with policy-makers and surveys/questionnaires can also be used when necessary.

Track record on previous climate commitments: this indicator measures the past performance of a country's policy effectiveness on climate change prior to the Paris Agreement, particularly with respect to the Kyoto Protocol. Were previous targets met by implementing the right policies? If so, how did the country adopt effective policies and implement them successfully? It is implied that the better the record of a given country on climate actions, the more credible that country will be in making effective policies for the Paris goals.

There are existing datasets that can be directly used to quantify this indicator, including *Climate Change Performance Index*, *Climate Action Tracker*, and *National climate change mitigation legislation and strategy survey*[115]. In addition, other data sources have been used to quantify similar indicators. For example, meeting the pledged targets of the Kyoto Protocol is a potential measurement of policy effectiveness for countries that had mandatory targets. And for countries without mandatory targets, the National Communications and Biennial Update Reports requested by the UNFCCC could be potential data sources for this indicator[17].

Dimension 5: Public opinion

Public opinion provides the socio-political context within which decision-making and operations for climate actions are rooted[17,120]. The public plays a key role in mitigation strategies[129]. Awareness of climate change consequences, knowledge on climate change, and concern for climate risks not only influence support for climate policies but also motivate individual climate actions[130]. Public concern about climate change is discovered to be associated with lower carbon emissions[131]. The public opinion dimension evaluates the popular perception of climate change and popular support for climate actions, and it aims to identify barriers to public consensus. However, the significance of public opinion in shaping political economy progress of climate mitigation varies across different country context, such as the political system or the level of development of a country. Therefore, it is important to consider the unique context of each country when assessing the public opinion dimension.

Table 6. Indicators and potential data sources for the public opinion dimension.

Indicator	Linkage to the progress	Potential data sources	Literature
Climate awareness	Progress is considered to have been made if the public's knowledge on climate change has increased	o *Gallup World Poll (2007-2008)*[132] o *Ipsos (2022)*[133] o *"Peoples' Climate Vote"*[134] o Country-specific surveys: UK[135], US[136-138], China[139], India[140] o Online and social media sources[141] o Large-scale national/across national surveys and questionnaires o	Averchenkova and Bassi (2016)[17]; Lee et al. (2015)[142]; Wang and Zhou (2020)[143], Zeng (2022)[141]
Public support for climate actions	Progress is considered to have been made if the actions gain more support from the public	o *"Peoples' Climate Vote"*[134] o Country-specific surveys: UK[135], US[137,144,145], China[139], India[140] o Online and social media sources o Large-scale national/across national surveys and questionnaires	Setterfield and Murray (2020)[135]; Tyson and Kennedy (2020)[144]; Kruse and Atkinson (2022)[146]
Heterogeneity in perception and specific interests	Progress is considered to have been made by building consensus and a convergence of interests among the public	o Country-specific surveys: Climate Insights 2020[147] (examines the partisan divide in the US) o Online and social media sources o Large-scale national/across national surveys and questionnaires	Ban Rohring and Akerlof (2020)[148], Brulle et al.(2012)[149], Chan and Faria (2022)[150]

- Online and social media sources
- Text data sources (e.g. research articles, newspapers)
- Fieldwork-based sources (e.g. small-scale surveys and interviews)

Climate awareness: This indicator measures the public's level of knowledge on climate change. Climate awareness reflects people's perceptions of climate risks. Increased knowledge of climate risks facilitates behavioral changes toward decarbonization across society[151], and shapes a country's climate policy preferences[152]. This indicator is quantifiable and generally relies on existing databases (mostly large-scale surveys/polls). Commonly-used databases include: (1) *Gallup World Polls in 2007 and 2008*[153], which is the first widely available and remains the largest global survey of public climate awareness to date. For instance, it was recently used by Wang and Zhou (2020)[143]. A total of 206,193 interviews were conducted across 128 countries. (2) *Peoples' Climate Vote*[154] is the latest survey conducted by the United Nations Development Program (UNDP) and the University of Oxford on public opinion on climate change, carried out in late 2020. It claims to be the largest international survey of its kind, with 1.2 million respondents from 50 countries[155]. (3) Country-specific surveys include surveys on public attitudes towards climate change, such as the series of surveys conducted by the Yale Program on Climate Change Communication for in the United States, China and India[138-140], surveys conducted by Ipsos MORI in the UK [135], and Pew surveys in the United States [136].

Public support for climate actions: This indicator measures the level of support from the public for actions aimed at meeting the Paris goals. Climate policy actions generally depend on gaining and maintaining public support for a wide range of societal changes[142]. More support from the public also increases the political feasibility of climate policy adoption and implementation at all levels[156]. This indicator is quantifiable, and data can also be obtained from the databases identified above for measuring climate awareness.

Heterogeneity in perception and specific interests: This indicator measures the divergence in climate change perceptions and interests of people from the same community, region, state, or other social group[148]. Despite the broad scientific consensus that climate change is a real phenomenon caused by anthropogenic greenhouse gas emissions, there are nonetheless major public disagreements on the reality and causes of climate change in many countries. For instance, the difference between the stances of liberals and those of conservatives (e.g., Democrats and Republicans) on climate change have widened over the last twenty years in the United States[157].

This is a necessary indicator since people's attitudes can be strongly influenced by perceptions of the beliefs and behaviors of others in their social group[148]. In addition, those who benefit and those who suffer from climate change mitigation may hold divergent perceptions towards climate change and defend their interests accordingly. The polarization of perceptions and interests severely undermines the capacity for collective action, as public advocacy is one of the strongest determinants influencing climate change concerns[149]. Therefore, building social consensus and convergent interests among the public are key to making progress on climate change mitigation. There are few existing databases that can directly quantify this indicator. Data could be obtained from national/cross-national surveys and polls, social media, and interviews.

EVALUATING DATA AVAILABILITY

Measurability is the core consideration in identifying indicators. Different types of data sources require various levels of efforts in translating raw data into quantifiable metrics. For example, online and social media sources are typically more accessible, comprehensive, and easier to collect systematically compared to other sources, while other text data sources such as research articles and newspapers, and fieldwork approaches such as interviews are often more labor-intensive and time-consuming and may produce less structured data.

Generally speaking, data for these indicators are qualitative as opposed to techno-economic indicators, which are inherently numeric. The challenge is to translate the

qualitative evidence into standardized quantitative data. Nevertheless, this does not mean that qualitative indicators are inconsequential, since they serve as preliminary examinations of local contexts before the collection of quantitative data, and they may be better tools for understanding processes and mechanisms. Although we tried to identify quantifiable indicators, there are still critical indicators that are difficult to measure and quantify due to lack of data availability. An intermediate solution to cope with this challenge is to convert qualitative information into binary or categorical data, categorizing it as either 'yes' or 'no', or by evaluating the degree of the assessed indicator. We limit our evaluation of data availability to the data sources/data collection approaches we have reviewed in this paper and summarize the data sources listed above (Figure 3).

Data source priority (High to low)	1	2	3	4	5	6
	Existing databases that are valid, reliable and consistent across countries	Existing databases that are less valid and accurate or less consistent across countries	Data availability can be improved by obtaining data from online and social media (i.e. big data)	Data availability can be improved by conducting large-scale national/cross national surveys and questionnaires	Data availability can be improved by obtaining data from text data sources such as research articles, news articles, and government and administrative records	Data availability can be improved by obtaining data from fieldwork-based approaches such as small-scale surveys and questionnaires, and interviews
Existing climate pledges	Y	N/A	N/A	N/A	Y	N/A
National commitments by heads of state or government	N	N	Y	N/A	Y	N/A
Scales and scope of climate institutions	N	Y	N/A	N/A	Y	Y
Robustness of climate institutions	N	Y	N/A	N/A	Y	Y
Prevalence of institutional veto points	Y	Y	N/A	N/A	Y	Y
Stakeholder inclusiveness	N	Y	N/A	N/A	Y	Y
Support from political elites	N	N	Y	N/A	Y	Y
Political influence of interested coalitions	N	Y	N/A	N/A	Y	Y
Number of co-benefits partnerships	N	N	N/A	Y	Y	Y
Effectiveness of policy adoption	N	Y	N/A	Y	Y	Y
Effectiveness of policy implementation	N	Y	N/A	Y	Y	Y
Policy coherence	N	N	N/A	N/A	Y	Y
Track record on previous climate commitments	Y	Y	N/A	N/A	Y	N/A
Climate awareness	Y	Y	Y	Y	N/A	N/A
Public support for climate actions	Y	Y	Y	Y	N/A	N/A
Heterogeneity in perception and specific interests	N	Y	Y	Y	Y	Y

Figure 3. Summary of the data sources . This figure summarizes six data source types for the indictors. The first two on the left indicate the existing databases, and the following four categories on the right indicate potential data sources for the indicators. The quality of data sources is rated 1- 6 and prioritized from high to low – i.e. from existing valid and consistent databases to collecting data through fieldwork approaches. N/A indicates that the data source is not applicable or not necessary for this indicator.

The figure shows that five indicators have the highest data availability (Grade 1): existing climate pledges, national commitments by head of states or government, track records on previous climate commitments, climate awareness, and public support for climate actions. Currently, no existing databases are available for quantification of four indicators: national commitments by heads of states or government, support from political elites, the number of co-benefits partnerships, and policy coherence. In addition, the figure also summarizes the data sources that can be used to increase data availability (Grade 3-6). Five indicators can potentially improve their data availability through big data techniques from online and social media sources. Six indicators can improve data availability through conducting large national/cross national surveys. Text data sources such as research articles, newspapers, and government records can be used to improve the data availability of most indictors.

Based on the summary of data sources, three principles are applied in the evaluation: (1) The definitional clarity of the indicator. Indicators with high quantifiability should be clearly defined (i.e., requiring minimum interpretation); (2) The level of current data availability(3) The potential to increase data availability if current data availability is moderate or low (Figure 4). Based on the reviewed literature and listed data sources of each indicator, a summary of the overall assessment on links to the progress, indicator clarity, current data availability and potential to increase data availability is presented in Figure 5. Note that indicator clarity and correlation to progress are based on the judgement of the authors—and are thus aspects that could be developed further in future work.

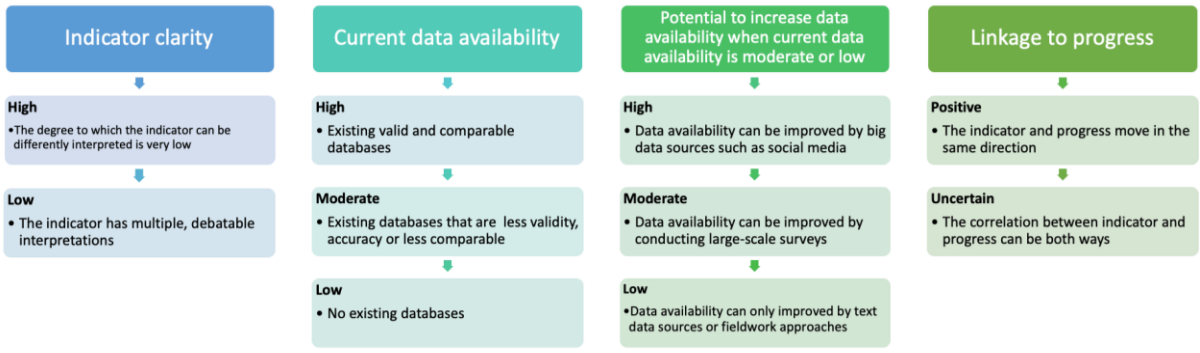

Figure 4. Criteria for the evaluation of data availability. Current data availability is rated as high, moderate or low when the quality of data sources indicated in Figure 3 corresponds to Grade 1, Grade 2, or neither Grade 1 nor Grade 2, respectively. The potential to increase data availability is evaluated for indicators with current data availability rated as moderate and low. The potential to increase data availability is high, moderate or low if data can be systematically obtained from online and social media sources (Grade 3), from large-scale national/cross national surveys (Grade 4), or can only be obtained from text data sources and fieldwork approaches (Grade 5&6) for further analysis.

Figure 5. Summary of key findings. Understanding how actors can achieve success in diverse political contexts is a critical next step in delivering action toward global climate

goals. This figure presents a framework for identifying areas of current strength as well as needs for additional refinement of indicators, data, and analysis toward supporting increased climate action.

AN ILLUSTRATIVE EXAMPLE OF POLITICAL ECONOMY ASSESSMENT FOR THE UNITED STATES, CHINA AND INDIA

This section provides an illustrative example of how the indicators could be applied to assess the political economy dimensions of climate mitigation. We used the United States, China and India as country examples based on current data availability. However, it is not our intention to conduct comprehensive and robust assessments of these countries; rather an initial attempt to test the feasibility of the framework and the underlying indicators. In addition, the assessments do not aim to rank the countries based on their performance. Instead, we aim to identify areas in which there have been better performance and those need improvement for each country by comparing across the dimensions and indicators.

For each country, we gathered both quantitative and qualitative information from various sources and quantified 15 out of 16 indicators, except for "policy coherence" due to data availability. Table 7 summarizes the evidence used for indicator quantification and assessments.

Table 7 Summary of evidence for the assessments of the United States, China, and India

	United States	China	India
Existing climate pledges	The US has set relatively high ambition pledges, including a net zero target (2050 net zero target in policy document), an interim target of 52% emissions reduction of the 2005 level by 2030 and 40% reduction of the 1990 level by 2030, a direct emissions reduction target, and all greenhouse gases included in the net zero target. Furthermore, 13 out of 50 states have announced a net zero target by far, indicating a growing trend towards subnational climate action[23].	China has made moderate to low-ambition pledges to address climate change, including a target to achieve carbon neutrality by 2060 that includes all greenhouse gases (in policy document), an interim target of a 65% reduction in emissions intensity compared to 2005 levels by 2030. However, it is an indirect emissions reduction targets, and only one out of 31 provinces have announced a net-zero target[23].	India has made low-ambition pledges to address climate change, including a policy document targeting net-zero emissions by 2070, an interim target of a 45% reduction in emissions intensity compared to 2005 levels by 2030. However, it is an indirect emissions reduction target. And the net-zero target does not specifically include greenhouse gases. Currently, only 9 out of 36 states have announced a net-zero target[23].
National commitments by heads of state or government	Current President Joe Biden has made multiple climate announcements that demonstrate strong commitments to addressing climate change[158].	Current President Xi Jinping has made multiple climate announcements that demonstrate strong commitments to addressing climate change[159].	Current President Droupadi Murmu has made climate announcements that demonstrate strong commitments to addressing climate change[160].

Scale and scope of climate institutions	The climate institutions in the country are relatively inclusive. The Environment Protection Agency (EPA) is the major designated authority for climate mitigation efforts. Multiple authorities, including the Department of Energy (DOE) and the White House Office of Domestic Climate Policy, directly support climate mitigation. According to existing database, most sectors have laws or policies addressing climate mitigation. Subnational governments have taken initiatives and have been largely involved in climate mitigation efforts[54,119,161].	The country has relatively inclusive climate institutions, with the Ministry of Ecology and Environment (MEE) as the designated authority for climate mitigation efforts. Additionally, multiple authorities including the National Development and Reform Commission (NDRC) directly support climate mitigation. Nearly half of the sectors in the country have laws in place addressing climate mitigation, and subnational governments have taken an active role in initiatives such as low-carbon pilot city programs[92,119,162].	The climate institutions of the country are relatively less inclusive, with the Ministry of Environment, Forest and Climate Change (MoEFCC) as the designated authority. Multiple authorities have indirect focuses on climate change embedded in the sectoral development goals, but only a few sectors have laws addressing climate mitigation. Additionally, subnational governments have been less involved in climate mitigation initiatives[33,119,163].
Robustness of climate institutions	Although the country has enacted multiple laws addressing climate mitigation, such as the Clean Air Act and the Inflation Reduction Act, the government's attitude toward climate change has been inconsistent across different administrations. Some administrations have taken steps to halt climate action, including the abolition of major climate laws and regulations[119,161,164].	Climate mitigation has been considered as a national priority and incorporated into key national plans, including the Five-Year-Plans. The country has institutionalized carbon peak and carbon neutrality targets through key national policies such as the "Working Guidance for Carbon Dioxide Peaking and Carbon Neutrality in Full and Faithful Implementation of the New Development Philosophy (2021)". The government's response to climate change has remained consistent and relatively robust over the years and has been reinforced to prevent backsliding[20,92,119].	Climate mitigation has been institutionalized by key national plans, specifically the National Action Plan for Climate Change (NAPCC). Even though climate policy has not been a major focus of political discussions and electoral cycles, the government's response to climate mitigation has been generally consistent and relatively robust over time, which prioritizes traditional developmental objectives but layers climate mitigation functions upon existing government bodies[20,33,119]. .
Prevalence of institutional veto points	The country has high political constraints, which means strong prevalence of veto points. These constraints make it more challenging for climate policies to be implemented, as there are multiple points where opposing political interests can block or delay progress on climate-related initiatives[165]	The country has relatively low political constraints, as there are very few veto points in the political system. This means that there are few oppositional forces that could block or delay climate mitigation actions[165].	The country has relatively high political constraints, which means relatively strong prevalence of veto points[165].
Stakeholder inclusiveness	The US has multiple programs that aim to mobilize subnational and non-government actors to take climate action, such as "Subnational Climate Action Leaders' Exchange (SCALE)". There is a relatively large number of business actors in the country that establish carbon emissions reduction target. And the extent to which various actors, such as companies, regional governments, and NGOs, involved in the climate mitigation is relatively high compared to the country's overall carbon emissions level[25,67,166,167].	China has multiple policies or programs that aim to mobilize subnational and non-government actors, such as the "Action Plan for Carbon Dioxide Peaking before 2030 ('1+N'). There is a moderate number of business actors in the country that establish carbon emissions reduction targets. The extent to which various actors involved is relatively low compared to the country's overall carbon emissions level[25,67,167,168].	India has enacted the State Action Plans on Climate Change (SAPCC) to facilitate subnational actions. There is a relatively small number of business actors that established carbon emissions reduction targets. The extent to which various actors involved is relatively low compared to the country's overall carbon emissions level[25,67,163,167].
Support from political elites	As a democratic country, the level of political elite support for climate mitigation in the country is moderate. Specifically, only one of the two major political parties, the Democratic Party, which currently holds the ruling position in	As an authoritarian country, the level of political elite support for climate action is relatively high, as the ruling party, the Chinese Communist Party, has strong support for climate action and has taken major steps to address climate change.	As a democratic country, the level of political elite support for climate action is relatively high. Both major political parties, the Indian National Congress (INC) and the Bharatiya Janata Party (BJP), have included climate

	government, has included climate mitigation in their party platform[169]		mitigation in their party platforms[170]
Political influence of interested coalitions	Despite the presence of a strong fossil fuel interest group, the government has shown relatively low support for fossil fuels in terms of subsidies. In fact, the amount of fossil fuel subsidies has been decreasing based on existing data, indicating a moderate political influence of fossil fuel interest groups[88,171].	The country has a very strong fossil fuel interest group, and the government has shown strong support for fossil fuels in terms of subsidies. The amount of fossil fuel subsidies has been increasing based on existing data, indicating a high political influence of fossil fuel interest groups[88,172].	The country has a very strong fossil fuel interest group, and the government has shown a moderate level of support for fossil fuels in terms of subsidies. The amount of fossil fuel subsidies has been increasing based on existing data[88,172].
Number of co-benefits partnership	Due to a lack of data, we have quantified the indicator by whether the country places a specific emphasis on co-benefits. In this case, the US has not had a specific focus on co-benefits in the political/policy discussions, according to available information.	Due to a lack of data, we have quantified the indicator by whether the country places a specific emphasis on co-benefits. China has specific emphasis on co-benefits to facilitate climate mitigation[20,92].	Due to a lack of data, we have quantified the indicator by whether the country places a specific emphasis on co-benefits. India has specific emphasis on co-benefits to facilitate climate mitigation[20,33].
Effectiveness of policy adoption	In response to the importance of methane mitigation discussed during COP26 and its critical role in climate mitigation, the country has passed the Inflation Reduction Act (IRA) to address this issue and has adopted multiple policies and legislations. However, according to Fekete et al. (2021)[123], the country has a moderate-low number of best practices in key mitigation areas. Additionally, the country has adopted a relatively large amount of climate policies annually since 1990[173,174]	China has not yet passed a law specifically addressing methane mitigation. However, the country is currently in the process of enacting a national methane strategy, and has adopted multiple policies targeting methane mitigation after COP26. The number of best practices in key mitigation areas is moderate-low, according to Fekete et al. (2021). Additionally, China has adopted a moderate number of climate policies annually since 1990[123,173,174]	India has not yet responded specifically to methane mitigation, and the country has zero best practices in key mitigation areas according to Fekete et al. (2021). However, India has adopted a moderate number of climate policies annually since 1990, reflecting its commitment to addressing climate change through a broader range of mitigation measures[123,174,175]
Effectiveness of policy implementation	There is evidence to suggest that the level of rule of law is positively correlated with the effectiveness of policy implementation. In this regard, the country's relatively high level of rule of law suggests a greater likelihood of effective policy implementation[174,176].	The country has a moderate level of rule of law, which indicates some limitations to the effectiveness of policy implementation[174,176].	The country has a moderate level of rule of law, which indicates some limitations to the effectiveness of policy implementation[174,176].
Policy coherence	No available data found	No available data found	No available data found
Track records on previous climate commitments	The country has withdrawn twice from international climate agreements in the past, but has not indicated any plans for significant investments in fossil fuels since announcing its net-zero target. As an Annex I country, it was able to meet the 2020 climate target under the Copenhagen Accord but has not sustained this achievement[177,178].	The country has not withdrawn from any international climate agreements in the past, however, it has planned for significant investments in coal power since announcing the carbon neutrality target, indicating a potential conflict between its climate goals. As an Annex II country, it was able to meet the 2020 climate target three years ahead of the schedule[177,179].	The country has not withdrawn from any international climate agreements in the past, but it has planned for significant investments in coal power since announcing the net zero target. As an Annex II country, it slightly missed the 2020 climate target[177].
Climate awareness	According to the most recent surveys (in 2022), 72% of the respondents acknowledge that climate change is happening. Only 56% of the respondents agree that climate change is caused mostly by human activities. And 61% of the respondents express concern about the impacts of climate change[138].	According to the most recent surveys (in 2017), 94.4% of the respondents acknowledge that climate change is happening. 66% of the respondents agree that climate change is caused mostly by human activities. And only 48% of the respondents express concern about the impact of climate change[139].	According to the most recent surveys (in 2022), 84% of the respondents acknowledge that climate change is happening. 57% of the respondents agree that climate change is caused mostly by human activities. And 78% of the respondents express concern about the impact of climate change[140]
Public support for climate actions	65% of the respondents support clean energy transitions and other mitigation methods. 62% of the respondents support immediate	90% of the respondents support clean energy transitions and other mitigation methods. 75% of the respondents support immediate	Only 44% of the respondents support clean energy transitions and other mitigation methods. 71% of the respondents support

	government actions. And 61% of the respondents support business actors to take actions (surveys in 2021 and 2022)[133,155].	government actions. And 74% of the respondents support business actors to take actions (surveys in 2017 and 2022)[133,139].	immediate government actions. And 69% of the respondents support business actors to take actions (surveys in 2021 and 2022)[133,155].
Heterogeneity in perception and specific interests	The perception of climate mitigation issues becomes notably polarized in relation to diverging political opinions and ideologies[147,180].	The perception of climate mitigation issues is not notably polarized in relation to diverging political opinions and ideologies[20,180].	The perception of climate mitigation issues is not notably polarized in relation to diverging political opinions and ideologies[20].

To characterize the indicators, we designed a questionnaire with 1-5 multiple choice questions for each indicator based on relevance and data availability. We transformed the gathered information into choices with scales/scores for each question, ranging from 0 as the lowest to 5 as the highest value. The score of each indicator is the average score of the questions for that particular indicator. And the score of each dimension is the average score of the quantified indicators within each dimension (Figure 6).

Due to the complexity of the topic, it is inevitable that these assessments are a simplified version. However, the design of the questionnaire, such as number of the questions and the scoring system can lead to varying weights on different indicators. This poses challenges to the quantification of the indicators and requires careful considerations in the future. Generally speaking, increasing the number of questions in a questionnaire can improve the validity and reliability of measurements by providing more comprehensive and diverse data points. More questions allow for a more robust quantification of each indicator, capturing its complexity from multiple angles. The questionnaire and methodology are provided in the Appendix.

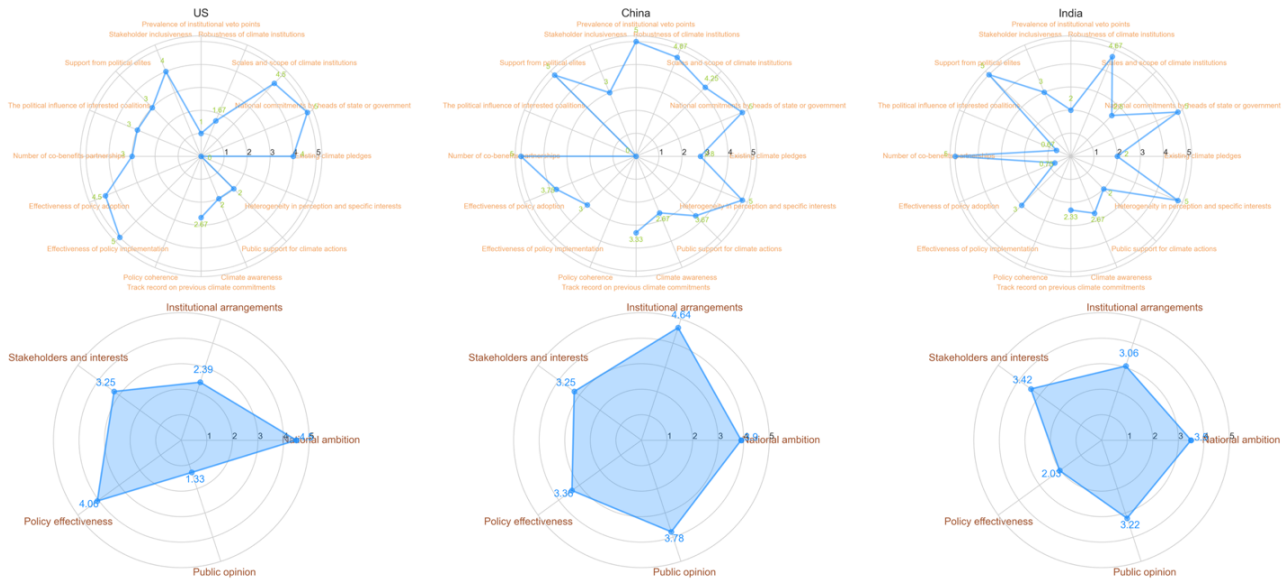

Figure 6. Political economy evaluation of the United States, China, and India, using a scale of 0-5 for each indicator/dimension. The top three subplots present the scores of each indicator based on our assessments of the three countries individually, while the bottom three subplots show the score of each dimension. It should be noted that a score of 5 does not necessarily indicate a perfect performance, but rather provides a comparative status of each indicator or dimension.

Taking the United States as an example, the assessment shows that the country has better performance in certain indicators such as existing climate pledges, the national commitments by heads of state or government, the scale and scope of climate institutes, stakeholder inclusiveness, and the effectiveness of both policy adoption as well as policy implementation. Improvements can be made in indicators such as heterogeneity in perception and specific interests, robustness of climate institutions, and the prevalence of institutional veto points in the context of political debates on climate agenda. Overall, the country currently shows much stronger performance in the policy effectiveness and national ambition dimensions but weaker performance in the public opinion and institutional arrangements dimensions.

This assessment suggests that the United States needs to take proactive actions to address climate change skepticism through various channels, such as investing in public education and awareness campaigns., and to enhance public support and engagement in

climate policymaking processes. It should pay specific attention to address the widening gaps in climate perceptions associated with political polarization within the public. In addition, the country should establish long-term mechanisms that can effectively institutionalize its climate efforts in order to prevent a shift of climate policies with each election cycle.

LIMITATIONS AND FUTURE DISCUSSIONS

This paper provides researchers and policy-makers with a framework for assessing country-level, political economy progress on climate mitigation. Our intention is more practical and immediate: to spur the analytical community to track progress more comprehensively on the critical societal dimensions of climate action. This paper also highlights many limitations and challenges that need to be overcome to apply this framework and assess relevant dimensions and their associated indicators more effectively.

Firstly, we acknowledge that the indicators we proposed are still relatively broad, which require further interpretations and careful design of quantifiable metrics. Especially, creating high-quality quantitative data from qualitative variables is always challenging and has been tried with mixed results in the past[181]. The research community has also attempted to shed light on measuring societal factors of mitigation progress. Yet little consensus has been reached due to the complexity of this topic[17-19].

Specifically, several notable methodological challenges emerge when conducting the above country assessments: (1) The selection of quantifiable metrics, such as the questions included in the example assessments' questionnaires, can be subjective due to variations in indicator interpretations, as these metrics aggregate to quantify each indicator. Limited data availability further constrains the choices of these metrics. Consequently, the effectiveness of the assessments is potentially undermined; (2) Assigning different weights to various dimensions and indicators is important for reflecting their level of importance in political economy progresses and capturing their interrelations and complex dynamics. Yet, determining those weights can be challenging. For simplification purposes, we assume that each indicator and dimension carry equal weigh in the example assessments; (3) The range

and specific numeric values provided in a rating scale can have a significant impact on the assessment results. They determine how the original quantitative and qualitative data are coded and the scores given to the quantifiable metrics and indicators. For example, a dichotomy rating scale (e.g., yes or now with a score of 5 or 0) may result in a larger impact on the score of an indicator than a multiple categorical rating scale (e.g., 0-5). The choice of rating scales and their numeric values should be carefully considered in order to avoid biased or inaccurate results, especially when comparing across dimensions and indicators within a country.

Secondly, it is essential to consider the variations among countries. While the goal is not to rank the countries, it is still important to use consistent criteria and data sources to quantify those indicators across countries in order to better inform the GST and the global community. In particular, it is difficult to synthesize and aggregate the information on political economy progresses made at the global level for the GST without normalized standards.

To do so would require a careful design of the quantification methodology to address the heterogeneity among countries. These variations include some of the fundamental biophysical and socioeconomic conditions, such as energy mix, land sizes, resource endowments, and the level of development, as well as political attributes such as regime types. Ignoring these differences can lead to inaccurate and biased results. The amount of efforts and the progresses needed by different countries to achieve the same level of mitigation outcomes can be divergent. For example, fossil fuel-intensive countries with few renewable resource endowments may face more challenges in energy transitions than those with abundant resources, making government leaders less willing to commit to climate targets. The challenge is to develop a consistent quantification method that can equitably demonstrate the effort made by countries while incorporating those variations.

In addition, data availability differs among countries. Some countries lack either capacity or willingness to collect or disclose basic data that can reflect their performance. Furthermore, countries that are underrepresented in global climate governance often receive less research attention, resulting in a scarcity of information available. Enhanced

transparency and capacity building for countries to improve data availability are necessary to ensure the usefulness of the framework.

Thirdly, despite the focus of this study on climate mitigation, the linkage between mitigation and adaption deserve particular attention as they may have synergies (e.g., forest management) as well as trade-offs. These interactions can complicate the political economy of climate efforts within a country, especially when trade-offs are involved. For example, the land use sector is a nexus of mitigation and adaption, in which key mitigation approaches such as renewable energy deployment may have conflict with adaptation measures such as ecosystems preservation. In addition, some countries would prioritize adaption in their climate agenda due to their unique geographic and biophysical characteristics or prominence of the matter, resulting in a relatively low demand for addressing climate mitigation. However, it is still unclear how these influences can be incorporated into the assessments, which requires future discussions.

Finally, in addition to the technical feasibility, applying the framework may encounter implementation barriers in which some countries may not be willing to have their political systems examined. In those cases, independent external assessments or bottom-up in-country evaluations can be used as complementary sources. Political advocacy is necessary to encourage positive responses from countries to participate in the assessments. And it is also important that countries recognize the need for broader transformation beyond simply "setting the right policies" in order for these indicators to truly facilitate mitigation efforts.

These challenges should be a key focus for the research community in the development of a more rigorous understanding of climate change mitigation progress. Better assessment of these political economy variables will be critical for understanding how we can get on a pathway towards our shared climate goals. A new approach consolidating societal and institutional factors needs to be defined around successful mitigation in the formal GST. A stocktake that fundamentally recognizes and reflects these issues can better depict mitigation progress and challenges, going beyond techno-economic information. This would also lend

greater support to the core goals of the stocktake, which are to understand the pathways for implementing enhanced action to keep 1.5C within reach.

METHODS CLARIFICATION

Defining political economy progress towards the global warming goals has been challenging due to the complexity of this topic, despite the aid of relevant literature. In such circumstances, expert opinions can provide knowledge that untangles some of the complexity and contributes to the scoping of the analytical framework. Therefore, we invited a group of 15 international experts to join a roundtable – 'Taking Stock of the Political Economy of the Transition towards a Net-Zero World: Assessing Progress through Measurable Indicators' held on April 29, 2021 – to elicit their informed judgment on the key political economy elements that should be accounted for in the stocktake.

However, we did not conduct a structured expert elicitation (SEE), which is often in the form of subjective probability distributions and requires systematic or formal procedures to recruit experts, develop questionnaires/surveys/ interview questions and analyze collected data[182,183]. Instead, we elicited expert opinion based on an informal expert knowledge-gathering exercise, which can serve as a complementary component of the research analysis[184].

Key high-level questions were proposed to the panel of experts in the roundtable, including: (1) What are the most useful elements/metrics to characterize and assess the political economy progress of climate mitigation? (2) How can the political economy or institutional barriers to climate mitigation be overcome and what are the narratives for success? (3) How can these political economy elements/metrics be measured?

Each expert was invited to answer the above questions or share opinions related to the topic. In particular, each expert was asked to propose the indicators/dimensions/elements that they thought were most relevant and useful to measure the political economy progress of climate mitigation. However, the roundtable discussions were semi-structured. Some of the experts did not directly point out the exact indicators; rather they either echoed the other

experts' opinions, or commented on the discussions in a general way. We incorporated the elements that were frequently addressed by into the framework based on our own judgement and understanding of the importance and relevance. These elements are either complementary or supportive of the existing literature on this topic. For example, elements such as "veto points" and "interested coalitions" were frequently mentioned by different experts in the roundtable but have been seldom discussed in the existing research. At the same time, climate co-benefits have been widely discussed in the existing studies and were also highlighted by the group of experts.

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AUTHOR CONTRIBUTIONS

Conceptualization, M.Z., V.C., L.C., K.H., N.H., A.V.-S.; methodology, M.Z., V.C., L.C., N.H., P.W.; investigation, M.Z., V.C., L.C., K.H., N.H., A.V.-S., P.W.; resources, L.C., N.H.; writing – original draft, M.Z., V.C., L.C., K.H., N.H., A.V.-S.; writing – review & editing, M.Z., V.C., L.C., K.H., N.H., A.V.-S., P.W.; visualization, M.Z.; supervision, V.C., L.C., N.H.; project administration, M.Z., V.C., L.C., N.H.; funding acquisition, V.C., L.C., N.H.

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