SYSTEMS CHANGE LAB

TECHNICAL NOTE

METHODOLOGY UNDERPINNING THE SYSTEMS CHANGE LAB PLATFORM

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Technical notes document the research or analytical methodology underpinning a publication, interactive application, or tool.

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ABSTRACT

The Systems Change Lab platform provides an overview of the world's collective efforts to accelerate the systemwide transformations needed to limit global average temperature rise to 1.5 degrees Celsius, protect biodiversity, and advance equity. This technical note explains the methodology of the Systems Change Lab platform. We identified key global systems that must transform and chose the most critical shifts needed within each system. We then translated those shifts into global targets and assessed the world's progress in achieving them. This technical note covers the overall methodology that we applied to all systems on the platform; the methods that are specific to each system (e.g., power, transport) can be found on the methodology page of the platform. Research is ongoing on systems related to biodiversity and equity, so this technical note will be updated as more systems are added to the platform.

This technical note draws heavily on the technical note for the *State of Climate Action* series (Schumer et al. 2022), the *State of Climate Action 2021* report (Boehm et al. 2021), and the *State of Climate Action 2022* report (Boehm et al. 2022). Some parts of this technical note are directly derived from those publications. However, the Systems Change Lab platform is a larger undertaking than the *State of Climate Action* series in that it expands the coverage of climate-focused systems change and includes the protection of biodiversity and the advancement of equity as additional goals.

1. Introduction

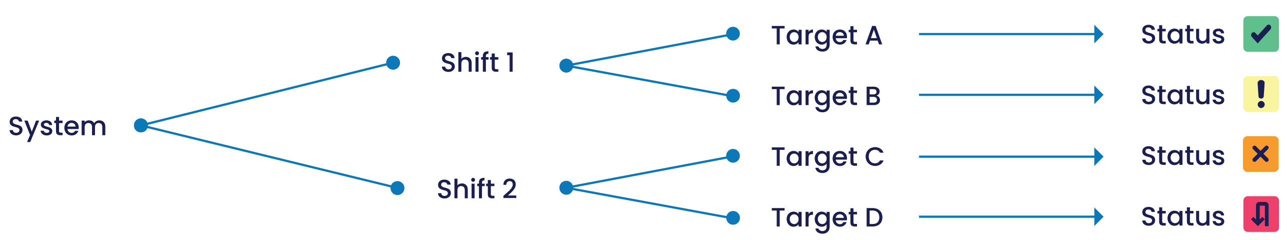
The Systems Change Lab platform (https://www.systemschangelab.org) focuses on three key goals: mitigating climate change, protecting biodiversity, and advancing equity. In their latest assessment reports, the world's most authoritative bodies on climate change and biodiversity find that limiting global temperature rise to 1.5 degrees Celsius (°C) above preindustrial levels, halting biodiversity loss, and ensuring just transitions will require systems change (IPCC 2022a; IPBES 2019).

On the Systems Change Lab platform, we identify key global systems that must transform, the most critical shifts needed within each system, and targets that must be achieved for those shifts to be successful (Figure 1).

We assess progress toward the global targets using relevant indicators and datasets, and if there are sufficient data we categorize recent efforts toward the targets as on track, off track, well off track, or wrong direction.

In this technical note, Section 2 describes our methodology for identifying key global systems. Section 3 explains how we chose the most critical shifts within each system. Sections 4 and 5 describe how we translated these shifts into global targets and selected indicators with accompanying datasets that we use to monitor change for each shift. Section 6 outlines our approach for assessing the world's collective progress made toward the targets. Section 7 details how we identify enabling conditions and barriers that can support or hinder transformations. Section 8 explains limitations to our methodology.

FIGURE 1 | Structure of the Systems Change Lab Platform



Source: Authors.

2. Selection of Key Systems

What Is a System?

A system can be defined as "a configuration of interacting, interdependent parts that are connected through a web of relationships, forming a whole that is greater than the sum of its parts" (Holland 2000). More simply, it is a set of coherently organized, interconnected elements that produce a characteristic pattern of behaviors, which some classify as a function or purpose (Meadows 2008). These component parts can include biotic entities (e.g., plants, animals, and fungi) and abiotic entities (e.g., buildings, rocks, and water), as well as immaterial social, political, economic, and cultural institutions.

Systems exist at different scales. They can be as minute as a single beehive that produces honey or as large as the global food system, which comprises fertilizer and seed companies, farmers, traders, manufacturers, distributers, and grocery stores that, together, feed the world's rapidly growing population. Smaller systems can also be nested within broader systems, such as a beekeeper within a national collective of farmers within the global food system.

Conceptualizations of systems can also vary by their components and relationships, with some focusing primarily on the interactions among people and technology (sociotechnical systems) and others on the connections between people and the natural world (social-ecological systems). Yet, in practice, it remains difficult to divide our highly interconnected world into such neatly defined and discrete systems. Food systems, for example, involve technologies, people, and natural resources and are deeply connected to terrestrial, freshwater, and marine ecosystems. Drawing the boundaries of a system by deciding to emphasize one component or interaction among elements over another, then, is ultimately a subjective exercise that depends on the system in question.

What Is Systems Change?

Calls for systems change have gained traction throughout the global climate change community (IPCC 2018, 2022a; Sachs et al. 2019; Steffen et al. 2018; Victor et al.

2019; IEA 2021a; Puri 2018; United Nations 2019; UNFCCC Secretariat 2021; WBCSD 2021), reflecting an emerging consensus that current efforts have failed to spur deep greenhouse gas (GHG) emissions reductions, halt biodiversity loss, and reduce inequity at the speed and scale required to secure a more sustainable, prosperous, and just future for all. Yet there is no widely accepted definition of systems change, nor is there a shared understanding of how such a process would unfold in practice (Feola 2015; Patterson et al. 2017; Few et al. 2017; Hölscher et al. 2018).

We define systems change as the reconfiguration of a system, including its component parts and the interactions among these elements, such that it leads to the formation of a new system that behaves in a qualitatively different way. This definition draws on commonalities across well-cited definitions in global environmental change research (Walker et al. 2004; Olsson et al. 2006; Folke et al. 2010; Chapin et al. 2010; Biggs et al. 2010; IPCC 2022b; Westley et al. 2011; Rotmans and Loorbach 2009; Geels et al. 2017b; Grin et al. 2010; Waddell et al. 2015).

Given the commonalities across definitions, we use the terms *transformation* and *transition* interchangeably with *systems change*. These terms all essentially describe a change from an initial state of a system to a new state with a different quality or character. Analyzing systems change requires understanding the starting and ending points of the required change—for example, a shift from a deforested pasture for beef cattle to a restored, healthy forest that sequesters carbon dioxide (CO_2), or from a transportation network dominated by fossil fuels to one that supports more sustainable forms of mobility like walking, bicycling, or electrified public transit. Such systems change entails "breaking down the resilience of the old and building the resilience of the new" (Folke et al. 2010). The exact starting and ending points will depend on the nature of the system in question.

Systems changes are often demarcated from incremental changes, which are defined as adjustments to elements or processes within an existing system that do not fundamentally alter its essence or integrity (Few et al. 2017; IPCC 2018, 2022a). New policies that increase the energy efficiency of existing products, for example, can help reduce greenhouse gases emitted from the current energy system in an incremental way, but efforts to phase out fossil fuels represent a transition to an entirely new system of energy delivery and behavior that supplies energy without releasing CO_2 into the atmosphere. Although sometimes conceptualized as a binary, these typologies of change are not mutually exclusive. Incremental shifts can create an enabling environment for future transformations and, in some instances, a progressive series of these lower-order changes can come together in ways that successfully "lock in" a transition to a new system (Levin et al. 2012; ICAT 2020; Termeer et al. 2017). The Systems Change Lab platform identifies both transformational and incremental shifts that, taken together, can help transform nearly all major systems.

Systems Included on the Platform

For the Systems Change Lab platform, we chose to include global systems that when transformed will contribute to achieving the three objectives of stabilizing our climate, protecting biodiversity, and advancing equity. Some of the global systems we selected are most closely related to climate, others to biodiversity, and others to equity. However, most systems are relevant for multiple objectives.

In the following section, we explain our selection of systems as they relate to each of our three objectives.

Climate: In modelled pathways that limit global temperature rise to 1.5°C above preindustrial levels with no or limited overshoot, GHG emissions peak immediately or before 2025 at the latest, and then fall by a median of 43 percent from 2019 levels by 2030 (IPCC 2022a). By around mid-century, CO_2 emissions reach net zero in these pathways. Achieving such deep GHG emissions reductions, the Intergovernmental Panel on Climate Change (IPCC) finds, will require rapid transformations across power, cities and the built environment, industry, transportation, food and agriculture, and forests and land systems—as well as the immediate scale-up of carbon removal technologies to compensate for the significant proportion of the carbon budget that we have already spent and residual GHG emissions that will likely prove difficult to eliminate altogether (IPCC 2022a).

Biodiversity: Similarly, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) finds that achieving goals to conserve and sustainably use nature will require transformative changes, particularly across systems most responsible for land-use and sea-use change, direct exploitation of species, climate change, pollution, and the spread of invasive, alien species (IPBES 2019). These systems include power, industry, cities and the built environment, transportation, and food and agriculture, as well as our management of terrestrial, freshwater, and marine ecosystems.

Equity: Equity is an essential consideration as we pursue the other two goals, as well as an important goal in its own right. There is no one commonly agreed upon definition of equity (Putnam-Walkerly and Russell 2016), but in its most basic sense, equity is the quality of being fair according to circumstances. Closely connected to this definition is that of climate justice, which is "concerned with the equitable distribution of rights, benefits, burdens and responsibilities associated with climate change, as well as the fair involvement of all stakeholders in the effort to address the challenge" (Okereke 2018). Under the umbrella of equity, procedural equity measures the fairness in processes and procedures used in decision making, while distributive equity measures the fairness in the distribution of benefits and burdens of policy action, initiatives, or interventions among different groups. We do not wish to duplicate efforts like the Sustainable Development Goals (SDGs), so on this platform we focus on equity as it relates to transitions to mitigate climate change and protect biodiversity. We monitor it to ensure that these transitions do not exacerbate existing inequities, but rather advance equity. In addition, we plan to include one system, social inclusion and equity, that collects relevant cross-cutting information on equity.

To help meet all three of these goals, other social, political, and economic transformations will be needed. To identify these critical transformations, we reviewed literature across academic disciplines and interviewed experts in topics such as sustainable development, just transition, and degrowth/post-growth. The main transformations we identified in the literature include moving toward a circular economy, good governance, a global financial system that supports sustainability, and a global economy that prioritizes human well-being over economic growth.

Therefore, the systems that the Systems Change Lab platform plans to report on include:

- Power
- Industry
- Transport
- Cities and the built environment
- Technological carbon removal
- Forests and land
- Oceans
- Freshwater
- Food and agriculture
- Finance
- Circular economy
- Good governance
- Social inclusion and equity
- New economics for climate and nature

We are launching the power, industry, transport, cities and the built environment, technological carbon removal, and finance systems along with this technical note. Research is ongoing for the other systems. This technical note will be updated once all systems are included in the platform.

There is no one right way to arrange everything into distinct systems, so we have chosen an arrangement that is relatively comprehensive, compatible with the literature, and speaks to coalitions working in these areas. We use the term *systems* for the above list, but the types of systems covered vary widely. Some of these are systems that look at the relationships between people and technology or between people and the natural world. Others are systems of institutions or approaches that enable transformation in technical or environmental systems. Some are groupings of shifts that cut across systems but have a common theme, so we collect information on those shifts together. All of the systems on the platform overlap and interconnect with each other. Although we have not cataloged these relationships, we plan to do so in the future.

3. Translating Systemwide Transformations into a Concrete Set of Shifts

To measure progress made in accelerating systems change, for each system we translated the change needed into a set of discrete shifts that could be monitored more easily. These shifts can be understood as categories of actions that need to take place to decarbonize the global economy, protect biodiversity, and/or advance equity. For example, we identified four shifts needed to transform the power system: phasing out unabated coal and gas electricity generation; rapidly scaling up renewable electricity generation; modernizing grids, scaling storage, and managing demand; and ensuring energy access and a just and equitable transition for all. We identified these shifts based on a review of the literature for each system and validated them through consultation with internal and external experts.

Some shifts are more closely related to our objectives on climate, others on equity, and others on biodiversity. However, the shifts can contribute to multiple objectives at once. For example, in the food system, reducing global food loss and waste is a shift that could simultaneously protect biodiversity by reducing the amount of agricultural land that is needed, reducing greenhouse gas emissions, and advancing equity and well-being by making food more accessible to all. Actions on climate, biodiversity, and equity can interact with each other in complex ways, so it is important to monitor all three of the goals to ensure that progress on one does not inadvertently lead to backsliding on another.

Shifts Related to Climate

For each of the climate-related systems, we chose a manageable set of critical shifts that, taken together, can help overcome the deep-seated carbon lock-in common to these systems (Seto et al. 2016). Identifying these critical shifts for each system, however, is an inherently subjective exercise, as there are innumerable possible ways to translate a global temperature goal into a set of individual actions. So long as the overall carbon emissions budget is maintained, a range of strategies can be pursued to hold global warming to 1.5°C (e.g., assigning more rapid and ambitious carbon emissions reduction targets to the power system than to the transport system, or vice versa).

However, because the remaining emissions budget is small, the degree of freedom to assign different weights to transformations that must occur in different systems is relatively limited, and the IPCC makes clear that, together, all systems will eventually have to dramatically lower emissions to limit global warming to 1.5°C (IPCC 2022a). So, if a transformation across one system is slower than this global requirement, another needs to transition proportionately faster, or additional CO_2 must be removed from the atmosphere. Arguing that a system needs more time for decarbonization, then, can be done only in combination with asserting that another can transition faster, if our global temperature goal is to be met.[1] A good starting point is asking whether a system can fully decarbonize by 2050. If so, how and how quickly, and if not, why and how much can be done (Climate Action Tracker 2020b)?

To that end, we reviewed modelled pathways that hold global warming to 1.5°C with no or low overshoot from integrated assessment models (IAMs) included in IPCC (2018),[2] as well as recently published peer-reviewed, system-specific roadmaps that limit temperature rise to 1.5°C and bottom-up sectoral estimates of mitigation potential, including those published in IPCC (2022b). In mapping out multiple pathways that the world might take to meet this global temperature goal, these studies consider a range of factors (e.g., cost, interactions and trade-offs among mitigation actions, technical potential, safeguards) when determining each system's mitigation potential, as well as the specific shifts that collectively deliver that system's contribution to limiting global temperature rise to 1.5°C. For each system, we identified both supply- and demand-side shifts common across these studies and then assessed their potential contributions to GHG emissions reduction and avoidance, as well as carbon removal. For inclusion in the Systems Change Lab platform, we prioritized shifts that featured prominently across all or nearly all studies reviewed and which collectively represent the primary actions needed to hold global temperature rise to 1.5°C. We considered additional criteria (e.g., data availability, environmental and social safeguards) when translating these critical shifts into quantitative targets for 2030 and 2050, as noted below.

Shifts Related to Biodiversity

The identification of shifts related to biodiversity is still underway. Methods under development currently focus on addressing the primary direct drivers of biodiversity loss across terrestrial, freshwater, and marine ecosystems. These top drivers of biodiversity loss include land-use and sea-use change, direct exploitation of species, climate change, pollution, and the spread of invasive, alien species. Many of these shifts will sit within the forests and land, oceans, and freshwater systems, but we will also focus on biodiversity impacts in agriculture and the impacts of extractives and pollution on biodiversity as it relates to the circular economy. Further detail will be provided as we expand the systems covered on the platform. We may revisit our approach to biodiversity as more research is done.

Shifts Related to Equity

At present, the equity-focused shifts included in the platform focus largely on access to basic goods (e.g., energy, mobility, shelter, financial services) and a just transition. These shifts are designed to ensure we reach our climate and biodiversity goals in a way that improves the livelihoods of historically marginalized and underserved communities, or at least does not exacerbate existing inequities. More shifts on equity will be developed as we add the good governance and social inclusion and equity systems to the platform.

We will mainly be considering equity as it relates to climate and biodiversity transitions. There will be individual targets and indicators related to equity distributed throughout other climate-related or biodiversity-related shifts to ensure that those shifts do not negatively impact equity (discussed in the following section). Our research is ongoing as to how to best integrate equity into our climate and biodiversity systems. We may revisit our approach to equity as more research is done.

4. Development of Targets and Indicators

Overall Selection of Targets and Associated Indicators

As noted above, the Systems Change Lab platform identifies key systems that must be transformed and a discrete set of critical shifts for each system. For each shift, we selected multiple quantitative global targets to show what specific changes are needed for the shift to occur. The idea is that the sum of the targets in each shift and each system together represent systems change.

We selected targets for the near term (primarily 2030) and, in some cases, additional targets for the long term (primarily 2050). The near-term targets can inform immediate action during this decade and are what we use to categorize whether or not progress is on track. We prioritized the selection of near-term targets, but the long-term targets, when identified, indicate further shifts required to support transformations to a net-zero, equitable, nature-positive world.

We designed the targets to be compatible with the three primary objectives tracked by the Systems Change Lab platform: limiting global warming to 1.5°C, protecting biodiversity, and advancing equity (further detail for each is provided below). Most targets directly contribute to the main objective of the shift they are in, while other targets ensure that pursuing that objective is done in a way that does not negatively impact the other objectives. For example, within the shifts focused on climate, the majority of targets are aligned with limiting global warming to 1.5°C, but some of those shifts also include targets that ensure that the shift also advances equity or biodiversity goals.

Each target has an associated indicator that we can measure to see if progress is being made toward the target. As an example, in the power system, one of the targets is that the "share of power generation from unabated coal falls to 0–2.5 percent in 2030 and 0 percent in 2040" and the indicator that corresponds with that target is "share of unabated coal in electricity generation (%)."

Some indicators are established in the literature as important to understand the general direction of progress toward broader climate, biodiversity, and equity goals, but have no quantitative targets established in the literature. In these cases, we included the indicators on the platform as "targets" even though they do not yet have targets. Platform users can see whether the indicator is going in the right direction or not, but not whether it is changing fast enough, so the status will always say "cannot calculate." We and our partners will attempt to derive new targets for these indicators or add new targets that are established in the literature in future updates to the Systems Change Lab platform. For now, the indicators without targets provide useful information on what is happening today, but we cannot assess whether the progress of the indicator is on track or say at what speed it should be moving.

In many cases, we did not fully capture every target and every indicator that could fit under a particular shift, but we aimed to select the most important or most representative targets. Some systems and some shifts have more targets and indicators than others, but that does not mean they are more important. It simply means that we have identified more discrete elements that can help track progress toward the overall goal.

While our analysis is focused on global systems and shifts, it is critical to consider that some countries and regions are starting from a different place than others and some will require more of a shift than others. Some countries and regions will also have more competing priorities than others. We have developed only global targets, not country targets, but the responsibility and timeline for meeting these global targets may vary among countries.

The reasons why we chose the particular global targets for each system are explained on the platform's system background content page. The targets and indicators were reviewed by several relevant experts for each shift to validate that they were the appropriate choices, and we will continue to gather feedback and update the targets over time.

Proxy Indicators

We primarily selected indicators that correspond directly to our targets, such as the carbon intensity of electricity generation or the share of electric vehicles in light-duty vehicle sales. Some targets, however, cannot be tracked directly, and for those, we selected the best available proxy indicators. For example, we used tree cover gain to assess progress made toward our reforestation targets, yet tree cover gain does not exclusively measure reforestation. Instead, this indicator measures the establishment of tree canopy in areas that previously had no tree cover, including gains due to harvesting cycles in areas that are already established as plantations and afforestation in non-forested biomes. Despite these limitations, we used tree cover gain because its accompanying dataset relies on satellite imagery, rather than infrequent, often outdated field surveys. We provide explanations of proxy indicators where they are used in the system background content page on the platform.

Climate Targets and Indicators

Multiple sources informed our selection of climate-related targets, including modelled pathways holding global temperature rise to 1.5°C with no or low overshoot from the IPCC (2018, 2022b), studies that conducted bottom-up modelling to identify system-specific mitigation pathways, and bottom-up assessments of both technical mitigation potential and cost-effective mitigation with environmental and social safeguards.

Consequently, we present targets as either a single number or a range of values. When applicable, we present a range of values to account for assumptions underlying distinct modelling approaches. The more and less ambitious bounds reflect varying degrees of trade-offs in decarbonization with other targets or systems, and/or uncertainty in terms of technical and economic feasibility (Climate Action Tracker 2020b). Reaching the least ambitious targets[3] across all systems will not likely be sufficient for achieving the Paris Agreement's 1.5°C global temperature goal. Consequently, only by achieving the more ambitious bound of some targets (e.g., phasing out coal as quickly as possible) will we create room for some systems to achieve their least ambitious bounds where decarbonization is difficult and therefore slower.

It is critical to note here that many selected targets are interdependent. Changes in one target can further or hinder another; for example, greater penetration of zero-carbon power on the electric grid would enable significant progress in decarbonizing industrial processes, while failure to sustainably increase crop yields could result in agricultural expansion across forests, spurring increases in deforestation.

Environmental and social safeguards

In selecting 1.5°C-aligned targets for inclusion in the Systems Change Lab platform, we employed various environmental and social safeguards where possible. Across power, buildings, industry, and transport, for example, we primarily adopted targets from modelled 1.5°C pathways from IAMs and bottom-up, system-specific studies that do not exceed environmental sustainability constraints identified by the IPCC for two land-based carbon removal strategies: bioenergy with carbon capture and storage (BECCS), and afforestation and reforestation (Climate Action Tracker 2020a). We similarly constrained our technological carbon removal targets to include levels of BECCS that avoid unintended negative impacts on food security, biodiversity, and/or net emissions from land-use change associated with accessing biomass feedstocks (Fuss et al. 2018).[4] For BECCS, specifically, this limit is 5 gigatonnes of carbon dioxide per year ($GtCO_2$/yr) between 2050 and 2100, while afforestation and reforestation is limited to 3.6 $GtCO_2$ /yr between 2050 and 2100. (Climate Action Tracker 2020a).

In selecting 1.5°C-aligned targets, our research of the literature filtered scenarios to focus only on those that minimize or do not include carbon capture, utilization, and storage (CCUS) in the power system. Today's CCUS systems can capture 90 percent of CO_2 emissions from a specific facility (IEA 2021a). Although future capture rates may increase, most CCUS systems—even under the most idealized, theoretical conditions—would still fall short of capturing 100 percent of CO_2 emissions (Brandl et al. 2021).[5] CCUS systems use additional water and energy (including causing upstream methane emissions through the use of natural gas) and increase operational expenses. Well-characterized and accessible geologic sequestration sites will also be needed to sequester captured CO_2.

For industry, CCUS remains one of the best available options for lowering CO_2 emissions from high-heat processes and non-combustion processes (e.g., calcination in cement production), which may prove difficult to eliminate. Similarly, in transport, CCUS may play a role in the development of fuels, such as ammonia and hydrogen, for harder-to-abate forms of travel, including aviation and shipping. Carbon capture and storage also has a role in 1.5°C pathways, when combined with bioenergy or direct air capture, as a form of carbon removal. So, while we consider CC(U)S to be a viable option for industry and carbon removal, and to play an indirect role in transport, we do not consider it as an option for fossil fuel combustion in the power system.

Across food and agriculture and forests and land, we selected targets that, if achieved, would not threaten food security, spur biodiversity loss, or undermine fiber production. All targets for reforestation and restoration, specifically, do not exceed those outlined by Griscom et al.'s global "maximum additional mitigation potentials," which are technical estimates of mitigation potential constrained by social and environmental safeguards (Griscom et al. 2017; Roe et al. 2019, 2021). In calculating this maximum additional mitigation potential for reforestation, for example, Griscom et al. (2017) limited forest cover gain to landscapes that are ecologically appropriate for forests, removed all existing croplands from their estimate of maximum potential extent to avoid dampening yields, and excluded the boreal region due to changes in albedo that would have a net warming effect. The area associated with this maximum additional mitigation potential is 678 million hectares (Griscom et al. 2017), which our reforestation target does not exceed (Roe et al. 2021). Similarly, our food and agriculture targets seek to avoid additional ecosystem conversion, as well as free up farmland for reforestation and restoration, by reducing agriculture's land footprint below its 2010 global extent, while also mitigating GHG emissions from production processes and feeding 10 billion people (Searchinger et al. 2019, 2021).

Finally, we did not systematically consider cost in selecting our targets. We derived some targets from models that optimize for least-cost pathways (e.g., IEA 2021b and BloombergNEF 2021), while for others, we selected those that the literature considers cost-effective (e.g., Roe et al. 2021). For targets presented as ranges, the less ambitious bound is often informed by least-cost scenarios modelled by IAMs, and the more ambitious bound does not account for cost-effectiveness (e.g., Climate Action Tracker 2020a). Others still, particularly those focused on mitigation across the global food system, do not include cost considerations (e.g., Searchinger et al. 2019). This variation reflects the broader diversity in top-down and bottom-up estimates of mitigation potential for specific actions, as well as our decision to prioritize other factors, such as social and environmental safeguards, over cost in our selection of targets.

We'll aim to identify further safeguards related to biodiversity and equity as we expand our analysis on the platform.

Biodiversity Targets and Indicators

Efforts to identify biodiversity-related targets and indicators are underway and will be launched as new systems are added to the platform, focusing on the direct drivers of biodiversity loss in forests and land, oceans, freshwater, food and agriculture, and the circular economy. It is an open question whether we want to include biodiversity-related targets and indicators for the systems that are already on the platform to assess their impact on biodiversity.

There is no internationally negotiated acceptable amount of biodiversity loss, unlike in the climate change community, where 1.5°C is a politically agreed upon target for climate. Therefore, we are developing methods to select targets that maximize the protection of biodiversity in all its forms (e.g., genes, species, ecosystems), while minimizing trade-offs that could impede efforts to deliver basic goods, services, and opportunities to all or constrain efforts to mitigate climate change. Even if we are unable to identify specific, quantitative targets for biodiversity, monitoring biodiversity indicators will provide useful information that will help platform users determine whether the world is moving in the right direction on these goals. We will provide further detail as we expand the biodiversity-related content on the platform.

Equity Targets and Indicators

Equity is a key consideration as we meet our objectives of limiting global temperature increase to 1.5°C and protecting biodiversity. It is also an important objective in its own right. However, it is not a given that equity will automatically improve as a result of improvements in the other systems: It is possible to achieve systems transformations for climate and biodiversity in which inequities are exacerbated. Therefore, we include equity targets and indicators within the climate- and biodiversity-focused systems and shifts, as well as the equity-specific shifts.

However, defining and developing global equity targets is a challenging task given the complexity of the issue and the lack of international consensus on the definition of equity. Equity targets are not directly derived from a specific overall goal (like the 1.5°C goal is for climate targets), but rather are representative of a series of dimensions relating to justice and equity that are relevant for systems transitions (Muñoz Cabré and Vega Araújo 2022; Heffron and McCauley 2022, 2017). Our equity-related targets and indicators are not comprehensive, as it would be extraordinarily difficult to ensure that we were accounting for every individual variable in determining equity. Instead, we focused on finding an indicative selection of equity targets and indicators that were related to climate and biodiversity for the systems in question. We focused first on including equity indicators where data were available, then identified other key indicators where data were not available. Many equity indicators do not have targets, but for some indicators we derived targets from the Sustainable Development Goals or other commonly agreed-upon sources. We will expand coverage of equity more in the future.

The two guiding principles for equity targets and indicators were access to goods and services and the distribution of positive and negative impacts. As of yet, we haven't been able to identify sufficient indicators for procedural justice.

On access, targets and indicators were selected relating to access to basic needs and access to sustainable technologies and services. This includes indicators covering access to electricity, access to zero-emission mobility, and access to clean cooking.

On achieving an equitable distribution of positive and negative impacts, the philosophy in defining the indicators was to have indicators representative of the following dimensions: jobs, gender, human rights, health, inequality between developed and developing countries, and distributions of investment and economic benefits. In some cases, these dimensions apply to access as well. All of these indicators can have very different outcomes in different geographic areas, so we aim to provide country-level data on the platform where possible using our map view.

Within the jobs dimension, we also considered subcategories focused on three elements of a just transition: decent work opportunities and income for workers, access of workers to training and skills for new occupations, and support for workers displaced by closures or measures related to climate change. There are a range of additional variables with the ability to assess the fairness of the transition which we did not include. For example, the just transition framework of the International Labour Organization emphasizes social dialogue and the respect for fundamental labor principles and rights (ILO 2015), but measurable indicators do not currently exist for all elements of this framework. The concepts related to the green economy are being incorporated gradually within labor statistics, and the lack of data is a methodological challenge affecting almost all indicators of a just transition.

Given the vast array of potential indicators to convey progress (or lack thereof) on these dimensions, priority was given to those indicators where robust and publicly accessible data were available. For some of the indicators, we derived targets from the Sustainable Development Goals, while others do not have targets. More details on all of these targets and indicators can be found in the system background content pages on the platform.

5. Selection of Datasets

To assess global progress made toward the targets for 2030, we first collected historical data for every indicator. We plan to update the data annually. Our selection of these datasets followed these six principles to ensure that all data are open, independent of bias, reliable, and robust:

- **Relevance.** Datasets selected directly measure each indicator, meaning they were created following a methodology and using types of units that are consistent with the units of the indicator in question.
- **Accessibility.** Datasets are readily accessible to the public. They are generally not hidden behind paywalls, and they are ideally subject to an open data license.
- **Accuracy.** Datasets are from reputable, trustworthy sources and have well-documented, openly accessible, and peer-reviewed methodologies that clearly note limitations. They are taken from data providers, including both authors of articles and organizations hosting datasets, that are either well recognized as core data providers or known experts in their fields (as suggested by authors and reviewers).
- **Completeness.** Datasets have sufficient temporal and spatial coverage. We note where the best available data are not globally available or are not published annually.
- **Timeliness.** Datasets selected represent the most up-to-date data available to reflect recent developments, and there is evidence that data have been and will be updated regularly. However, in many instances, there is a time lag before the best available data are published, and as such, the year of most recent data varies among indicators.
- **Ease of Collection.** Datasets prioritized for each indicator are relatively easy to collect and update (e.g., those that require minimal processing or that are directly downloadable). However, in some instances, data selected require some calculations and processing (e.g., geospatial data).

If multiple potential datasets for an indicator were similar, we chose the dataset that best followed the above criteria, was most comprehensive, and was easiest to access through a data sharing agreement. Within the Systems Change Lab platform, the datasets used to assess global progress are clearly noted for each indicator. Our first priority is to identify global data, but we also collect and present data at the country level when it is available. However, we do not assess progress at the country level as of yet.

In many cases, data limitations prevented us from assessing global progress toward a target, and we noted these accordingly. We followed these six principles as closely as possible, but given that there are so many indicators with limited data, following them too strictly would have left more of the platform empty. Therefore, in some cases we included data that did not meet all six principles when we deemed that it was still useful to understand the topic. We noted the limitations, particularly when the indicator is categorized as “on track.” Up to this point, most of the data we have used do meet all of the criteria. However, certain indicators do not meet the criteria of ease of collection and/or timeliness. If the datasets aren’t up to date, however, it ultimately doesn’t affect our confidence in the years of data we do have. In the future as we start researching and adding more systems that don’t have as much quality data (e.g., land-use-based systems), we may consider other options for highlighting data limitations.

6. Assessment of Progress Toward Targets

Selecting targets, indicators, and datasets allows us to learn about the recent progress that has been made and evaluate whether the world is on track to meet the goals of stabilizing the climate, protecting biodiversity, and advancing equity. Our assessment provides a snapshot of global progress across each system and each shift that can help the world take stock of shared efforts.

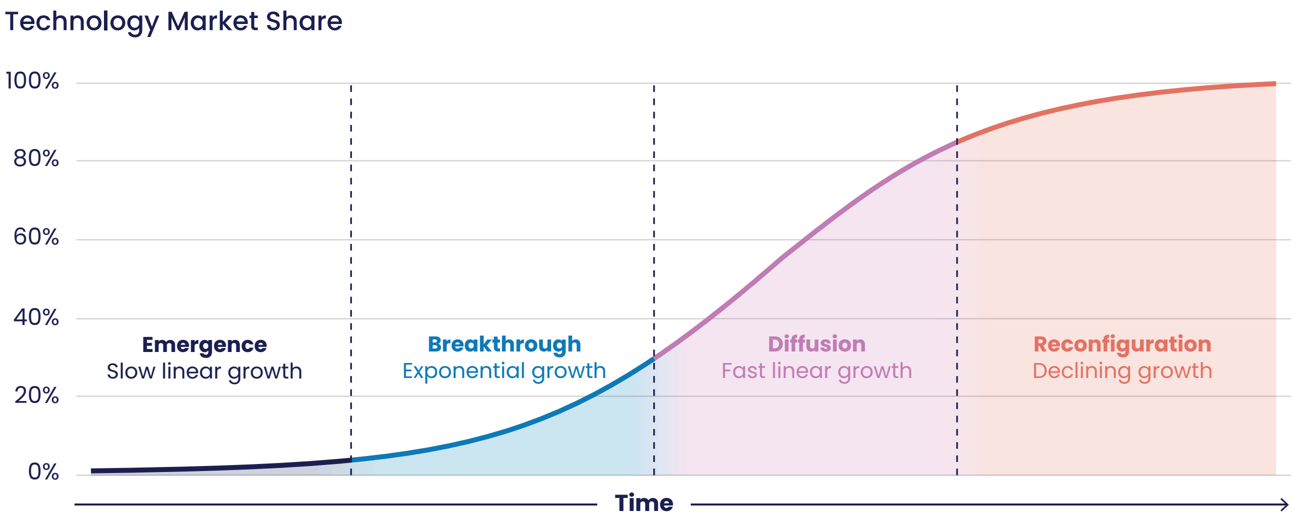
Assessing the gap between recent progress and future action needed to meet our targets required us to project a trajectory of future change for each indicator. The simplest way is to assume that growth continues at its current rate of change following a linear trajectory, and indeed this is an effective method for some indicators. However, it is unlikely that all indicators will follow a linear path. In this section we first provide background on why some indicators, and particularly those focused on technology adoption, may follow nonlinear paths. Then we explain the methods we used to determine whether indicators are on track to meet their targets, which required making adjustments for indicators that are likely to follow nonlinear paths.

Background on the Potential for Nonlinear Change

Many mainstream assessments still use linear assumptions for forecasts when they are not warranted. For example, in its Stated Policies Scenarios, the International Energy Agency (IEA) has historically assumed that future growth in solar photovoltaic (PV) generation would be largely linear. However, it has had to repeatedly increase the amount of solar PV generation in these forecasts, as the technology has grown exponentially. In 2012, for example, the IEA estimated that global solar energy generation would increase to 550 terawatt-hours in 2030, but that number was instead reached by 2018. Other institutions have similarly underestimated the path of solar and wind, such as the U.S. Energy Information Administration in its *Annual Energy Outlook* (Saha and Jaeger 2020). Even if it is likely that most technologies will grow in a nonlinear manner, it is difficult to predict the exact path they will follow, which is one reason projections stick to linear assumptions. Linear assumptions often suffice for short-term projections, but longer-term projections should consider the potential for systems change and nonlinear growth.

When considering how to track nonlinear progress, it is important to consider that the adoption of new technologies has often followed a roughly S-curve trajectory (Figure 2). At the emergence stage of an S-curve, progress is linear and quite slow. Then, once a breakthrough is reached, it accelerates exponentially. This exponential growth continues until the technology reaches its maximum speed of uptake. This is the steepest part of the curve, which is linear again but growing at a much faster rate. Most of the diffusion of the technology occurs during this stage. Finally, as the technology approaches a saturation point, growth gradually slows down once again. This S-curve concept can be expanded beyond a specific technology to the broader transition from one socio-technical system to another, such as the entire power sector (Victor et al. 2019).

FIGURE 2 | Illustration of an S-curve



Source: Authors. Adapted from Boehm et al. (2021) and Grubb et al. (2021).

The inflection point on an S-curve in the breakthrough stage can be conceptualized as a tipping point. A tipping point is defined broadly as a critical threshold beyond which a system reorganizes often abruptly or irreversibly (IPCC 2022a). In the context of technology adoption, a tipping point generally occurs when the cost of a new technology falls below that of the incumbent. Factors beyond monetary cost, such as an improvement in the technology or an increase in the value of the technology as more people adopt it, can also push technology adoption past a tipping point. Often, seemingly small changes in these factors can trigger disproportionately large responses within systems that catalyze the transition to different future states (Lenton et al. 2008; Lenton 2020).

Once tipping points are crossed, self-amplifying feedbacks help accelerate the diffusion of new technologies by lowering costs, enhancing performance, and increasing social acceptance (Arthur 1989). Learning by doing in manufacturing, for example, can generate progressive advances that lead to more efficient production processes, while reaching economies of scale enables companies to distribute the high costs of improvements across a wider customer base. Similarly, as complementary technologies (e.g., batteries) become increasingly available, they can boost functionality and accelerate the uptake of new innovations (e.g., electric vehicles) (Sharpe and Lenton 2021). These gains allow companies that adopt new technologies to expand their market share, deepen their political influence, and amass the resources needed to petition for more favorable policies. More supportive policies, in turn, can reshape the financial landscape in ways that incentivize investors to channel more capital into these new technologies (Butler-Sloss et al. 2021). These reinforcing feedbacks spur adoption and help new innovations supplant existing technologies (Victor et al. 2019).

Widespread adoption of new technologies, in turn, can have cascading effects, requiring the development of complementary innovations, the construction of supportive infrastructure, the adoption of new policies, and the creation of regulatory institutions. It can also prompt changes in business models, availability of jobs, behaviors, and social norms, thereby creating a new community of people who support (or sometimes oppose) further changes (Victor et al. 2019).

Meanwhile, incumbent technologies may become caught in a vicious spiral, as decreases in demand cause overcapacity and lead to lower utilization rates. These lower utilization rates, in turn, can increase unit costs and lead to stranded assets. Thus, for technologies with adoption rates that are already growing nonlinearly or could be expected to grow at an exponential pace in the future, it is unrealistic to assess progress by assuming that future uptake will follow a linear trajectory (Abramczyk et al. 2017; Mersmann et al. 2014; Trancik 2014). In addition to technology adoption, social and political forces can also contribute to or hinder nonlinear change (Moore et al. 2022). Our assessment of recent progress made toward near-term targets did not consider them fully, given the challenges of modelling these effects and data limitations. However, a body of research is emerging on this topic, and we will aim to consider these effects in future iterations of the platform as we expand the systems included.

Methodology for Assessment of Progress Toward Targets

To assess global progress made toward our targets, we used the following steps for each indicator:

Step 1: Determine whether exponential change is unlikely, possible, or likely.

Step 2: Calculate an acceleration factor by comparing a linear trendline based on the last five years of historical data with the average annual rate of change needed to achieve an indicator's 2030 target. Using the acceleration factor, we assigned the appropriate progress status to the indicator. An acceleration factor of 0-1 means it is on track, 1-2 is off track, >2 is well off track, and <0 is wrong direction. The final status is "cannot calculate."

Step 3: Adjust the status of progress where appropriate.

- If exponential change is unlikely for the indicator, we used the status determined by the acceleration factor.
- If exponential change is possible for the indicator, we used this status but noted that change may occur faster than expected.
- If exponential change is likely for the indicator, we consulted the literature and experts to determine if the status should be adjusted.

In the following sections, we explain each of these steps in detail.

Step 1: Determine Each Indicator's Potential for Nonlinear Change

First, we evaluated the likelihood that each indicator will experience exponential change[6] and placed indicators into one of three categories based on our understanding of the literature and consultations with experts:

- *Exponential change unlikely*: We identified indicators that we do not expect to follow the S-curve dynamics seen in technology diffusion, given that they do not directly track technology adoption. These often fall within systems related to food and agriculture and forests and land, as well as finance (e.g., reforestation, ecosystem restoration, reducing food waste, increasing finance flows).
- *Exponential change likely*: We considered indicators that directly track the adoption of specific technologies, or in some instances a set of closely related technologies, to be prime candidates for following S-curve dynamics, though it is not guaranteed that they will do so. These technologies are innovative, often displacing incumbent technologies (e.g., zero-carbon electricity, electric vehicles, green hydrogen).
- *Exponential change possible*: Finally, we identified indicators that do not fall neatly within the first two categories, with most tracking technology adoption indirectly (e.g., those focused on carbon or GHG emissions intensity). While many factors, such as increases in resource efficiency, may impact future changes in these indicators, the adoption of innovative technologies will likely also have an impact on their future trajectories. Thus, although these indicators have generally experienced linear growth in the past, they could experience some unknown form of nonlinear, exponential change in the coming decades if the nonlinear aspects grow to outweigh the linear aspects.

  For example, reducing carbon intensity in the power sector is dependent on multiple trends: an increase in the efficiency of fossil fuel power, which is linear; a switch between higher-emitting and lower-emitting fossil fuel power, which is generally nonlinear; and a switch from all types of fossil fuel power to zero-emissions power, which is expected to be nonlinear. If the nonlinear growth in zero emissions power overtakes the linear growth in efficiency, the trajectory of carbon intensity could follow an inverted S-curve.

Step 2: Assess Progress Based on Acceleration Factors

For each indicator with sufficient historical data, we calculated a linear trendline, also known as a line of best fit, based on the most recent five years of historical data (Box 1).[7] We extended this trendline out to the near-term target and compared this projected value to the indicator's target for that same year. Doing so enabled us to assess whether or not recent progress made toward the target is on track.

Next, we calculated an "acceleration factor" for each indicator by dividing the average annual rate of change needed to achieve the indicator's near-term target[8] by the average annual rate of change derived from the historical five-year trendline. These acceleration factors quantify the gap in global action between current efforts and the targets. They indicate whether recent historical rates of change need to increase by twofold, tenfold, or twentyfold, for example, to meet near-term targets.[9] We then used these acceleration factors to assign our indicators one of five categories of progress:

- **On track.** The recent historical rate of change is equal to or above the rate of change needed. Indicators with acceleration factors between 0 and 1 fall under this status. However, we do not present these acceleration factors, since the indicators are on track.
- **Off track.** The historical rate of change is heading in the right direction at a promising yet insufficient pace. Indicators with acceleration factors between 1 and 2 fall under this status.
- **Well off track.** The historical rate of change is heading in the right direction but well below the pace required to achieve the 2030 target. Indicators with acceleration factors of greater than or equal to 2 fall under this status, meaning that they need to more than double their pace to be on track.
- **Wrong direction.** The historical rate of change is heading in the wrong direction entirely. Indicators with negative acceleration factors fall under this status. However, we do not present acceleration factors for these indicators as a reversal in the current trend is needed, rather than an acceleration of recent change.
- **Cannot calculate.** Limited historical data or a lack of a target made it impossible to estimate the historical rate of change relative to the required action.

Note that we calculated acceleration factors and assessed progress needed to reach only the near-term (e.g., 2030) targets, not the long-term (e.g., 2050) targets for the indicators that have them.

BOX 1 | COVID-19's Impact on Assessment of Progress

Government responses to the COVID-19 pandemic caused widespread changes in human behavior in 2020, such as people spending less time in commercial building spaces and making fewer trips, that likely impacted many of the indicators tracked in this report. In some cases, these changes are likely temporary, as there is little evidence that they have spurred structural changes and preliminary analysis suggests that GHG emissions are already rebounding (e.g., buildings sector emissions dropped by around 10 percent from 2019 to 2020, but initial evidence for 2021 is that emissions in the sector rebounded and the progress will not be sustained.[a]

But for others, new policies or practices adopted during COVID-19 may have long-term impacts (e.g., the rollback of environmental regulations in some countries or increased public financing for fossil fuels). It may take many decades to evaluate the permanence of measures adopted during the pandemic, as well as their impacts on global progress made toward our targets. Changes in carbon intensity indicators, for example, cannot be clearly attributed to measures adopted to slow the spread of COVID-19.

Thus, for each indicator with a 2020 data point, we included this value in our linear trendline calculations unless the latest science indicated that this change was temporary. We considered whether there had already been a rebound in annual data for 2021 or later. If annual data were not available, we considered semi-annual data in our determination. We also considered other qualitative research and observations if necessary. In these instances where the change did appear to be temporary, we showed the 2020 value in the chart, but excluded it from our linear trendline calculations and categorizations of progress. The removal of the 2020 value is noted where applicable.

Note: [a] IEA 2022; UNEP 2021.

Step 3: Make Additional Adjustments for "Exponential Change Likely" Indicators

For indicators that are categorized as "**exponential change unlikely**," we simply used the linear trendline and associated acceleration factors to assign the status of progress. For indicators that are categorized as "**exponential change possible**," we also used the linear trendline and associated acceleration factors to assign the status of progress, but it is critical to note that these linear trendlines form a baseline or floor for action. If nonlinear change begins, progress may unfold at significantly faster rates than expected, and the gap between the existing rate of change and required action will shrink.

However, for indicators categorized as "**exponential change likely**," adoption of new technologies will likely spur rapid, nonlinear change in the coming decades, and future trajectories of growth may resemble an S-curve. For these indicators, acceleration factors based on linear trendlines likely underestimate the pace of future change, as well as overestimate the gap in required action to reach the global targets. Therefore, we used the acceleration factor method only as a starting point for our evaluation of "exponential change likely" indicators, then if needed we adjusted the categorization to account for exponential change based on our qualitative research of the literature and expert consultations.

In the following section, we explain the steps we took for "exponential change likely" indicators:

A. Use the acceleration factor based on the linear trendline as a starting point to categorize the indicator.

B. Consider what stage of an S-curve the indicator is in:

- *Emergence*: In this stage, the rate of adoption is slow and still fairly linear. Indicators in this stage will almost always be "well off track" based on the linear trendline. However, when categorizing an indicator's progress, we also considered whether a breakthrough is near, which would mean that it would outperform the linear trendline.
- *Breakthrough*: In this stage, change is exponential. When categorizing the progress for indicators in this stage, we took into consideration that they will usually outperform the linear trendline.

- *Diffusion*: In this stage, the rate of adoption has reached its maximum steepness. Growth is linear but fast. When categorizing progress for indicators in this stage, we considered that they are likely to approximately follow the linear trendline for a while, but eventually will under-perform the linear trendline.
- *Reconfiguration*: In this stage, growth is declining as it approaches the saturation point. When categorizing progress for indicators in this stage, we considered that they are likely to underperform the linear trendline.

C. Review the literature and consult with experts to consider nonlinear growth.

For some indicators, existing literature evaluating their progress already employs a range of methodologies to consider nonlinear change. This could be in the academic peer-reviewed literature or the gray literature. For example, we reviewed current policy projections from institutions like BloombergNEF that make future projections that consider more than just linear growth. We reviewed these studies and reports to assess the likelihood that each indicator's future growth will outperform what is suggested by the linear trendline, weighing the results based on the methods' rigor and the extent to which consensus exists across sources. We also evaluated whether the literature finds that recent rates of change need to increase by less than two times (off track) or by greater than two times (well off track), if the targets in the literature align with ours, or if we are able to compare the literature's projections to our targets.

Given time constraints, we weren't able to review all available literature. The literature is particularly important when considering technology-specific indicators that do not have enough data to show the rate of historical growth or assign an acceleration factor because they are so nascent. If the literature shows that the development of these technologies is advancing quickly, even in the pre-deployment stage, we can reasonably say the indicator is progressing in the right direction but is "well off track" at a minimum, noting that nonlinear change is possible.

System experts around the world reviewed our categorizations, commenting on the extent to which they agreed with our assessment of each indicator's progress. We took these comments into consideration when categorizing progress.

D. Decide whether to adjust the status of progress.

We defaulted to keeping the indicator in the original status, but if we found compelling evidence that it should be changed, we updated its status of progress and explained why.

We will likely adjust these methods as data availability improves and the literature on nonlinear growth increases. But given the immediate need to move beyond linear thinking, it is important to acknowledge and grapple with the possibility of nonlinear growth, while also recognizing that assessing it entails considerable uncertainties.

Drawing Illustrative S-curves

For indicators that are "exponential change likely" and have at least one historical data point, we presented S-curves as dotted lines in the graphs to show one possible pathway for what's needed to meet the near-term and long-term targets, starting from wherever we are at today. These S-curves are simply illustrative drawings. They are not intended to be the only pathways to reach the targets and are not predicting what future growth will be. We used a simple logistic S-curve formula to create these figures, but also adjusted the S-curves manually in some cases to ensure they matched up with the targets and were not too steep or shallow. Generally, our drawings are symmetrical, with the speed of acceleration in the first half mirrored by the speed of deceleration in the second half, but this symmetry is often not replicated in reality. When we drew S-curves, we ensured that the target years were aligned with 1.5°C, but we did not check to determine whether all the other years on the curve were consistent with 1.5°C based on an accounting of the carbon budget.

7. Selection of Enablers and Barriers

In addition to presenting targets and assessing their progress for each shift on the platform, we also identified enablers and barriers that influence systems change. These differ from the targets described above because they do not directly reflect progress on high-level outcomes (e.g., number of electric vehicles on the road, number of hectares reforested) that contribute to our goals of limiting climate change, protecting biodiversity, and improving equity. Instead, they may contribute to or hinder the achievement of these targets. Given the complexity of determining causal connections, we present on the platform a range of relevant enablers and barriers, rather than a comprehensive accounting and prioritization of every possible enabler or barrier within each system.

The specific enabling conditions that support systems change range widely, but in the *State of Climate Action* series, we identified five common categories that enable climate action: innovations, regulations and incentives, strong institutions, leadership from key change agents, and shifts in behavior and social norms (Table 1). We used these same categories as the basis for identifying enabling conditions for the systems in the Systems Change Lab platform. While we present these five categories of enabling conditions as discrete from one another, we also recognize that, in reality, supportive measures may fall into more than one category.

TABLE 1 | Enabling Conditions for Systems Change for Climate Action

CATEGORIES OF ACTION	EXAMPLES OF SPECIFIC ACTIONS	DESCRIPTION (examples focus on climate action, but the categories of action can also be applied to other goals)
Innovations in technology, practices, and approaches	Development and adoption of complementary technologies Investments in research and development Research networks and consortiums Education, knowledge sharing, and capacity building Experimentation, pilot projects, demonstrations, and other early application niches	Innovations, which broadly encompass new technologies, practices, and approaches, often offer solutions to seemingly intractable challenges. Investments in research and development, support for research networks and consortiums, and universal access to education provide a strong foundation for innovation. Similarly, creating protected spaces for experimentation, pilot projects, and small-scale demonstrations facilitates learning that can lead to improvements in performance and reductions in cost. Developing complementary technologies (e.g., batteries and charging infrastructure for electric vehicles) can also boost functionality and support widespread adoption of innovations.
Regulations and incentives	Economic incentives, such as subsidies and public procurement; economic disincentives, such as subsidies reform, taxes, and financial penalties Noneconomic incentives, including removal of bureaucratic hurdles, measures that spotlight good or bad behavior to influence reputations, transitional support to affected communities, or giving ownership of natural resources to local communities Quotas, bans, regulations, and performance standards	By establishing standards, quotas, bans, or other “command-and-control” regulations, governments can not only mandate specific changes but also create a stable regulatory environment, often cited as a prerequisite for private sector decarbonization. Using non-economic or market-based instruments to create incentives (or disincentives) can also shape action from companies, nonprofit organizations, and individuals—and, in some contexts, may be more politically feasible than command-and-control regulations. For subsidies in particular, revenues must be raised to cover these costs, and the mechanisms to do so will also vary by system and region.

Strong institutions	Establishment of international conventions, agreements, and institutions	Establishing new institutions or strengthening existing ones can ensure that the policies designed to reduce GHG emissions are effectively implemented. These institutions can enforce laws, monitor compliance with regulations, and penalize those who break the rules. Creating more transparent, participatory decision-making processes at all levels of government can also help reconfigure unequal power dynamics and enable marginalized communities—those who have often suffered from business-as-usual actions and who generally have the most to gain from transitions to new systems—to steer transformations to a net-zero future.
	Creation of national ministries, agencies, or inter-agency taskforces	
	Changes in governance, such as more participatory, transparent decision-making processes or natural resource management	
	Efforts to strengthen existing institutions by, for example, increasing staff, funds, or technological resources	
Leadership from change agents	Leadership from national and subnational policymakers, such as setting ambitious targets and developing plans to achieve them	Successful transitions often depend on sustained, engaged leadership from a wide range of actors who envision new futures, develop roadmaps for change, initiate actions, and build coalitions of those willing to help implement these plans. While these champions may lead governments, companies, and nonprofit organizations, they need not always sit at the helm of an institution. Civil society organizations, as well as social movements, can effectively pressure those in power to accelerate transitions, and beneficiaries of these changes play an important role in resisting attempts to return to business as usual. Diverse, multistakeholder coalitions that bring these champions together can be a powerful force for change, unifying disparate efforts, pooling resources, and counterbalancing well-organized, influential incumbents.
	Leadership from incumbents in the private sector, such as establishing ambitious climate commitments and adopting good practices to implement them	
	Diverse, multistakeholder coalitions	
	Beneficiaries of transitions	
	Civil society movements	
	Research networks and consortiums	
Behavior change and shifts in social norms	Changes in behavior	Through educational initiatives, public awareness campaigns, information disclosure, or targeted stakeholder engagement, agents of change can make a clear, compelling case for transitions, explain the consequences of inaction, and identify concrete steps that individuals can take to help collectively accelerate transitions. They can build consensus for a shared vision of the future, as well as prime people for behavior change interventions. As social norms begin to shift, so too will the policies communities support, the goods and services they demand, and their consumption patterns.
	Shifts in social norms and cultural values	

Sources: Enabling conditions were identified from a synthesis of the following studies: Chapin et al. 2010; Few et al. 2017; Folke et al. 2010; Geels et al. 2017a; Geels and Schot 2007; Hölscher et al. 2018; ICAT 2020; Levin et al. 2012; Moore et al. 2014; Olsson et al. 2004; Otto et al. 2020; O'Brien and Sygna 2013; Patterson et al. 2017; Reyers et al. 2018; Sharpe and Lenton 2021; Sterl et al. 2017; Victor et al. 2019; Westley et al. 2011; Levin et al. 2020; Bergek et al. 2008; Hekkert et al. 2007.

Our selection of these five categories was informed by a review of the academic literature on transition, transformation, and systems change theory in the global environmental change research. We also assessed case studies of historical transitions of sociotechnical systems (e.g., power, transport, and industry) and transformations of social-ecological systems (e.g., management of forests and wetlands).

We used these overarching categories of enabling conditions that support systems change to identify them for each system. We reviewed the academic literature, as well as peer-reviewed, well-cited papers published by independent research institutions, United Nations agencies, and high-level sectoral coalitions (e.g., Energy Transitions Commission and the High Level Panel for a Sustainable Ocean Economy) to identify critical barriers to transformational change within each system, as well as key enabling conditions across these five overarching categories that may help decision-makers surmount such obstacles.

We also identified equity-related enabling conditions that apply to equity-related shifts and equity-related targets in other shifts. These enablers were selected based on the five categories, but not limited to those categories. So far, most of the enablers and barriers we've included relate to a just transition. These indicators were selected with three categories in mind: improving skills, institutional factors, and economic factors. For example, we selected enabling conditions related to the number of active programs to relocate fossil fuel workers to other jobs, the number of firms offering training in skills for clean energy, and the number of jobs in green sectors. Our analysis of equity-related enabling conditions and barriers will become more systematic and expansive as we develop the equity-focused systems on the platform and as we further explore equity considerations for all systems.

Exogenous changes, including both shocks (e.g., economic recessions, conflicts, or pandemics) and slower-onset events (e.g., demographic shifts), can also create windows of opportunity for transformation by destabilizing existing systems. These external forces, for example, can focus public attention on reducing previously unseen risks, motivate policymakers to adopt niche innovations to address new crises, or create space for leaders who support transforming existing systems to win elections. On the other hand, exogenous shocks can also spur backlash against change. Given that such crises are often immediate, unforeseen, and disruptive, we did not include them in our identification of enablers and barriers.

After we identified which enablers and barriers to focus on, we then attempted to find indicators and datasets that most closely reflected them. We did not identify targets for these enablers or barriers. Given that there are no targets, and that some are barriers while some others are supportive measures, it does not always mean that it is a positive development if the indicator is going up. In future updates of the Systems Change Lab platform, we plan to expand and improve our analysis of enablers and barriers across all of our goals. We may include targets for enablers and barriers if they are well established in the literature.

8. Key Limitations

Improvements to address these limitations will be sought in future iterations of the platform.

Incomplete Consideration of All Systems

We are launching the power, industry, transport, cities and the built environment, technological carbon removal, and finance systems along with this technical note. The others will be launched on a rolling basis, and this technical note will eventually be updated. In particular, we will be adding new systems focused on forests and land, oceans, freshwater, food and agriculture, circular economy, good governance, social inclusion and equity, and new economics for climate and nature. As we add these systems, we will further refine our consideration of biodiversity and equity as they relate to the existing systems as well.

Lack of Prioritization of Systems, Shifts, or Targets

Systems change requires a complex web of shifts. Accordingly, this introduces limitations in the way that the findings on the Systems Change Lab can be interpreted.

On the platform, we do not evaluate which systems and shifts are more important than others in terms of reaching the overall goals of reducing climate change, protecting biodiversity, or improving equity. For example, in terms of climate, some systems are the cause of more emissions than others, but we do not rank or categorize these systems differently. Prioritization is challenging, in part, because there are many different criteria that could be applied (e.g., mitigation potential, contributions to all three goals, cost-effectiveness) and because these systems are related. For example, an increase in the use of renewable electricity in the power system will enable emissions reductions in other systems like transport and industry, which need to shift to electrify a greater proportion of their energy use.

In addition, we do not systematically consider hierarchies, interconnections, or overlaps among indicators and targets. For example, in the power system, we have a shift, "rapidly scale up renewable energy generation," that contains a hierarchy of indicators. In this shift, an increase in the indicator "annual capacity additions of renewable energy" contributes to the indicator "renewables share of total capacity," which in turn contributes to the indicator "share of zero-carbon power in electricity generation." In this particular shift, the ultimate goal is a higher share of zero-carbon power in electricity generation, but we display data for all of these as indicators. In many cases, hierarchies among indicators are too complex to define. Interconnections among indicators are also complicated. For example, an increase in the "share of zero-carbon power in electricity generation" will likely have a corresponding decrease in the "share of coal in electricity generation," which is part of a separate shift in the power system. We present them as separate shifts, but these two transformations are happening in tandem, with each affecting the other and being affected by other shifts as well.

The shifts and targets on this platform are a complicated network of hierarchies, interconnections, and overlaps like these, so it is impossible to map out and communicate all these relationships. Likewise, we do not fully consider trade-offs among shifts and targets when there are multiple pathways to reach a goal or there are goals that conflict with each other. For example, a shift to electric vehicles is needed to meet our climate goals, but it could have a negative impact on biodiversity due to the impacts of mining for critical minerals for electric vehicle batteries, or on equity if there are human rights violations in the course of the mining. This is why we track all of the goals separately: to ensure progress on one doesn't lead to backsliding on the others.

Finally, some systems and some shifts have more indicators than others, but that doesn't mean they are more important. It simply means that there are more discrete transformations that can help track progress toward the goal.

Therefore, simply counting the number of targets that are on track or off track cannot provide a complete picture of progress. If two of out five indicators in a particular shift are on track to meet their targets, it does not mean that that shift is 40 percent on track.

The Systems Change Lab will attempt to define these relationships more rigorously in the future, identifying causal connections, but a straightforward hierarchy is impossible given the nature of complex systems.

Constraints in Aggregating Climate Targets

Targets for climate-focused systems and shifts were designed using a variety of different underlying sources and methodological approaches. Each of these targets were either directly extracted or adapted from modelled pathways that hold global warming to 1.5°C with no or low overshoot, recently published peer-reviewed, system-specific roadmaps that limit temperature rise to 1.5°C, or bottom-up sectoral estimates of mitigation potential; or constructed by authors using top-down or bottom-up methods with 1.5°C-alignment as the priority constraint. This aggregation technique allowed us to track progress toward targets across diverse systems, drawing on high-quality 1.5°C-aligned modelling and mitigation potential estimation that already exists for each system.

However, a key limitation of this process is that because our targets are not all derived from one common model or model ensemble, we cannot definitively state that achieving all targets, together and on time, would collectively deliver all of the GHG emissions reductions and carbon removals needed to limit warming to 1.5°C with no or limited overshoot. Similarly, because the targets on this platform do not cover every single shift needed to transform all global systems, the collective mitigation potential of all targets together may also fall short of holding global temperature rise to 1.5°C. Rather, each individual target is aligned with a 1.5°C pathway. We opted for this approach—adopting different targets from different studies—because there are merits and drawbacks to strategies for developing targets that vary significantly across each power, buildings, industry, transport, technological carbon removal, forests and land, food and agriculture, and finance system. To accommodate these challenges, we strove to select the best available targets using the most appropriate and rigorous methods for each unique system.

Finally, because we took the approach of aggregating individual 1.5°C-aligned targets across each of our eight systems, we cannot robustly account for interaction effects that likely occur among systems (e.g., competition over land). For example, different models allocate different quantities of land for various emissions reduction and removal approaches. The competition for this land area for food production, energy production, carbon removal, and more may not be thoroughly accounted for when all targets are aggregated.

Challenges Associated with Global Measurements of Equity and Biodiversity

Our methodological approach focuses on tracking global progress, and while considerable efforts have been made to develop worldwide indicators to monitor equity, as well as biodiversity and drivers of biodiversity loss, such as those supporting the post-2020 Global Biodiversity Framework and the Sustainable Development Goals, there are considerable challenges in aggregating highly localized indicators up to the global level. Commonly monitored water quality indicators, for example, typically include dissolved oxygen, total dissolved solids, and pH levels, among others, and when considered together, these indicators can provide a comprehensive picture of levels of pollution in an aquatic ecosystem. But they cannot be tracked at a global level, nor can they be combined in a meaningful way. Instead, existing global indicators approximate water quality by tracking the proportion of domestic and industrial wastewater flows that are safely treated or the proportion of water bodies with good ambient water quality.

Equity indicators are even more complex, as "fairness" can be conceptualized differently across cultures, and historical patterns of marginalization vary immensely among countries. Moreover, indicators that are easier to track quantitatively—for example, those that monitor access—often measure binaries that leave out important nuance (e.g., does a person have access to electricity, yes or no?). But many people that technically have access to the service or good in question often struggle with quality issues, affordability, and more. Efforts are underway to adopt more nuanced definitions of access, for example, the World Bank's "multi-tier framework" for evaluating off-grid service provision, but that framework includes data for only a handful of countries.

Where possible, we plan to present disaggregated data (e.g., by nation, eco-region, species type) alongside global data. But even these data may still only approximate changes in equity and biodiversity occurring at local levels. As we develop the Systems Change Lab platform, we will continue to explore approaches for managing this limitation and may revisit our current methods in the future.

Data Limitations

A lack of high-quality, consistently updated, and publicly available data constrained our assessment of global progress across many systems and shifts. For some indicators, data were patchy, and continuous time series of annual data were not available. While the data that were available did provide some indication of progress, they did not allow us to conduct robust trend analysis. Similarly, for other indicators, we could find only a single historical data point, and this lack of data prevented us from projecting a linear trendline and categorizing progress in a quantitative way. Still other indicators lacked even a single historical data point. We still present these on the platform to show that they are important, but we cannot present useful quantitative information. Likewise, we cannot assess progress for the indicators that do not have targets. Indicators without enough data or without targets are also important even though we are unable to categorize their progress. If data become available, we will add them to subsequent updates.

Inherent Uncertainty of Assessing Nonlinear Change

Assessing whether an indicator is on track to reach its targets comes with inherent uncertainties given the possibility of nonlinear change. Even at the outset, classifying indicators as "exponential change likely," "exponential change possible," or "exponential change unlikely" is subjective. While we have criteria for which indicators fit in which category, the decisions were not always clear-cut and were ultimately based on author judgment. The terms "likely," "possible," and "unlikely" do not refer to specific likelihood percentiles, as they do in other research documents such as IPCC reports. Instead, they are categories assigned by authors based on the nature of the indicator (i.e., whether the indicator is based on technology adoption fully, partially, or not at all).

For "exponential change likely" indicators, determining whether they are on track or not carries considerable uncertainty. Accurately projecting adoption rates for new technologies that are just beginning to emerge or diffuse across society is an enormously difficult endeavor. Any small fluctuations in the initial growth rate will create statistical noise, which introduces uncertainty into predictions that can reach orders of magnitude (Kucharavy and De Guio 2011; Crozier 2020; Cherp et al. 2021). Indeed, it is not until growth has reached its maximum speed (the steepest part of an S-curve trajectory) that robust projections for future growth can be made with more confidence (Cherp et al. 2021). Even then, additional assumptions must be made about the shape of the S-curve and the saturation point at which growth rates stabilize.

For example, whether deceleration at the end of the S-curve mirrors the acceleration at the beginning significantly impacts the speed at which a technology reaches full saturation. Yet no S-curve in the real world is perfectly symmetric, and new evidence from past transitions suggests that S-curves can be highly asymmetric (Cherp et al. 2021). Technologies can also encounter obstacles as they diffuse—such as supply-chain constraints—that alter or limit the shape of the growth, but these challenges are similarly difficult to anticipate.

For the "exponential change possible" indicators, many of these same limitations also apply. Moreover, even for the "exponential change unlikely" indicators, there is still some nonquantifiable possibility of nonlinear change. For indicators within both categories, we defaulted our methods to looking at acceleration factors assuming continued linear change, as described above. However, these values should be seen as just a general guide to inform how much faster change needs to occur compared with what has occurred over the past five years. We did not make quantitative predictions based on changing economics, supply-chain constraints, or expected policy factors, and we acknowledge that there are multiple potential pathways that these targets may follow.

Lack of Causal Analysis to Identify Enablers and Barriers

The enabling conditions and barriers we present on the platform are by no means exhaustive, given how complex systems change can be. Rather, they represent a critical subset of relevant factors that may contribute to or stymie these shifts. We did not conduct a causal analysis to ensure that the enablers and barriers we included for a given system directly contribute to our targets in that system. Likewise, we did not prioritize among the enablers and barriers included on the platform when there were multiple pathways to achieve transformation or when there were trade-offs between pursuing one pathway versus another.

Given how complex systems change can be, there is no perfect way to arrange the enablers and barriers. Some of the enabling conditions contribute to a specific target, while others promote general progress within a shift. Enabling conditions may also contribute to other enabling conditions. In some cases, the shifts themselves may act as enabling conditions for other shifts, which means that it is sometimes difficult to disentangle the shifts from the factors that support them.

Despite these limitations, our aim was to provide useful information for users of the platform to further understand what is happening in the world beyond the targets alone.

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About Our Partners and Funders

UN Climate Change High-Level Champions

The United Nations High-Level Champions for Climate Action for COP26 and COP27— Mahmoud Mohieldin and Nigel Topping—build on the legacy of their predecessors to engage with nonstate actors and activate the "ambition loop" with national governments. Their work is fundamentally designed to encourage a collaborative shift across all of society towards a decarbonized economy, so that we can all thrive in a healthy, resilient, zero-carbon world. Gonzalo and Nigel have convened a team to help them deliver on this work through flagship campaigns, targeted stakeholder engagement, and leadership in systems transformation.

Climate Action Tracker

The Climate Action Tracker (CAT) is an independent scientific analysis that tracks government climate action and measures it against the globally agreed Paris Agreement aim of "holding warming well below 2°C, and pursuing efforts to limit warming to 1.5°C." A collaboration of two organizations, Climate Analytics and NewClimate Institute, CAT has been providing this independent analysis to policymakers since 2009. CAT quantifies and evaluates climate change mitigation targets, policies and action. It then aggregates country action to the global level, determining likely temperature increase by the end of the century under different scenarios. CAT also develops sectoral analysis to illustrate required pathways for meeting the global temperature goals.

Bezos Earth Fund

The Bezos Earth Fund is Jeff Bezos's $10 billion commitment to fund scientists, activists, NGOs, and other actors that will drive climate and nature solutions. By allocating funds creatively, wisely, and boldly, the Bezos Earth Fund has the potential for transformative influence in this decisive decade. Funds will be fully allocated by 2030—the date by which the United Nations' Sustainable Development Goals must be achieved.

ClimateWorks Foundation

ClimateWorks Foundation is a global platform for philanthropy to innovate and accelerate climate solutions that scale. We deliver global programs and services that equip philanthropy with the knowledge, networks, and solutions to drive climate progress. Since 2008, ClimateWorks Foundation has granted over $1.3 billion to more than 600 grantees in over 50 countries.

World Resources Institute

World Resources Institute is a global research organization that turns big ideas into action at the nexus of environment, economic opportunity, and human well-being.

Our Challenge

Natural resources are at the foundation of economic opportunity and human well-being. But today, we are depleting Earth's resources at rates that are not sustainable, endangering economies and people's lives. People depend on clean water, fertile land, healthy forests, and a stable climate. Livable cities and clean energy are essential for a sustainable planet. We must address these urgent, global challenges this decade.

Our Vision

We envision an equitable and prosperous planet driven by the wise management of natural resources. We aspire to create a world where the actions of government, business, and communities combine to eliminate poverty and sustain the natural environment for all people.

Our Approach

COUNT IT: We start with data. We conduct independent research and draw on the latest technology to develop new insights and recommendations. Our rigorous analysis identifies risks, unveils opportunities, and informs smart strategies. We focus our efforts on influential and emerging economies where the future of sustainability will be determined.

CHANGE IT: We use our research to influence government policies, business strategies, and civil society action. We test projects with communities, companies, and government agencies to build a strong evidence base. Then, we work with partners to deliver change on the ground that alleviates poverty and strengthens society. We hold ourselves accountable to ensure our outcomes will be bold and enduring.

SCALE IT: We don't think small. Once tested, we work with partners to adopt and expand our efforts regionally and globally. We engage with decision-makers to carry out our ideas and elevate our impact. We measure success through government and business actions that improve people's lives and sustain a healthy environment.

ENDNOTES

[1]Benchmarks from the IPCC's Sixth Assessment Report will be incorporated into future iterations of the Systems Change Lab platform.

[2]It is important to note here that because some of our targets call for reductions (e.g., phasing out of coal), the lower bound of a target range is not always the less ambitious bound.

[3]Biomass for bioenergy with carbon capture and storage (BECCS) must be sourced in such a way to avoid unintended negative impacts. For example, clearing forested land to grow biomass for BECCS would reduce the forest carbon sink and that lost carbon sequestration would need to be included in net GHG calculations; using agricultural land for BECCS feedstocks could reduce land available for food production and threaten food security; and planting large areas of feedstocks could have negative impacts on biodiversity and ecosystems. Use of waste biomass can help avoid these challenges, but life-cycle calculations (including emissions from accessing and transporting biomass) are still needed to ensure there is a net benefit to the climate.

[4]An exception is a variation on CCUS—the Allam Cycle—which is in development and involves combustion of natural gas in a high oxygen environment. It would theoretically be able to capture 100 percent of direct emissions from natural gas combustion and has been demonstrated at a 50 megawatt scale, but not yet at a large scale (Yellen 2020).

[5]Note that we use the term "exponential" instead of "S-curve" for communication purposes because it is a more commonly known term. Not all stages of an S-curve are exponential.

[6]In some cases, most notably in the forests and land system, we calculated a linear trend line based on more than five years of data to account for natural interannual variability. In other cases, if we didn't have five years of historical data to calculate a line of best fit but did have the values for five years ago and today, we simply drew a straight line between the two and used that as the trajectory of progress. Deviations from our standard methods were noted accordingly.

[7]Note that for the indicators with targets presented as a range, we assessed progress based on the midpoint of that range—that is, we compared the historical rates of change to the rates of change required to reach the midpoint.

[8]For acceleration factors between 1 and 2, we rounded to the tenth place (e.g., 1.2 times); for acceleration factors between 2 and 3, we rounded to the nearest half number (e.g., 2.5 times); for acceleration factors between 3 and 10, we rounded to the nearest whole number (e.g., 7 times); and for acceleration factors higher than 10, we noted as >10.

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