CARBON BUDGETS ARE NOT ENOUGH:

THE CASE FOR TRANSITION MILESTONES

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SUMMARY

- **Carbon budgets can support emissions reduction by focusing political attention, providing a framework for planning, and enabling accountability over time. These are important advantages compared to ad hoc policymaking without a governance framework.**

- **However, there are risks in making near-term (as well as long-term) emissions reduction the measure of success in a governance framework. Not all actions that reduce emissions in the short-term make progress towards the elimination of emissions in the long-term. Governments that focus on reducing emissions by increasing the efficiency of fossil fuel systems and deploying lower emission technologies risk wasting time, wasting investment, and storing up problems for the future.**

- **Eliminating anthropogenic emissions is the only plausible way to reduce climate risk, and only the development of zero emission systems can achieve that outcome. Making this the measure of success in a governance framework would strongly align short-term focus with long-term goals. We propose transition milestones for this purpose: interim targets for the market share of zero emission solutions in each of the greenhouse-gas emitting sectors, accompanied by qualitative descriptions of conditions necessary to complete each stage of the transition.**

- **Transition milestones can be set to reflect a country's circumstances, strengths, and strategic objectives. Since most countries account for a very small share of global emissions, influencing global economic change is at least as important as eliminating national emissions, for reducing climate change risks.**

- **Transition milestones have their own limitations and risks, and will not direct attention towards all opportunities for useful emissions reduction. There may be advantages in using a combined framework, with transition milestones alongside carbon budgets.**

CONTENTS

Introduction

Most countries in the world aim to achieve net zero greenhouse gas emissions by around the middle of this century. Many also have interim emissions targets reflected in national laws and policies or international commitments. These are intended to contribute to the global effort to avoid dangerous climate change. An important question is: what kind of governance frameworks can best support progress towards meeting these goals?

A growing number of countries have adopted carbon budgets as a governance framework. These include the UK, France, Finland, the Netherlands, Denmark, New Zealand, Ireland, and at a regional level, the European Union.[1] While frameworks differ between countries, the common element is a series of interim emissions targets, with each target typically covering several years, on the way to the eventual goal of net zero emissions. Many express these targets as a fixed quantified emissions budget over a specific time period. These are useful as a framework for limiting total contributions of emissions over time, to support planning, monitor progress, and to hold governments to account.[2]

Here we consider the risk that emissions targets and carbon budgets are insufficiently aligned with the process of economic transformation through which emissions are eventually eliminated, and propose a complementary, or alternative, approach.

What is a governance framework for?

A governance framework is a way of directing a government's attention. It can increase the political priority given to a particular issue, by creating clear expectations and responsibilities. It should lead government to focus on the right problems at the right times; often this involves shifting the focus to longer-term goals that would otherwise be ignored in favour of shorter-term obligations. It can improve the quality of decision-making by ensuring decisions are informed by good evidence, careful deliberation, or consultation. It can also increase political accountability, by making it easier for parliament, the media, and civil society to see whether government is acting in line with its stated objectives.

Governance frameworks can contribute in all these ways, but they are not substitutes for political leadership, policymaking, or analysis. Their role is not to provide the answers to policy questions, but to ensure the right questions are asked.

The positive role of carbon budgets

The setting of successive, continuous carbon budgets has important advantages compared to having either no governance framework for the reduction of emissions, or an ad hoc, arbitrary or partial selection of point-in-time targets. These advantages include:

- Directing a government's attention to the problem of emissions-reduction – attention which might otherwise be held by any other political priorities.[3]

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[1] O'Neill, S., 2023. Small scale study of carbon budgeting in selected countries. The Climate Change Advisory Council, Ireland.
[2] Evans, N. and Duwe, M., 2021. Climate governance systems in Europe: the role of national advisory bodies. Ecologic & IDDRI.
[3] Averchenkova, A. et al, 2024. Impacts of climate framework laws: lessons from Germany, Ireland and New Zealand. Grantham Research Institute, LSE.

- Establishing a whole economy process where all government departments begin asking the question 'where can net, absolute emissions reductions be found?' – prompting policymakers to look for the answers.
- Guiding planning towards constraining emissions within a given pathway over a given time period – essentially dictating cumulative emissions (the 'area under the curve') which is what determines the negative impact on climate change. This is better than focusing on a specific emissions level target at a single point in time and failing to dictate the pathway, which can result in very different cumulative emissions.
- Providing a sense of proportion. By establishing the scale of emissions reductions that are needed, they can help distinguish between actions that contribute substantially, and those that are tokenistic.
- Creating accountability for emissions reduction; enabling monitoring of progress. This can help increase political pressure when the government is off-track, and provide an additional argument in favour of policies that would help to close the gap.

The underlying logic is that a country's emissions determine its contribution to the problem of climate change, so policymaking should be focused on emissions reduction.

The limitation of carbon budgets: incomplete alignment between short-term and long-term objectives

The long-term objective of emissions reduction is clear. Climate change occurs as a result of increased atmospheric concentrations of greenhouse gases. Hence the UN Framework Convention on Climate Change in 1992 set the objective of *stabilizing greenhouse gas concentrations* at a level that would prevent dangerous anthropogenic interference with the climate system. Concentrations can only be stabilized when the balance between anthropogenic emissions and carbon sinks goes to net zero.[4] In the event of overshooting our global average temperature goals, a reduction in long term climate risk will require a net negative emissions balance where enhanced sinks are more than compensating for any residual emissions. In any scenario, the speed with which we reduce anthropogenic emissions is the strongest parameter determining the risks we face.

The only technologically and economically plausible way to reach net zero anthropogenic emissions is by building a new, zero emission economic system to replace fossil fuel systems in each of the GHG-emitting sectors of the global economy. (While negative emissions technologies such as direct air carbon capture and storage may have a role, there is no suggestion that they could be deployed at a scale anywhere close to matching all anthropogenic emissions. Moreover, these technologies impose costs for no benefit other than emissions reduction, whereas many zero emission technologies provide economic services at similar or lower cost than fossil fuel alternatives.) A new system means new technologies, and also the new infrastructure, business models, occupations, skills, standards, institutions, and everything else that goes with them. This new system must entirely replace the fossil fuel system: that is the only plausible way for emissions to be eliminated, for GHG concentrations to be stabilized, and for the extent of climate change to be limited.

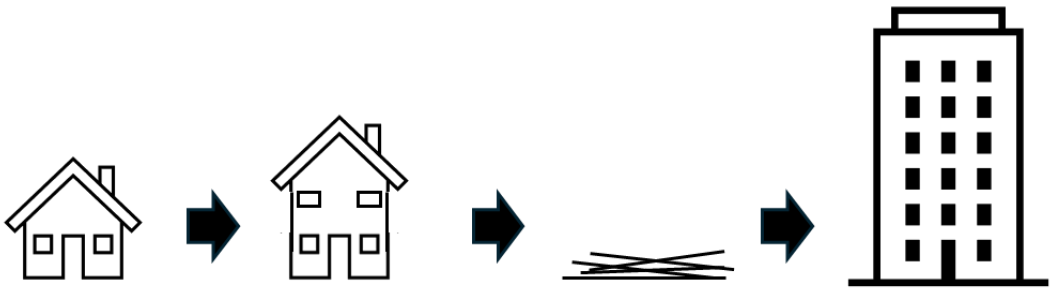
[4] And even then, maybe not – if too many reinforcing feedbacks in the Earth system have been set off – but that is another discussion.

The only short-term steps that make progress towards this long-term goal are those that contribute to creating, establishing and growing the new zero emission systems. These steps do not necessarily reduce emissions in the short term. For example, the actions taken by governments of the USA, Japan, Germany and China from the 1950s to the 2010s, which developed solar photovoltaics from an experiment to an affordable mass market technology, achieved almost no emissions reductions at the time. But it was those actions that enabled countries all over the world to reduce emissions by deploying solar power now.

Similarly, there are ways of reducing emissions in the short-term that do not contribute to developing zero emission systems. These include:

- **Making fossil fuel systems more efficient.** For example: switching from coal to gas in the power system; producing steel in more efficient blast furnaces; or increasing the efficiency of internal combustion engine vehicles. These all reduce emissions, but the gas power plants, blast furnaces, and combustion engine vehicles are not likely to be part of the zero emission system (with some theoretical exceptions – e.g. using carbon capture and storage).
- **Introducing and blending biofuels to replace fossil fuels.** This can be an easy and low-cost way to reduce emissions[5], because it does not tend to require changes in technology, production machinery, or infrastructure. But the limited global supply of genuinely sustainable biomass means that in most sectors, for most countries, biofuels are unlikely to be a major part of the zero emission system.

It may seem counterintuitive that actions to reduce emissions do not necessarily make progress towards the goal of zero emissions. By way of analogy: if a land-owner wants to replace a house with a more valuable high-rise apartment block, building an extra floor on top of the house will make it higher, but will not bring the land-owner any closer to achieving his or her objective. To achieve that objective, they will have to start again.



Emissions can also be reduced by accident, as a result of economic growth being lower than expected, or of structural change in the economy (such as a shift from manufacturing to services as the main driver of growth; reaching a saturation point in construction of large-scale infrastructure; or increasingly importing instead of producing energy intensive materials).

This mismatch between the actions that reduce emissions in the short-term and the actions that make progress towards eliminating emissions in the long-term creates a risk. The actions themselves are not inherently mutually exclusive. It often makes sense to do both at once. The

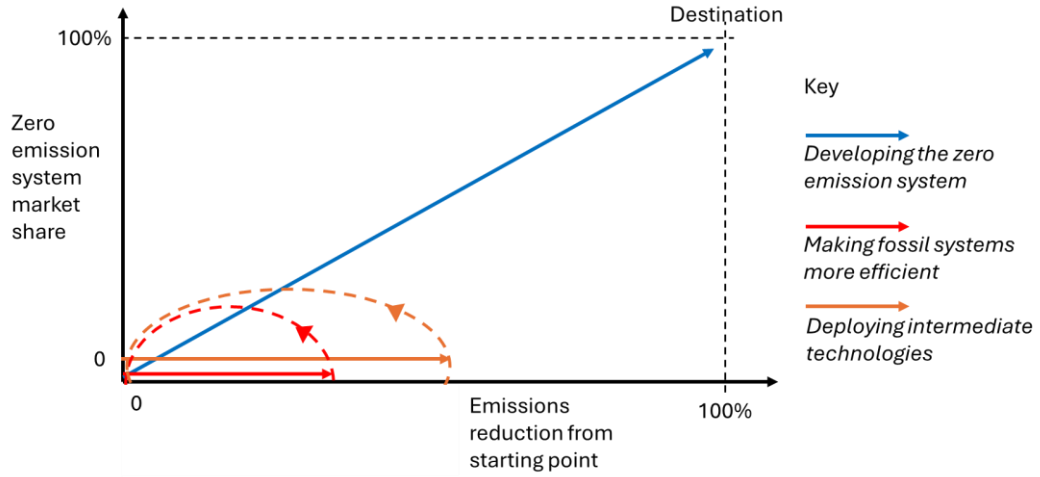
[5] Provided the biofuels are sustainably produced. Otherwise, this may not reduce emissions at all.

issue is with where attention and accountability are focused. In a governance framework where emissions reduction is the measure of short-term (as well as long-term) performance, attention may be misdirected, since 'success' in the framework can be achieved at least in part by measures that do not contribute to long term progress. This can have two significant negative consequences: wasted time, and wasted investment.

Wasted time

Increasing the efficiency of fossil fuel systems is often the cheapest way to reduce emissions, especially in the early stages of a sector's transition. For example, when solar and wind power were still expensive, emissions could be reduced at lower cost by upgrading the efficiency of coal plants. When electric vehicles were still expensive, emissions could be saved at low or even negative cost by requiring petrol cars to be more efficient. If a government chooses to meet near-term emissions targets through actions such as these, and if it considers that by meeting these targets – or by being on track to meet them – it has done enough, then the development of the new zero emission system will be delayed. Since the development of the new system is the only way to achieve the long-term policy goal, its delay is, in general, unhelpful.

Similarly, if near-term economy-wide carbon budgets can be met through progress in sectors where emissions reduction is easiest, then the framework creates little immediate pressure to move forward in other sectors. The Intergovernmental Panel on Climate Change found in its sixth assessment report, 30 years after countries agreed to stabilize atmospheric concentrations of GHGs (requiring complete elimination of emissions), that while improving the efficiency of energy intensive industries was a well-established policy field globally, efforts to develop the zero emission system were still focused on developing technical solutions and had not yet progressed to creating market demand.[6] Any government that meets its near-term emissions targets in the coming years through progress in the power and road transport sectors may feel able to delay the start of the industry transition even longer.



[6] Bashmakov, I.A., L.J. Nilsson, A. Acquaye, C. Bataille, J.M. Cullen, S. de la Rue du Can, M. Fischedick, Y. Geng, K. Tanaka, 2022: Industry. In IPCC, 2022: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [P.R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, J. Malley, (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA. doi: 10.1017/9781009157926.013 p1164

The figure above illustrates different pathways for reducing emissions. Since the *fossil fuel efficiency* and *intermediate technology* pathways do not contribute to developing the zero emission system, a government that has pursued either of these routes still has to start from the beginning of the *zero emission system* pathway in order to reach its destination.

Wasted investment

When the construction of zero emission systems is delayed, the risk of wasted investment in fossil fuel systems increases. This can take two forms: replacing old fossil fuel assets with new fossil fuel assets, when they come to their end of life; and retrofitting fossil fuel assets to make them more efficient.[7] Neither of these are inherently bad things to do – some turnover of fossil fuel assets during the transition is inevitable, and retrofitting for efficiency can be a good way to reduce near-term emissions, provided it does not create a new long-term financial commitment to a fossil fuel asset – but they can be wasteful compared with earlier investment in the new system. To extend the analogy given above, these actions are like refurbishing the house before knocking it down. It may in some cases be better to extend the operating lifetime of a fossil fuel asset until a zero emission technology is ready to replace it, rather than investing in a new and more efficient fossil fuel asset.

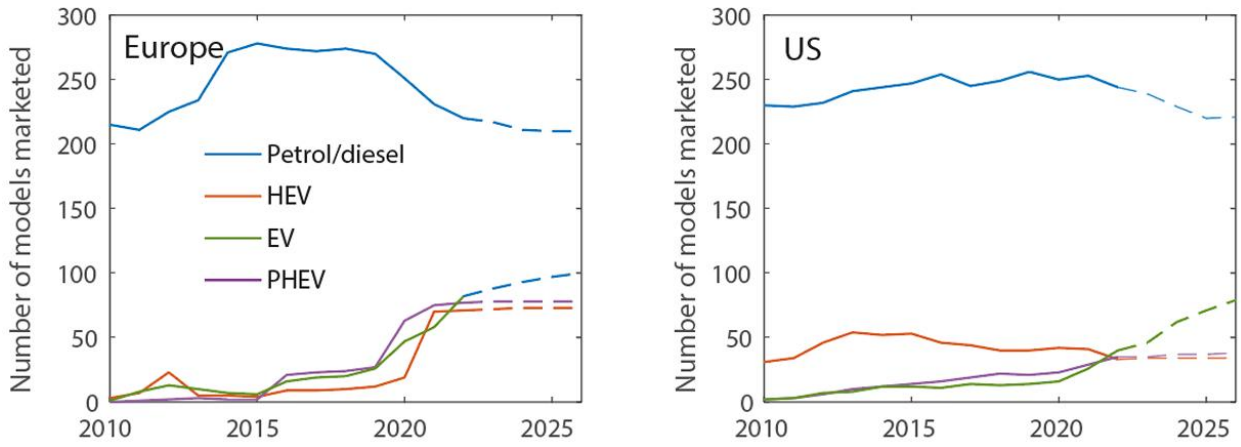
Examples of wasted investment include:

	New coal power plants (typical lifetime: 40+ years)	**New blast furnaces for steelmaking (typical lifetime: 25 years)**
Net zero 2050 trajectory	No new coal plants from 2021 (IEA Net Zero by 2050)[8]	No new blast furnaces without CCS from 2025 (various studies)[9]
Ongoing investment	Around 50GW – 100GW of new coal power capacity has started operation globally each year for the past 20 years,[10] including 213GW since 2021.[11] A further 116GW of new coal power capacity was proposed for construction, globally, in 2024.[12]	65Mt of new high emission blast furnaces planned or under construction globally, in 2024.[13]

A further example can be seen in the automotive sector. In Europe, where regulatory and fiscal policies incentivizing industry to reallocate investment towards electric vehicles have been

[7] Retrofitting buildings for improved energy efficiency does not fall into this category. The building itself is not a fossil fuel asset (though its heating system may be).
[8] International Energy Agency, 2021. Net Zero by 2050. IEA.
[9] Leadership Group for Industry Transition. From 'hard to abate' to net-zero: policy priorities for decarbonising steel by 2050.
[10] Global Energy Monitor, 2024. Boom and bust coal 2024.
[11] Global Energy Monitor, 2025. New coal drops to lowest level in two decades.
[12] Ibid.
[13] International Energy Agency and UN Climate Change High-Level Champions, 2024. Breakthrough Agenda report 2024: accelerating sector transitions through stronger international collaboration. IEA.

relatively strong, the number of EV models on the market has risen rapidly, while the number of internal combustion engine models has begun to decline. In the USA, where policy has been weaker, growth in the number of EV models has been slower, and the number of petrol car models remains high, reflecting manufacturers' ongoing investment in the old technology.[14]



Number of car models marketed in Europe and the USA. Dashed lines show estimates based on manufacturers' announcements for the period up to 2026. Source: Lam, A. and Mercure, J-F., 2022. Evidence for a global electric vehicle tipping point. Exeter GSI Working Paper.

How to achieve the transition most cost-effectively is a question that is beyond the scope of this policy brief. There are some ways in which acting later can lead to lower costs, such as when technology costs fall due to the actions of other countries. However, given that the net savings globally of a fast transition to a zero emission energy system have been estimated at around $12 trillion compared with continuing to rely on fossil fuel systems (and lower levels of savings are estimated to arise from a slow transition), it appears likely that to a first approximation, money will be saved by constructing the zero emission systems sooner rather than later.[15]

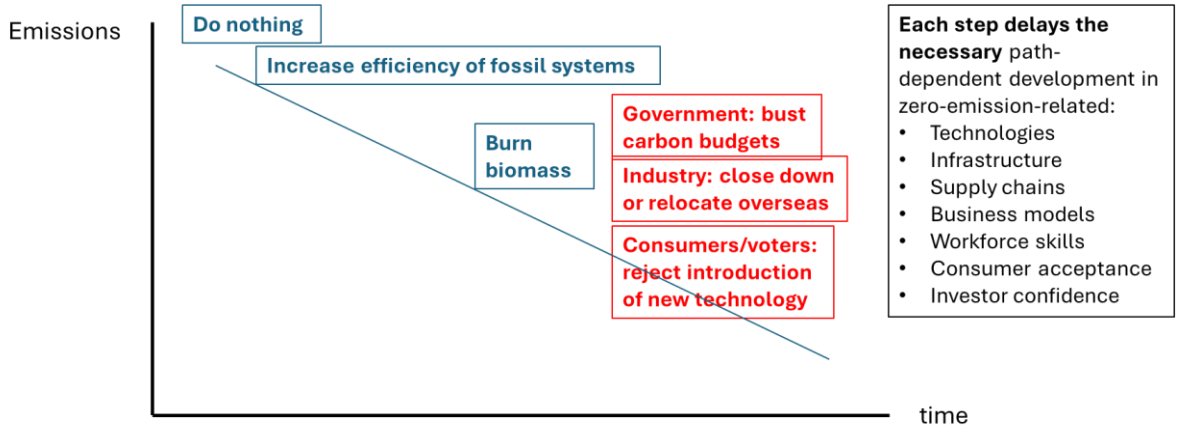
Problems stored up for the future

If a government focuses on near-term emissions reduction and neglects the construction of zero emission systems, this will store up problems for the future. Meeting carbon budgets will become increasingly difficult, as the ground has not been prepared. Introducing zero emission technologies will be more difficult if the technologies themselves have not been well developed, if the skills to install and maintain them are not widespread in the workforce, and if the infrastructure to support their use has not been established.

[14] Lam, A. and Mercure, J-F., 2022. Evidence for a global electric vehicle tipping point. Open Research Exeter.

[15] Way, R. et al, 2022. Empirically grounded technology forecasts and the energy transition. Joule. Note: this estimate refers to a transition in all sectors except agriculture and land use. A large part of the saving comes from the avoided operational costs of burning fossil fuels. In an extremely simplified way, the replacement of fossil fuel capital stock with zero emission capital stock can be thought of as a one-off cost. The sooner this is done, the sooner the continuous, lower operating costs of the zero emission system can be accessed.

In such circumstances, consumers are less likely to adopt zero emission products, and voters are less likely to support policies that advance the transition. Industry will be less able to maintain competitiveness while undergoing the transition, and may choose to relocate to another country instead. The government may find it impossible to meet its emissions targets (undermining the standing of the governance framework itself), or may find that it can only do so by spending large amounts of money to overcome the difficulties.



The time-lag effect on accountability

Generally there is a time-lag between policies and emissions reductions. The research, development and first deployment of zero emission technologies may cause no measurable emissions reductions at the time, but can enable deep emissions reductions decades later. Even when clean technologies are mature, most policies influence their rate of *flow* into the economy, or the rate of flow of fossil fuel technologies out of the economy. But it is the *stock* of assets in the economy that determines emissions.

For example, purchase incentives and zero emission vehicle mandates increase the flow of electric vehicles into the economy, but emissions depend on the stock of vehicles on the road, which takes longer to change.

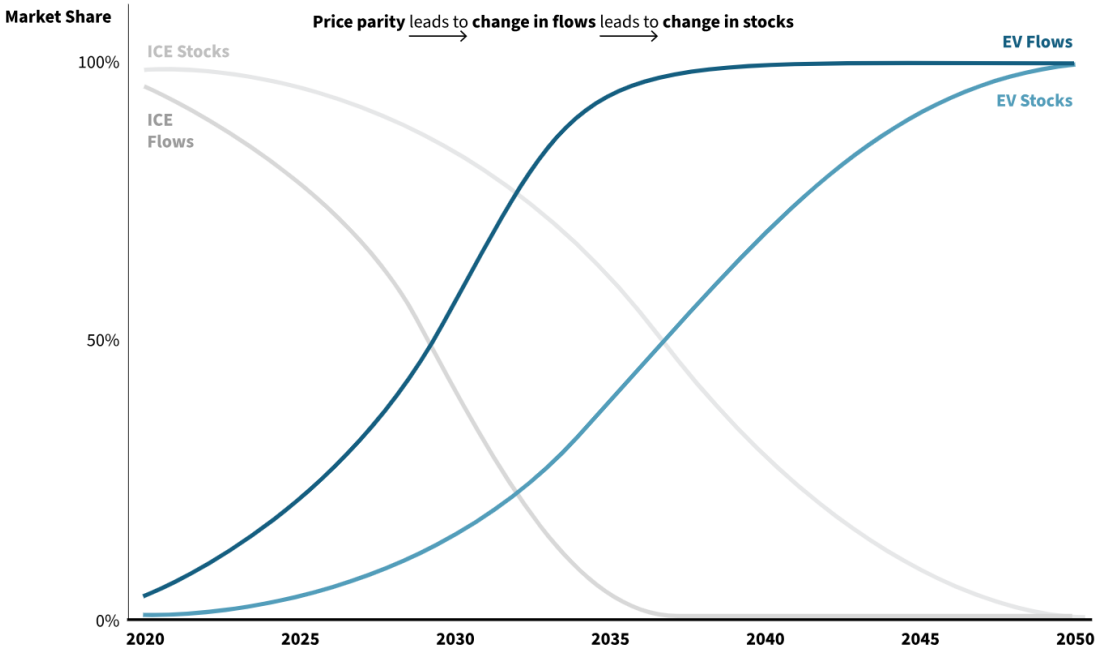
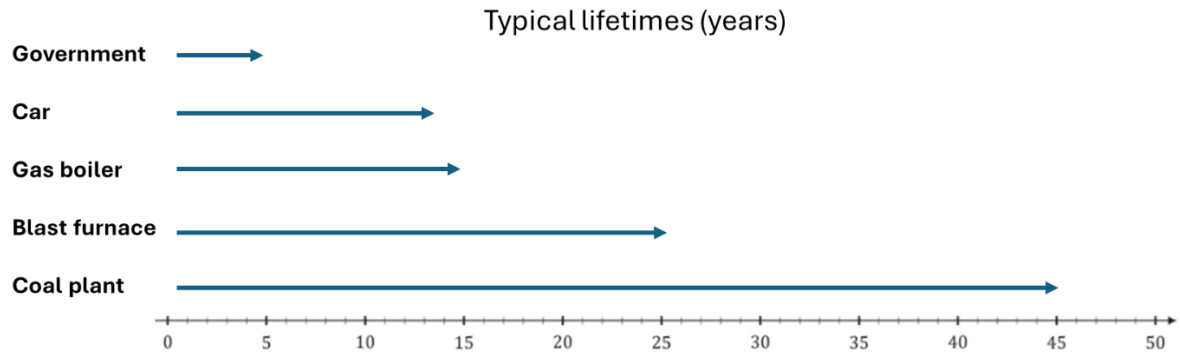


Figure source: Bond, K. and Butler-Sloss, S., 2022. Peaking: a theory of rapid transition. How patterns of peak, plateau, and decline point to fossil fuels' accelerating end. RMI.

The time-lag between a change in flows and an equivalent change in stocks depends on the typical lifetime of the assets in each sector of the economy. In most sectors, the typical lifetime of a fossil fuel asset is longer than the typical lifetime of a government.



For these reasons, a government that is meeting its carbon budgets is likely to be doing so not primarily because of its own actions, but thanks to the actions of its predecessors.[16] A government taking no actions can be criticized for being off-track for future carbon budgets, but may be tempted to dispute this by giving optimistic projections of the effects of policies that are planned but not yet implemented. Since this will be an argument about the future, it cannot be decisively won by either side. By the time severe problems are encountered, such as those described above, the governments whose lack of action led to them will have long ago left office.

[16] In an interconnected global economy where much of the technology needed to make significant cuts in emissions (such as solar, wind, heat pumps, batteries, and electrolysers) is both available and increasingly affordable, success can also be attributed to the efforts of other countries.

The case for transition milestones

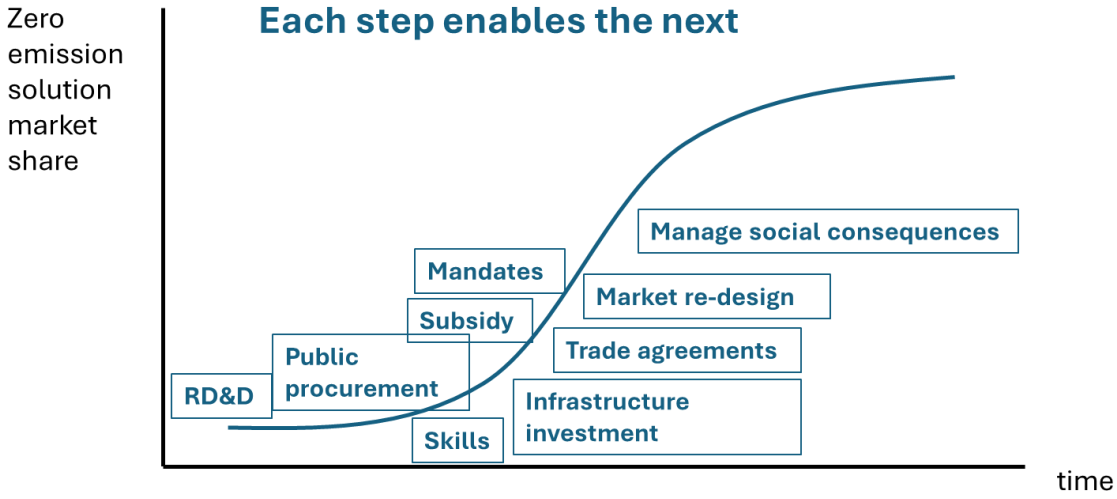
An alternative approach is to focus attention on the development of the zero emission system – the only process through which the emissions of the fossil fuel system can eventually be eliminated. This would strongly align short-term focus and long-term goals.

The development of zero emission systems and their displacement of fossil fuel systems is a process of technology transition (or system transition). Many technology transitions have happened in the past, and while each is unique, they follow recognizable patterns. A transition can be understood as happening in three or four stages, which can be roughly summarized as follows:[17]

- **Emergence:** In this early stage of the transition, radical new ideas and technologies are developed and tested. Innovation takes place through trial and error, in a context of high uncertainty. Competition and learning eventually leads to stabilisation of a dominant design. The new technology is first deployed in niche markets. This stage is sometimes described as being split into two, with **invention** describing the process up to the stabilization of a dominant design, and **market introduction** describing the processes associated with initial deployment.
- **Diffusion:** In this middle stage of the transition, the new technology spreads through markets and society, and competes with the incumbents. The incumbent technologies are entrenched within the regime of markets, infrastructure and business practices that has built up around them, and are supported by vested interests that typically oppose major change.
- **Reconfiguration:** In this late stage of the transition, as the new technology becomes dominant and displaces the old regime, wider changes take place as social and economic systems reorganise around it.

When attention is focused on the actions needed to move the transition through each of these stages, each step forward will enable the next. Proving the viability of a new technology enables policies to be adopted to support its first deployment. The improvement and cost reduction that follow from deployment enable its wider diffusion. The greater investor confidence and job creation that follow from wider diffusion help build support for the market reforms, extension of infrastructure, and establishment of new institutions that allow the zero emission technologies to eventually take over the entirety of the market.

[17] Sharpe, S. et al, 2025. Analytical tools for innovation and competitiveness in the low carbon transition. S-Curve Economics. Based on the work on Frank W. Geels.



If the critical steps in construction of the zero emission system are prioritized, this is likely to lead to a relatively fast route through the transition, tending to minimize wasted time and wasted investment in incremental improvements to or replacements of fossil fuel assets.

The market share of zero emission technologies in a given sector is the best single indicator of that sector's progress in the transition, provided the technologies are genuinely zero emission and capable of being deployed at a scale consistent with the sector's needs (an important caveat: see 'understanding the first milestone', below). A wider set of indicators could be used for monitoring progress,[18] but we suggest using one indicator as the basis for transition milestones for the sake of simplicity. Target values for this indicator could in principle be set for each year of the transition, but governance frameworks are likely to be more effective when they force attention to be concentrated at particular moments in time – since neither political attention within government nor scrutiny from outside government can be maintained at a high level on a continuous basis. It is likely to be more useful to set out a small number of target values for the zero emission technology market share, at specified future points in time, as milestones to aim for.

Milestones could be set to mark the completion of each of the stages of the transition – helping to align attention and accountability with progress through those stages. These stages are best understood qualitatively, and do not automatically correspond to particular market shares. However, having quantitative milestones is likely to be necessary for the governance framework to support accountability. For this reason, we suggest using a combination: specific market shares to aim for, along with qualitative descriptions of conditions that should be achieved. Both will be important in monitoring progress: if the qualitative conditions necessary for a stage of the transition to be completed have not been achieved, more work may be needed in these areas before it is possible for the transition to progress to the next stage.

For example, a set of milestones could be:

[18] For a wider set of indicators of progress in transitions, see Bersalli, G. et al., 2024. Assessing zero emissions energy transitions: a systemic view. BertelsmannStiftung.

Market share	Conditions that should be achieved	Marking end of transition stage
(0%)	Viable zero emission solution demonstrated.	Emergence 1: invention
5%	Industry established, with different producers of the zero emission technology competing. Zero emission technology improving and reducing in cost.	Emergence 2: market introduction
50%	New technology more profitable than old. Decreasing investment in the old (high emission) technology.	Diffusion
100%	Zero emission technology accessible to the whole population.	Reconfiguration

Transition milestones must be set for each of the main greenhouse gas-emitting sectors of the economy, because each sector is unique, and their transitions cannot be expected to proceed at exactly the same rate. We illustrate the concept with only four milestones because this must be replicated in each sector, and having a large number in total could be administratively unwieldy and less suited to concentrating political attention at particular moments in time. However, countries will vary in their preferences, and it would be possible to include additional milestones, for example at 10%, 25%, and 75% market shares.

Unlike emissions, which are a lagging indicator of change, the zero emission technology's market share is a current indicator of progress in the transition.[19] Since change is path dependent and cumulative, a government's ability to meet transition milestones will still depend on the actions of its predecessors, but compared to carbon budgets there will be a stronger relationship between a government's actions and its performance against milestones within the same period of time. There will be less opportunity to take credit for past actions, and less need to argue over future projections. This will have advantages for accountability.

Understanding the first milestone

The first milestone we suggest is the demonstration of a viable zero emission solution for the sector. 'Zero emission' must be interpreted according to a reasonable system boundary for the sector in question. For example, a battery electric vehicle can be considered a zero emission solution for road transport, because it creates no emissions while serving its purpose of providing a means of transport. The emissions associated with charging its battery fall within the boundary of the power sector transition, and the emissions associated with its manufacturing fall within the boundaries of the transitions in materials sectors such as steel and plastics.

'Viable' in this context means that the technology has the potential to be deployed at a scale that is sufficient, along with any other technologies that may be used, to achieve the complete

[19] An example of a leading indicator is industry investment in the development of zero emission technologies. This is usually difficult to measure since the data is often commercially sensitive and not disclosed by companies. That is one reason why we do not propose this indicator as the basis for transition milestones.

elimination of emissions from the sector. In making a judgment about viability, governments will need to consider factors including:

- Affordability: viability will be higher if there is a stronger expectation of cost reduction, or of relatively low costs compared to alternatives.
- Claim on resources: a solution will be less viable if it makes inefficient use of resources such as land or energy in ways that inhibit transitions in other sectors.
- Global trends: a solution may be less viable if most other countries are choosing a different option, meaning that global supply chains are developing in a different direction. However, in other cases there may be good reasons for different national choices.

In some of the most significant sectors the first milestone has already been passed globally: in the power sector, solar and wind and nuclear have been demonstrated as viable zero emission technologies; in road transport, battery electric vehicles; in heating, heat pumps; in light industry, electrification. In other sectors, such as steel, cement, plastics, aviation, shipping, and agriculture, it is less clear that the first milestone has been passed, and there remain difficult judgments to make.

Some countries may choose only to begin the transition nationally in a given sector after a viable zero emission solution has been clearly established globally (see 'strategic considerations' section below).

For those countries that choose to take a leading role in the early stages of the transition, an obvious concern is that they may make the wrong judgement about which technology is the best solution. This risk cannot be eliminated: until at least one viable zero emission solution is identified, none of the other steps in the transition are possible. The risk can best be managed by taking a portfolio approach to technology development and deployment until the direction of travel, nationally and globally, is sufficiently clear. If it later becomes apparent that what was thought to be a viable solution is not viable, and if a better alternative has not ready emerged, then the process to identify a solution must begin again.

Setting the subsequent milestones

Just as governments can use different analytical approaches to setting a trajectory for carbon budgets, different approaches can be taken to setting transition milestones – the market share values by which they are defined, and the years in which they should be met. Here we describe four possible approaches, in descending order of confidence and commitment with respect to the pace of the transition. Which of these is most appropriate for a given country will also depend on strategic considerations, as discussed in the next section.

- **Straight line to the top:** Milestones would be set on a straight line trajectory from the zero emission technology's market share in the start year to 100% in the end year (which could be either the national economy-wide net zero target year, or an earlier year). Compared to the natural S-curve trajectory for a new technology's market share over the course of a transition, this is likely to require faster progress in the first half of the transition, but may allow slower progress later (depending on its stringency).

- **Goal-consistent S-curve:** A mid-point would be fixed half way between the year of first deployment of the zero emission technology and the target year for 100% market share

(national net zero year or earlier). Milestones before and after the mid-point would be set below and above the straight-line, to create an S-curve trajectory. These points could be set based on modelling, stakeholder consultation, or other analysis of feasible rates of growth of the zero emission system.[20]

- **Follow the global S-curve:** In sectors where the global transition has already entered the diffusion stage (currently, the power sector and road transport), the shape of the S-curve is becoming clear. Analysis of progress across European countries, Chinese provinces, and states of the USA shows that although some are far ahead of others, all are following roughly the same trajectory. This data indicates the number of years typically needed to progress from one market share value to another, making it possible to set milestones on this basis.

- **One step at a time:** Instead of setting the entire trajectory of milestones at the outset, in this approach a government would only set one milestone in each sector at a time, based on a judgement of feasibility. After one milestone was met, the next would be set. This could be suitable for governments facing high uncertainty and limited resources.

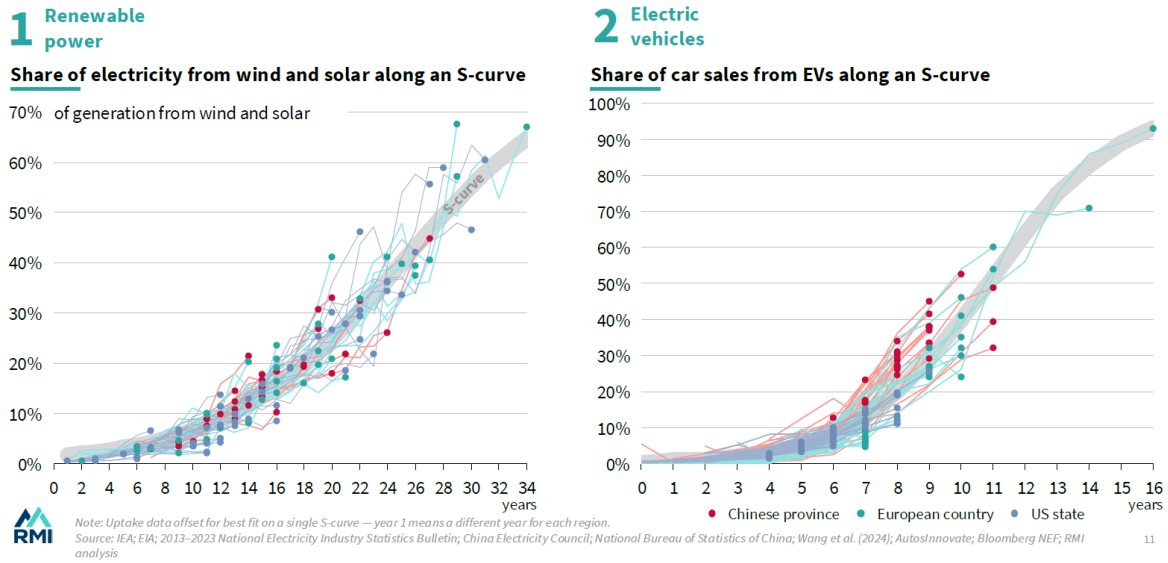


Figure source: Walter, D., Bond, K., and Butler-Sloss, S., 2024. Inside the race to the top. RMI.

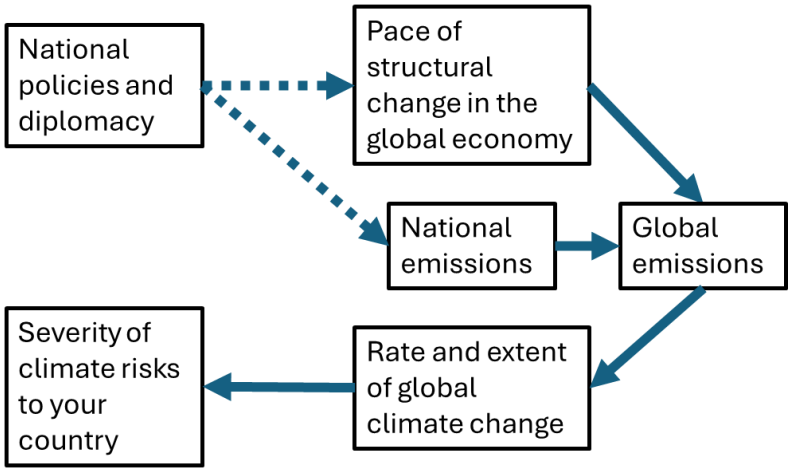
As with carbon budgets, transition milestones could be recommended by an independent authority such as a climate change committee, with the government being required to explain its reasons if it does not accept these recommendations. This could help ensure the milestones are not unduly weak, and could increase trust in the process. Consultation with business, experts, and civil society groups could inform the setting of appropriate milestones, and increase support for them.

[20] The exact shape of the S-curve of a technology transition is not generally known in advance. Consequently, an element of judgement is inevitable, when setting milestones of this kind. Similar judgements are made in analysis that informs the setting of a trajectory for carbon budgets.

The milestones do not all need to be set at once. As with carbon budgets, while an overall trajectory can usefully be outlined from the starting point to the end goal, it may be best to confirm milestones for each decade ahead, on a rolling basis. This is because the pace of the transition is difficult to anticipate. The experience of the low carbon transition so far is that when governments back viable technologies and implement effective policies, change often happens more quickly than they expect.[21]

Strategic considerations: what is national emissions reduction for?

The climate change risks faced by any country depend on global emissions. Most countries are 'small' in terms of their own contribution to global emissions. Only five countries account for more than 2% of the global total. The median country contributes 0.03%.[22] Consequently, the usefulness of national actions to reduce emissions depends strongly on the extent to which they influence economic change and emissions reduction globally.



Countries can influence change in the global economy by developing, demonstrating, and improving zero emission technologies, systems, and policy solutions, and by actively cooperating with other countries to facilitate their increasingly widespread use.[23]

Although countries with greater financial and industrial resources have more potential to lead in technology development, and larger economies are better able to scale up technologies and dramatically reduce their costs, these are not the only ways to exert leadership and influence. Skillful adoption of new technologies, such as India's use of bulk public procurement to enable the first deployment of electric buses, can demonstrate a model for other countries to follow.[24] Thought leadership can also be influential, and can be exercised by countries whatever their size, as shown by Barbados in its creation of the Bridgetown Initiative for reform of international financial institutions. Countries can gain greater leverage from national progress by coordinating and aligning actions with others, through plurilateral initiatives or multilateral

[21] See for example changing expectations with regard to deployment of solar PV. Beinhocker, E.D., Farmer, J.D. and Hepburn, C., 2018. The tipping point: how the G20 can lead the transition to a prosperous clean energy economy.
[22] Worldometer. CO2 emissions by country. Accessed 10 May 2025.
[23] Many examples of these possibilities are documented in the Breakthrough Agenda Report series, coauthored by the IEA and the UN Climate Change High Level Champions.
[24] Gowande, B. and Kohli, S., 2024. Facilitating electric bus adoption by private bus operators across India. International Council for Clean Transportation.

institutions.[25] (The International Maritime Organisation and the International Civil Aviation Organisation are two examples of multilateral rule-setting institutions that can have a more or less powerful effect on the global transition in their sectors depending on the positions taken and agreements reached by their member countries.)

These considerations can inform the setting of transition milestones. A government should form a view of the sectors in which it is most likely to be able to exercise positive influence on the global transition, taking into account its political economy, industrial capabilities, natural resources, geographical position, and any other relevant factors. In these sectors, there may be a good case for adopting a more aggressive set of milestones, following a method such as the straight line to the top, or goal-consistent S-curve. In sectors where there is less potential for international influence, an approach that follows the path set by other countries may be sufficient.

Additional advantages of transition milestones for developing countries

Many developing countries have set near-term emissions targets that correspond to emissions increasing rather than decreasing.[26] This reflects their governments' expectations that growth in demand in the GHG-emitting sectors will outpace growth in the market share of zero emission technologies. The uncertainty over the rate of demand growth makes it difficult to set meaningful carbon budgets in these circumstances. Some countries, such as China, have chosen instead to set carbon intensity targets, which function as a proxy for tracking emissions independently of the uncertainty of economic growth. Carbon intensity targets share some of the advantages and limitations of carbon budgets, as described above, but differ from carbon budgets in not aiming to constrain the total contribution over time to global concentrations of greenhouse gases.

Transition milestones centered on the zero emission technology's market share have the characteristic of being, like carbon intensity targets, independent of economic growth in the relevant sectors. In this sense, they are as well suited for use in countries where significant demand growth is expected as in countries where demand for energy and related goods and services is relatively stable.

The main difference in application is likely to concern timing. A developing country may be likely to go through the milestones in a given sector later than a developed country, either by choice – waiting for other countries to identify and demonstrate viable technologies, and bring down their costs, before beginning its own deployment – or by necessity.

A study on transition indicators undertaken by researchers in China, Germany, India, Indonesia, Kenya, South Korea, and the Netherlands suggested that using indicators relevant to economic development goals together with those measuring progress in the transition to zero emission technologies could help increase social engagement and support for the process.[27] The same

[25] Victor, D.G., Geels, F.W. and Sharpe, S., 2019. Accelerating the low carbon transition: the case for stronger, more targeted and coordinated international action. Energy Transitions Commission. See also the Breakthrough Agenda Report series.

[26] This is reflected in the estimated global emissions trajectory implied by the aggregate of all countries' targets, which is roughly flat or only slightly declining to 2030, despite most developed countries having targets to cut emissions by around 50% by then compared to their baseline years.

[27] Engelhardt, A. et al, 2024. Transition indicators to broaden perspectives beyond adaptation and mitigation. Climate Strategies.

could apply to transition milestones, and this may be particularly useful for any developing countries where there is greater social consensus around unmet economic needs than around avoiding GHG emissions.

Potential limitations and risks of transition milestones

The use of transition milestones could risk allowing increased emissions in the short- to medium term due to various factors in greenhouse gas-emitting sectors and in the wider economy. For example, if increased numbers of heavier vehicles are sold or total demand for road transport rises significantly, emissions may increase despite the diffusion of electric vehicles.

There are some opportunities for emissions reduction that a transition milestones governance framework would be less well suited to encouraging. These include:

- **Demand reduction:** Reducing overconsumption or inefficient use of the goods and services of GHG-emitting sectors would fall largely outside the scope of the transition milestones framework. For example, measures to increase the energy efficiency of electrical appliances would not directly increase the zero emission technology share of power generation, but are still helpful in reducing the quantity of electricity infrastructure needed, making the transition less difficult.

- **Product substitution:** A focus on developing a zero emission version of a particular product may overlook its potential to be replaced by a different product, in a way that not only reduces emissions but also alleviates other environmental and social problems. Examples include enabling increased use of public transport instead of cars; moving to healthier diets; using wood in construction, instead of steel and cement; and using better practices to preserve soil nutrients in place of fertilisers. There may even be a risk that policies designed to meet a transition milestone, such as subsidies for a zero emission technology, could make such alternative solutions less competitive.

- **Protection or enhancement of natural carbon stores:** Forests, peatlands, wetlands, and other natural carbon stores do not fit naturally within the transition milestones framework. These natural systems need preservation, not transitions, for the avoidance of emissions.

- **Interactions between sectors:** As the framework focuses attention on individual sectors, it may direct less attention to opportunities for synergies between transitions in multiple sectors, or to risks of incompatibility between solutions adopted in different sectors.

Other governance arrangements may be needed to ensure each of the above opportunities are not missed. For example, the need to exploit synergies between sectors may be best handled by governance arrangements that bring different policy teams and government departments together in analytical and policymaking processes. This would be distinct from the high-level governance framework that supports monitoring and scrutiny of progress.

Since the balancing of multiple competing objectives and interests is a routine part of policymaking, it is not essential (or possible) for every opportunity to be encouraged and every risk managed within a single governance framework.

As noted above, risks around technology choice are unavoidable in a technology transition – it is not possible to fully decarbonize a sector without going through a process in which viable technologies are identified and scaled up – but these risks may be higher if choices are made too quickly. The risks can be mitigated by using competitive processes that are focused on outcomes, rather than specific technologies that have been identified as potentially viable, and market or policy designs that make different zero emission solutions compete for market share as they scale up. Monitoring the progress of different technologies in global markets is another way to inform judgement. Governments could usefully cooperate on creating and maintaining Best Available Technology lists, as used in the past for the control of pollutants, as the basis for policies that require the use of zero emission technologies wherever these are available.

Since economic structures are not static, it may be important to build some flexibility into the governance framework. This could involve periodic reviews to ensure sector boundaries remain appropriately defined, and to identify areas of tension between measures to advance transitions and opportunities for product substitution.

The possibility of a combined or hybrid framework

Carbon budgets and transition milestones could be combined within a hybrid governance framework. The transition milestones would focus attention on the developments most important for advancing the transition to zero emission solutions in each sector, while the carbon budgets would focus attention on ensuring that in aggregate emissions are reduced, including through other opportunities such as increased efficiency.

In a combined framework, it may be particularly important to avoid having too many targets, so that the power of focusing political attention at specific moments in time is not lost. One approach could be to use transition milestones only for the largest emitting or most strategically important sectors, while the rest are subsumed within economy-wide carbon budgets.

The differences between carbon budgets and transition milestones will be greatest for sectors in the early stages of transition, when critical steps to advance the transition achieve minimal reductions in emissions. In the later stages, there will be increasing convergence between the measures needed to bring the zero emission solutions to 100% market share, and the measures to eliminate the last remaining emissions.

While a combined framework of carbon budgets and transition milestones may be ideal, most countries at present have neither, meaning that the adoption of either one could be a step forward. Larger countries, in particular, should design their governance frameworks carefully: they are likely to have greater potential to influence the global economy, but also face a greater need to control their national economy-wide emissions to limit climate change risks.