



Smith School
of Enterprise and the Environment



The role of Ministries of Finance in driving and shaping the low-carbon energy transition

Swedish Energy Agency and Smith School collaboration

January 2023

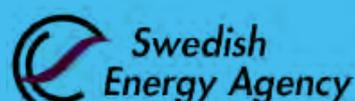
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Report scope:

This report sets out 10 recommendations for how Ministries of Finance can play a critical role in delivering a rapid and just low-carbon energy transition. These recommendations are split into two key themes: driving an enormous capital reallocation in a just way and transforming ways of working. Our recommendations primarily focus on how MoFs can modify existing tools and approaches to better enable climate mitigation. Highlights include the application of climate-relevant conditionalities to the use of public funds, the introduction of policy decision tools that are fit for a transition context, a reconfiguration of the tax and subsidy pots to

incentivise transition-consistent behaviours and committing funds to a Global Climate Mitigation Trust as proposed by the Bridgetown Initiative.

The low-carbon energy transition is the canonical example and many of these recommendations are applicable in other sectors. This report primarily focuses on the role of Ministries of Finance with respect to driving mitigation, however, it recognises the imperative of their role with respect to loss and damage, adaptation and resilience financing and recognise that there is an extensive literature on this topic.

Authors and Acknowledgements

This report has been a collaborative effort and we would like to extend thanks to individuals who have shaped this report. All names are listed alphabetically by first name.

Swedish Energy Agency

We are hugely grateful to our colleagues at Swedish Energy Agency including Sandra Ideskar, Paul Westin and their collaborator Dennis Pamlin for their contributions.

Steering Committee

This report has benefited enormously from contributions from our Steering Committee members (listed alphabetically): Professor Doyne Farmer, Professor Eric Beinhocker, Professor Joseph Stiglitz, Professor Mariana Mazzucato, and Assistant Professor Marion Dumas.

Practitioners and policy advisors

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Coalition of Finance Ministers for Climate Action

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Report preparation

This report has been prepared by Emma Walsh and Cameron Hepburn from Smith School of Enterprise and Environment at The University of Oxford together with Marion Dumas of the Grantham Institute at London School of Economics. Support was provided by Christine Cavallo, Christopher Lomax, Laurence Wainwright, Leah Tillman-Morris, Lucy Lyons, Matthew Ives, Kevin Tang and Puninda Thind. Thanks to Brian O’Callaghan and Jono Faber for their review inputs.

Executive Summary

The world is in crisis and permacrisis

With a war, a pandemic, an energy crisis, inflation, slower economic growth and a possible global recession in 2023, it is no surprise that the Collins Dictionary 2022 word of the year was “permacrisis”. These acute crises and their economic symptoms are related to an unchecked and endless erosion of our social and natural capital. Declines in social capital have reduced trust and exacerbated geopolitical tensions. Declines in natural capital have increased the risk of pandemics such as COVID-19, as environmental and climate changes increase interactions between human and non-human species (Carlson et al, 2022; Romanello et al, 2022). The climate crisis, and its associated impacts in floods, fires, droughts and other extreme weather events is already destroying physical capital and is testing the resilience of key systems, such as food production.

It is increasingly obvious that unless we rethink our systems and institutions we will remain in permacrisis, with the impacts likely continuing to worsen over time. As observed in the aftermath of the 2008 financial crisis, “our multiple crises are not the result of a failure or failures of the system. Rather, the system itself...is the cause of many of these failures” (Stiglitz, 2010). So while 2023 may not appear to be a year for great optimism, necessity is the mother of invention and the need for change is increasingly obvious. The payoff for innovation is also now as high as ever. Across a range of areas in technology, economics and finance, there are opportunities for mission-led innovation to reverse the depreciation of our social and natural capital.



A more prosperous and just global economy is possible

The transition to a low-carbon economy has the potential to create a more prosperous and just global economy. Not only can bold action now reduce the worst impacts of climate change but it can solve other problems whilst creating material opportunities and driving climate compatible growth (Stern, 2022).

The transition presents policymakers with an opportunity to collapse the energy trilemma. Eventually energy can be cheaper driven by rapid technology cost declines, exposure to energy supply shocks can be reduced and the worst impacts of climate change can be avoided (Way et al., 2022). Furthermore, this transition offers an opportunity to increase the number of middle-income jobs globally: the IEA estimates that a clean energy transition could generate four times as many jobs as it would replace in the fossil fuel industry (IEA, 2021b). Further potential benefits include reduced social and environmental costs associated with fossil fuels (e.g., oil spills, conflicts) and health impacts from air pollution (Vohra et al., 2021). The broader transition to a lower-carbon economy offers opportunities to reduce environmental damage driven by global waste and biodiversity loss (Dasgupta, 2021). Longer-term, as a key input to economic production, cheaper energy will enable all sorts of new activities, just as it did during the industrial revolution.

A fast energy transition could save \$12 trillion compared to business-as-usual (Way et al, 2022). The logic is that clean technologies are already cheaper, and their “learning rate” - the rate at which costs decline with increased deployment - is much higher than that of fossil fuels (ibid). Investing in these technologies now accelerates the cost declines, while at the same time reducing stranded assets - wasted investment in fossil infrastructure that will be rapidly outcompeted (ibid).

The transition is the global growth story of the 21st century. The scale of opportunities appears vast: eleven of the highest potential low-carbon technologies could generate revenues equivalent to ~10% of the global economy (McKinsey & Company, 2022).

The race is on: The 2022 US Inflation Reduction Act aggressively promotes clean energy to build US dominance in an area of future strategic importance, following China’s similarly aggressive government-led moves a decade earlier. The EU announced a response to its perceived competition threat at the World Economic Forum 2023 with the announcement of the Green Deal Industrial plan. Decarbonisation impacts should be positive but impacts on economic products will vary greatly between countries – winners and losers will be defined by early actions. Whilst these policy reforms accelerate the pace of decarbonisation, they are also motivated by a dawning realisation that the low-carbon transition is starting to disrupt global competitiveness.

New dimensions of competitive advantage are emerging. First, natural capital endowments for resources with increasing demands. The difference between the distribution of natural resources required for the low-carbon transition (e.g., solar, wind, minerals) compared to today’s fossil fuel economy (e.g., oil, gas) has the potential to “shake up the global geopolitics of energy” (Economist, 2018). Second, scaling of new markets adjacent to existing technology and trade strengths. Although green complexity can evolve over time, it is typically easier for countries that currently export a diverse range of green, technologically sophisticated products to become more competitive in new green goods and services that are adjacent to existing competitive strengths because of local skills, know-how and infrastructure (Hidalgo et al., 2018; appendix).

This world is within our grasp: increased investment and innovation are critical to achieving it.

Ministries of Finance are vital to delivering this future

MoFs have a critical role in driving and shaping the transition. In particular, by directing the necessary capital flows and ensuring a fair and acceptable distribution of the costs and benefits.

Although the precise remit of Ministries of Finance varies internationally, most interventions required fall under the direct remit of the MoF. MoFs are gatekeepers to government expenditure and influence the use of strategic public assets such as state-owned enterprises, state investment banks and sovereign wealth funds. Furthermore, they are well placed to coordinate cross-government policy. And they are frequently the owners of cross-government policy decision-making and tools. A successful transition, which is fundamentally about the future direction of the economy, must take a whole of government approach – it is not an issue reserved for environment ministries.

Some MoFs are beginning to offer the visionary leadership required. A handful of countries have announced major new climate investment packages (e.g., US' IRA) and 80+ countries have joined the global Coalition of Finance Ministers for Climate Action. However, in many countries there remains a large disconnect between ambition and action. History shows many occasions where MoFs have demonstrated visionary and innovative intervention in times of crisis, often galvanising economic transitions in the process. The most recent example is, of course, the response to the COVID-19 pandemic: MoFs responded with rapid financial support, amounting to ~USD 19 trillion to rescue and recover their economies (O'Callaghan et al., 2022).

Image credit: Danae Kyriakopoulou of LSE

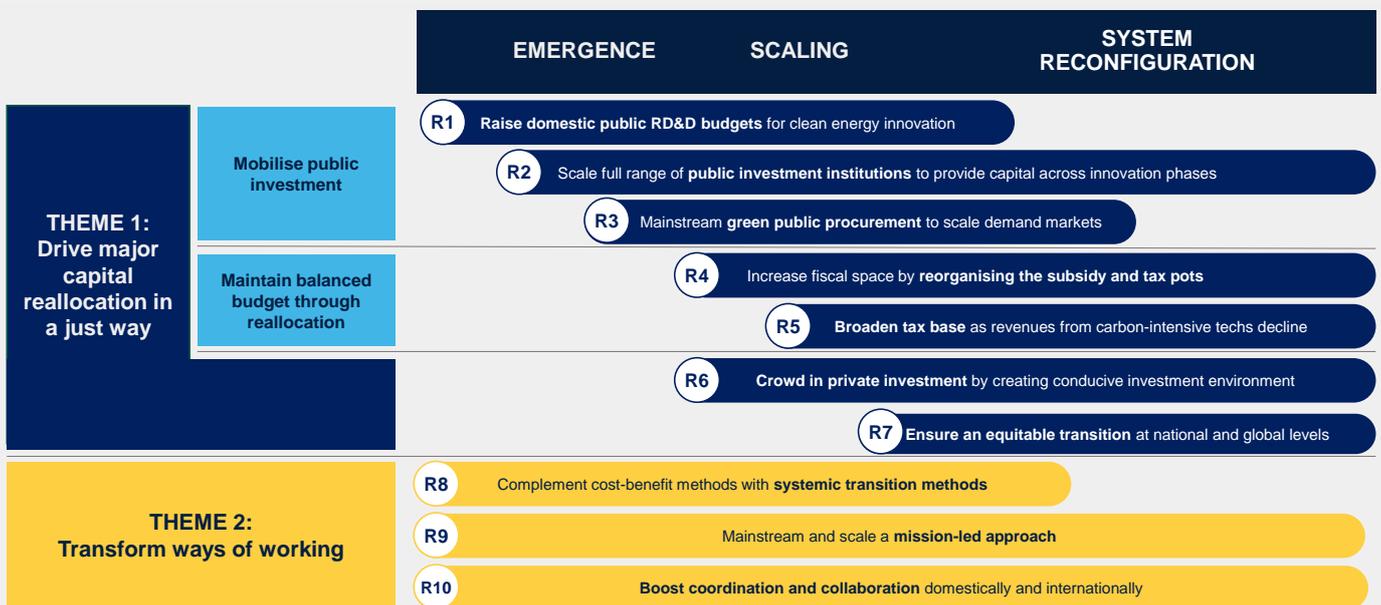


10 recommendations for how Ministries of Finance can drive and shape the transition

This report outlines 10 recommendations for within two key themes for Ministries of Finance to lead on the delivery of a rapid and just low-carbon energy transition. Our recommendations primarily focus on how MoFs can make modifications to their existing tools and approaches that better drive climate

mitigation. Highlights include the application of climate-relevant conditionalities to the use of public funds, the introduction of policy decision tools that are fit for a transition context and a reconfiguration of the tax and subsidy pots to incentivise behaviours consistent with a low-carbon transition.

Framework of principles to better drive and shape a low-carbon transition



“Although public funds are key, the majority of the investment is expected to come from the private sector.”
(McKinsey, 2023)

MoFs must drive an unprecedented capital reallocation (Theme 1). Incremental investment is estimated to be between USD 3-5 trillion per annum (2-3% of GDP), front-loaded this decade (IHLEG, 2022; McKinsey, 2022). These figures are approximately equivalent to half of annual global corporate profits or one-quarter of total tax revenue (ibid). The first three recommendations outline ways to deploy public capital and the subsequent two suggest approaches to reallocating public funds.

MoF must mobilise public and private capital types and ensure the right funding is available at the right time. MoF's role is to deploy patient capital for the earlier-stage innovations and introduce coordinated incentives to rapidly crowd-in private capital to the more mature innovations. Public money can be deployed via a range of mechanisms and this report advocates for an expansion of the use of environmentally-aligned conditionalities applied to the use of such public funds (Mazzucato, 2022):

- First, MoFs should **increase direct public low-carbon energy R&D investment** to rise to the innovation challenge of the century. This ensures pipeline development for the next wave of scalable low-carbon technologies, such as utility-scale long-duration energy storage and low-carbon fuels (recommendation 1). The innovation payoff now is high: social value is driven by positive externalities and spillovers, there is a precedent of many low-carbon technologies (e.g., solar) making significant advances (Way et al., 2022) and our scientific communities have a good mapping of the potential advances in the short-, medium- and long-term (IEA, 2022). Funding should be available via sub-national funds and portions ring-fenced for disruptive startups and social science research. This can widen the pool of engaged actors and drive investigation into the economic, political and social barriers to deployment of the possible production frontier.
- Second, MoFs should **leverage a full range of public investment institutions** and state-owned enterprises to **supply public capital across the innovation phases (recommendation 2)**. MoFs should use their oversight over these entities to make the transition an explicit part of their mandates and require use of conditionalities to align use of funds to the mission.
- Third, MoFs can **mainstream green public procurement** to both create niche markets and scale demand markets. MoF can do this by harnessing the budgetary control over line ministries, providing clear guidelines and deliver training programmes to relevant colleagues (recommendation 3).

Such public funding can be afforded within the envelope of a balanced budget. Without raising excessive debt, incremental public capital required (for lower-carbon technologies and capital stock) can be raised using two approaches:

- Short-term, **reconfigure the subsidy and tax pots to increase fiscal space (recommendation 4)**. First, industrial subsidies should be reorganised by phasing out fossil fuel subsidies. Indirect fossil fuel subsidies alone have been estimated by the IMF at ~7% of GDP in 2020, or ~\$6 trillion, which is roughly equivalent to double the annual investment required in low-carbon deployment to achieve Net Zero in 2050 (IEA, 2022; Parry et al., 2021). Second, pricing for negative externalities should increase gradually: specifically, carbon prices should be increased such that energy sources are taxed in proportion to their carbon content. The current implicit tax on most energy sources is well below the social cost of carbon (Blyth, 2018). Thirdly, taxes on rents and excessive consumption should be established, increased and/or expanded in scope (e.g., wealth taxes, financial transaction taxes, of which stamp duty was the first imposed on the LSE in 1694 (Dieter, 2003); land taxes; windfall taxes).
- Longer-term, **tax income could be increased by broadening the tax base** to incorporate the economic surplus generated from new low-carbon innovations (recommendation 5). This not only avoids eventual erosion of fossil fuel tax revenues but also generates new tax revenue streams that can be reinvested.

MoFs must **crowd-in private finance** by creating an attractive investment environment (**recommendation 6**; McKinsey, 2023). Private investment will come from diverse sources including venture capital, private equity, bank finance, state agencies and institutional investors. MoF can reduce the risks of low-carbon investments by acting as the lead investor offering patient capital for early-stage innovations (as outlined in recommendations 1-3). Furthermore they can reduce policy risk by providing long-term coherent policy (see recommendation 10) and also revenue risk through subsidies (e.g. feed-in-tariffs). Furthermore, MoFs can mainstream greening financial instruments by issuing green sovereign financial instruments (e.g., bonds, loans) and establish a national (or regional) consortium tasked with developing an economy-wide green finance strategy and implementation plan.

MoFs have a critical role in ensuring the transition is just at the global, national and regional levels (recommendation 7). At a national level, MoFs must use their economy-wide view and budgetary control powers to deliver whole-of-government interventions to mitigate two impacts: firstly, concentrated loss of local economic activity and employment opportunities, and secondly, regressive impacts on consumers, especially the risk of energy poverty for those at the lower end of income distribution.

Globally, it is imperative that MoFs in developed countries use their budgetary control powers to provide financial assistance to developing countries to address climate injustices and redress global imbalances. This report focuses on the role of MoFs with respect to providing support for mitigation deployment but it recognises MoFs must play a broader role that includes providing support for loss and damage, adaptation and resilience initiatives too. Developing countries are likely to have higher costs of capital, more constrained fiscal space and even more insufficient private capital. This report advocates for MoFs in developed countries to actively engage with the promotion, design and implementation of proposals put forward by the Bridgetown Initiative. This includes a USD 500 billion Global Climate Mitigation Trust through unused Special Drawing Rights (SDRs) issued by the IMF but highlights the need to monitor global inflation and consider how the fund can be deployed.

Mindset shifts and reforms to ways of working will be needed to enable these changes (Theme 2). This theme underlines the need for alterations to existing approaches: the way that policy decisions are made, the overarching mission and a renewed commitment to domestic and international coordination.

MoF will need to augment their intellectual toolkits, particularly cost-benefit analysis, to incorporate dynamic analysis of system and structural transformation (recommendation 8).

Many of the changes required are set out in the ten policy guidelines advanced by Anadon et al (2022). Policymakers must adapt their tools and approaches to system transformation context (away from comparative static analysis). A strategic, mission-oriented and market-shaping mindset can deliver the low-carbon transition by scaling novel technologies (**recommendation 9**). Given their economy-wide policy remit, MoF are well placed to lead the defining, coordination and progress measurement of these missions. As the transition continues, the need for both domestic and international coordination becomes increasingly important.

MoF must double down on domestic and international coordination (recommendation 10).

MoF's cross-economy role positions them well to coordinate whole-of-government interventions to economy-wide challenges. Domestically, these include welfare measures to ensure fair distribution of positive and negative impacts; ensuring a pipeline of skilled labour in relevant areas and identification of areas of strategic comparative advantage. International cooperation is essential to (i) support the Global South in driving climate-compatible growth and (ii) can increase the pace of the global transition. Well-targeted international collaboration can make low carbon transitions faster, less difficult, and lower cost (Breakthrough Agenda, 2022). For example, the cost parity of electric vehicles and internal combustion engines could be upto 5 years earlier if the world's largest car markets coordinated a mandate on the sale of internal combustion engines (Lam & Mercure, 2021).



Section A

The world is in crisis and permacrisis

Governments around the world are now facing crisis after crisis. The Collins English Dictionary word of the year for 2022 was “permacrisis”, recognising that we are lurching from one crisis to another (Collins, 2022). The infamous 1979 Sun newspaper headline “Crisis, What Crisis?”, which captured the perception at the time that the British government was refusing to acknowledge the chaos of the “Winter of Discontent”, could now be seen as a mere request for clarification about the crisis under discussion (Cawood, 2013).

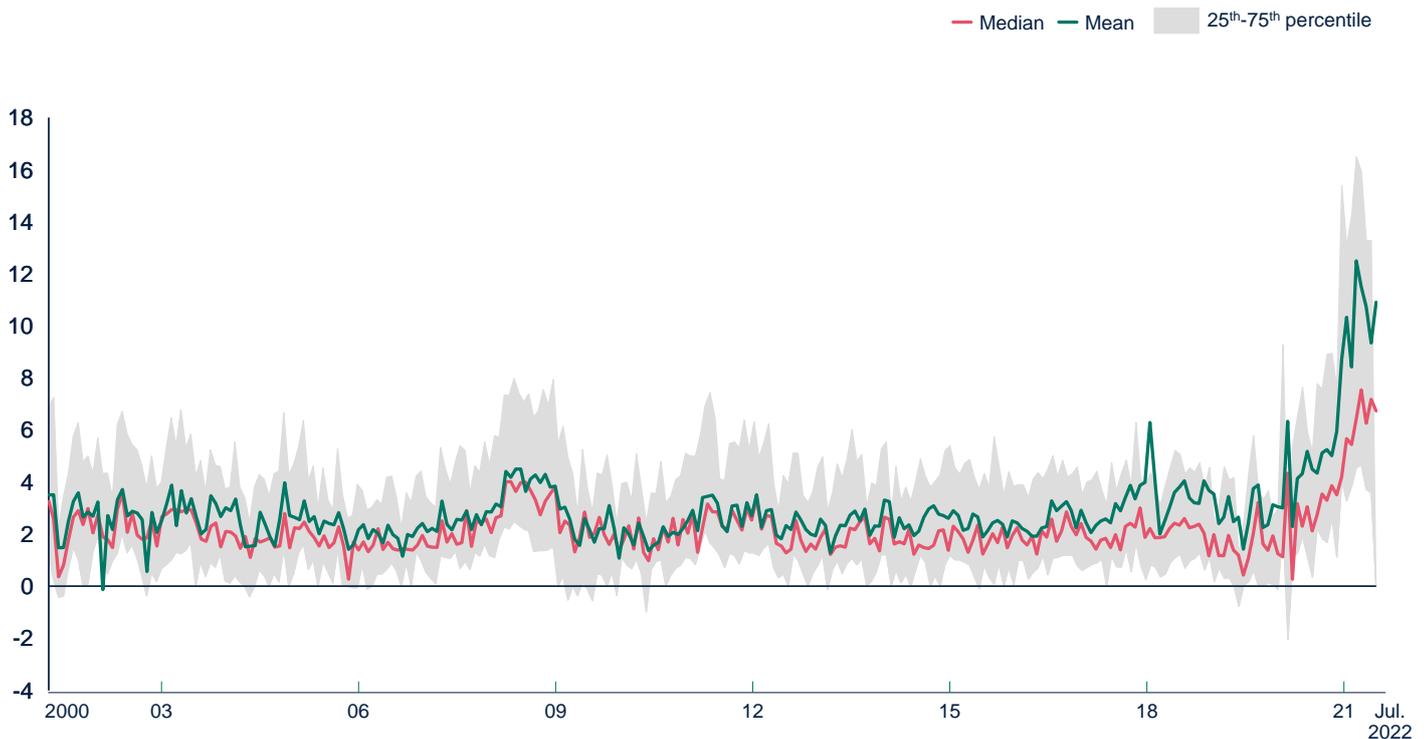
These crises are related and can be loosely understood in terms of symptoms, causes and root causes. The painful symptoms emerge as acute economic and financial challenges. These vary from country to country. That said, all face higher inflation (see Figure 1) driven by higher energy and food prices and slower growth (IMF, 2022). Some face possible recession: the IMF expects “one third of the world economy to be in recession” (Georgieva, 2023). Many have historically high levels of public debt. Some face currency crises. Clearly our economic systems are more brittle, and governments globally feel more constrained in their available set of responses.

The Collins English Dictionary word of the year for 2022 was “permacrisis”

Figure 1: Core inflation and its distribution across countries (recreated from IMF World Economic Outlook, 2022)

Core Inflation and Its Distribution across Countries*

Annualised percent



* Includes ARG, BRA, CAN, CHE, CHL, CHN, COL, CZE, DEU, DNK, ESP, FRA, GBR, HKG, HUN, IDN, IND, ISR, ITA, JPN, KOR, MEX, MYS, NOR, PER, PHL, POL, RUS, SGP, SWE, THA, TUR, TWN, USA, and ZAF. The group represents 89.4 percent of advanced economy GDP, 75 percent of emerging market and developing economy GDP, and 81 percent of world GDP based on purchasing-power-parity weights. Economy list uses International Organization for Standardization (ISO) country codes.
Source: International Monetary Forum (2022)

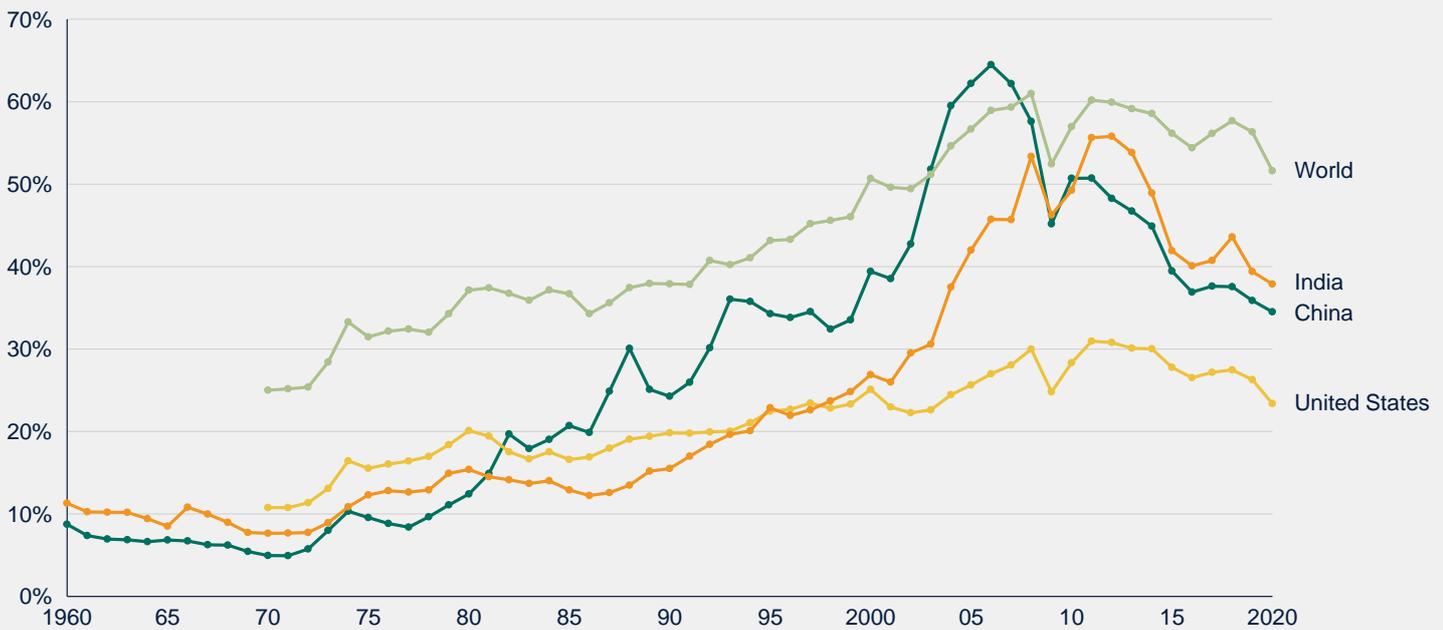
The immediate consequences have been war (in Ukraine) and plague and pestilence (COVID-19). While we haven't ticked off all of the list of biblical disasters in, say, the libretto of Handel's Israel in Egypt, alas we are getting there. Reductions in trade as a share of GDP (see Figure 2), exacerbated by supply chain disruptions from COVID-19 and deliberate policy choices by governments to decouple parts of the global economy, has not helped. Trade frictions are a completely understandable response to lower social capital and trust between peoples and nations. The consequences, though, are reduced resilience and prosperity.

The root causes of these crises are to be found in the depreciation of our social capital and natural capital. The decline in our social capital (e.g. trust-based relationships between nations) is leading to a range of geopolitical tensions that are harmful to people around the world. The threats to natural capital (e.g. our continued failure to tackle the underlying climate and biodiversity crises seriously) are leading to fires, floods and other disasters that are already having direct impacts on capital stocks and GDP, increasing risks of migration (of humans and non-human species), conflict and disease. The risks are approaching the existential. These root causes will not just disappear without significant effort, and without recognition of the interconnectedness of the issues at hand (Figure 3).

Figure 2:
Trade integration has plateaued (recreated from World Bank and OECD, 2021)

Trade as a share of GDP, 1960 2020'

Trade openness index: the sum of exports and imports of goods and services, divided by GDP



Source: World Bank and OECD (2021)

Acute crises, permacrises and root causes

Illustrative

Symptoms



Inflation (energy and food prices)



Recession



Conflict

Acute Crises



Russian invasion of Ukraine



Geopolitical tensions

Permacrises



COVID-19



Climate change impacts (e.g., extreme weather, climate damages, migration)



Biodiversity crisis impacts

Root causes



Depreciation of natural capital



Depreciation of social capital

Figure 3:

Simple visualisation of acute crises, permacrises and root causes

Reprioritising sustained innovation and investment in social and natural capital, and addressing the root cause of these problems, will be vital to re-establishing stability and enabling continued economic and financial prosperity. In a world where public resources appear increasingly scarce, this requires shrewd policy, thinking in systemic and mission-driven ways, and a focus on achieving double or triple wins, where the same euro, dollar, or renminbi achieves multiple valuable goals.

¹ Direct amounted to USD 697 billion in 2021 across 51 major economies (OECD G20-IEA combined estimates)

A major reorganisation of the subsidy and tax pots is needed: reallocation of capital is required away from fossil fuel subsidies hampering low-carbon support and towards low-carbon innovation and diffusion. Today, the indirect subsidies for fossil fuels (inclusive of the unpriced social cost of carbon) amounted to 6.8% of GDP in 2020 at \$5.9 trillion (IMF, 2021)¹. This is a similar order of magnitude to the annual investment in clean energy (not just innovation) required to achieve Net Zero emissions by 2050, which the IEA (2021) estimates must triple to \$4 trillion by 2030. Public investment in low-carbon R&D pales in comparison, despite its essential role as patient capital. And despite the fact that 50% of technologies required for the transition are still mere prototypes, only 0.035% of GDP (USD 34bn) in OECD countries was invested in low-carbon R&D (IEA, 2022; Nemet et al., 2016). Sustained subsidisation of fossil fuel production and consumption makes low-carbon technology scaling and system reconfiguration more challenging.

Role of public R&D funding in demonstration projects

(Nemet et al., 2016)

The median public share of funds financing demonstration projects in concentrated solar power, wind power, and biofuels was above 50%.



The energy transition offers key opportunities.

The most important yet underappreciated feature of the energy transition is that clean energy will be cheaper than fossil fuels. It is already cheaper, according to the International Energy Agency, in many parts of the world. This is of first order significance because of the centrality of energy in the modern economy. Fairly obviously, without energy, there can be scarcely any economic activity at all. MoFs and central banks monitor energy prices carefully, despite them being a small fraction of measured GDP, because increases in energy prices lead to increases in food and other prices, significantly harming economic prosperity. The flip side is that the reduction in the costs of energy drives an economy forwards. The energy cost declines during the industrial revolution are arguably a foundational plank of the growth of the modern economy. The transition to clean, cheaper and more secure energy could save GDP \$12 trillion (Way et al 2022) in lower input costs, even before these broader macroeconomic benefits are accounted for.

The remainder of this report explores how we can reduce the likelihood of permacrisis and its associated impacts. This starts with greater clarity about what sort of economy we wish to build and the opportunities it holds (section B). In our vision of the future, greater investment in innovation, social and natural capital has led to economies with cheaper and more secure energy, higher social capital, reduced geopolitical tensions, and richer and more resilient natural capital.

However, we are clearly a long way off achieving such a vision, given that “permacrisis” is the word of the year, and given that many governments are failing to deliver the stability and prosperity that their people desire. Our diagnosis leads to some feasible actions that we can take now to put us on a better path (section D). Ministries of Finance are absolutely critical actors to fixing the mess we are in (section C). By adopting more systemic, mission-driven thinking, supporting sensible and strategic policy in shifts other government departments, MoFs can lead our exit from the permacrisis, and also prevent worse acute crises in the future.

Section B

A more prosperous and just global economy is possible

The transition to a low-carbon economy has the potential to create a more prosperous and just global economy. Not only can bold action now reduce the worst impacts of climate change but also bold action on driving the energy transition can solve other problems whilst creating material opportunities and driving climate compatible growth (Stern, 2022).

The transition presents policymakers with an opportunity to collapse the energy trilemma.

Eventually energy can be cheaper driven by rapid technology cost declines, exposure to energy supply shocks can be reduced and the worst impacts of climate change can be avoided (Way et al., 2022). Furthermore, this transition offers an opportunity to increase the number of middle-income jobs globally: the IEA estimates that a clean energy transition could generate four times as many jobs as it would replace in the fossil fuel industry (IEA, 2021b). Further potential benefits include reduced social

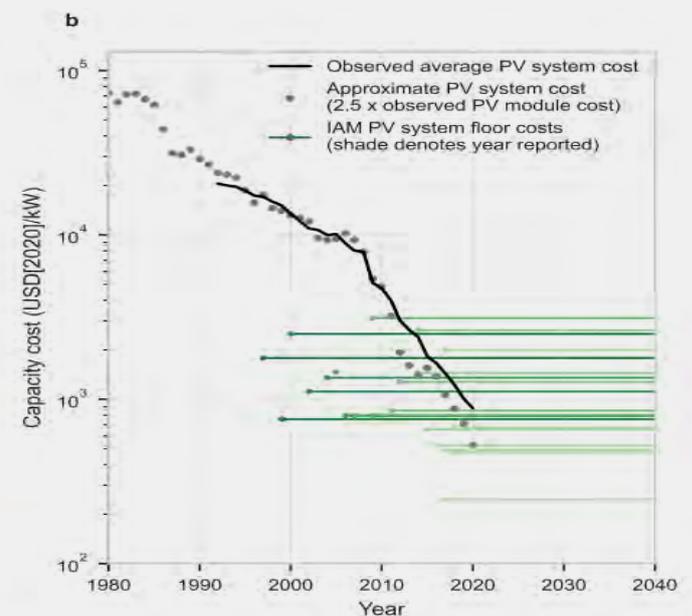
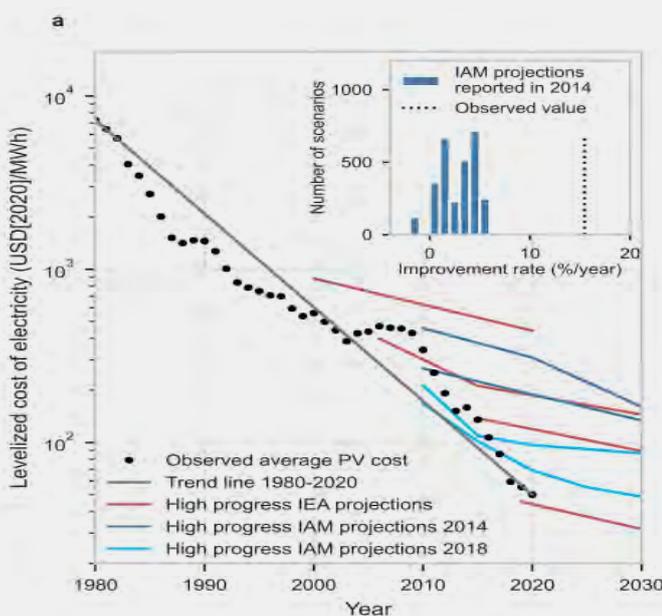
and environmental costs associated with fossil fuels (e.g., oil spills, conflicts) and health impacts from air pollution (Vohra et al., 2021). The broader transition to a lower-carbon economy offers opportunities to reduce environmental damage driven by global waste and biodiversity loss (Dasgupta, 2021). Longer-term, as a key input to economic production, cheaper energy will enable all sorts of new activities, just as it did during the industrial revolution.

A fast energy transition could save \$12 trillion compared to business-as-usual (Way et al, 2022).

The logic is that clean technologies are already cheaper, and their “learning rate” - the rate at which costs decline with increased deployment - is much higher than that of fossil fuels (ibid). Investing in these technologies now accelerates the cost declines, while at the same time reducing stranded assets - wasted investment in fossil infrastructure that will be rapidly outcompeted (ibid).

Solar PV cost of energy and capacity costs: forecasts and outturn*:#

Figure 4: Renewables price declines (Way et al., 2022)

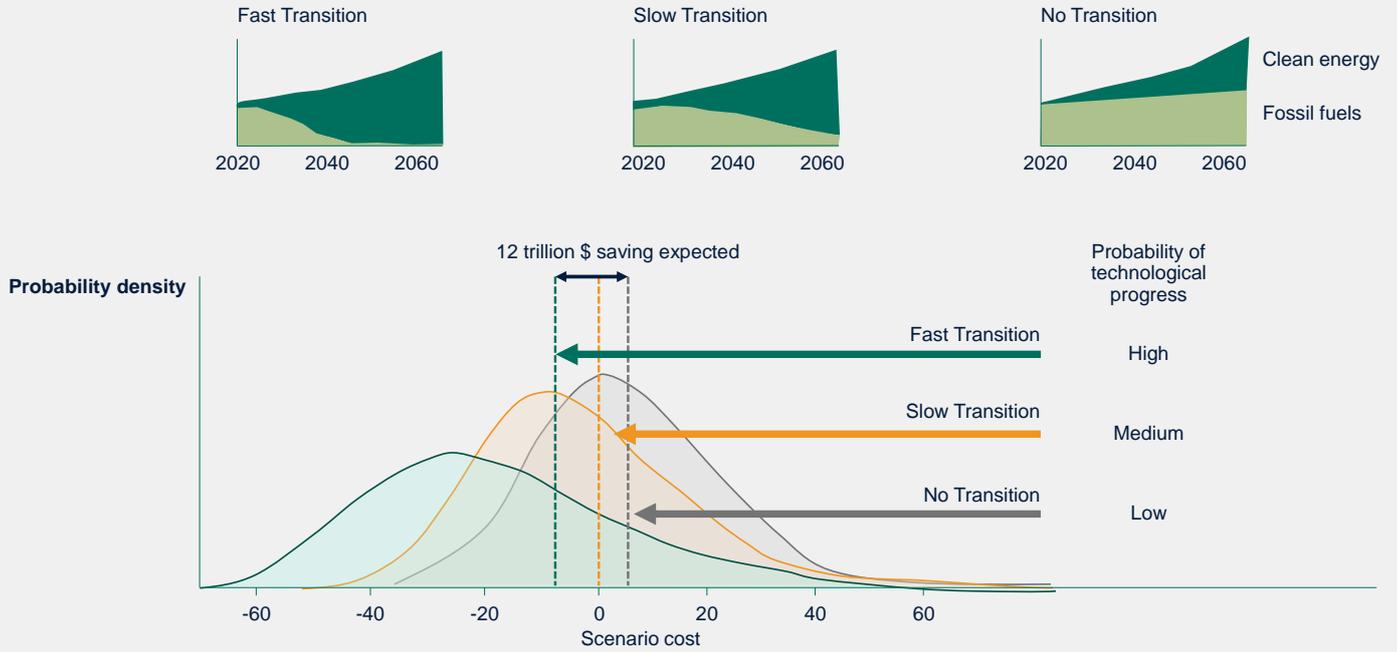


* In A, the black dots show the observed global levelized cost of electricity (LCOE) over time. Red lines are LCOE projections reported by the IEA, dark blue lines are integrated assessment model (IAM) LCOE projections reported in 2014 and light blue lines are IAM projections reported in 2018. IAM projections are rooted in 2010 despite being produced in later years. The projections shown are exclusively 'high technological progress' cost trajectories drawn from the most aggressive mitigation scenarios, corresponding to the biggest projected cost reductions used in these models. Other projections made were even more pessimistic about future solar PV cost # In B, solar PV system floor costs implemented in a wide range of IAMs. The colours denote the year the floor cost was reported, ranging from 1997 to 2020. Observed solar PV system costs are also shown. Source: Way et al., (2022)

A fast energy transition could increase energy security and save \$12 trillion compared to business-as-usual

Recreated from Way et al., 2022

Three energy system scenarios



Source: Way et al., (2022)

Figure 5:

A fast energy transition could increase energy security and save \$12 trillion compared to business-as-usual (recreated from Way et al., 2022)

Innovations to support higher-quality, cheaper, cleaner and more secure energy are emerging that will take us towards this imagined future.

The International Energy Agency already considers solar energy the cheapest in human history. As noted above, in addition to simply reducing the costs of a key factor input into the global economy, the range of innovations in energy, storage and distribution are leading to new opportunities to have the right sort of high quality energy available in the right place at the right time. The financial and macroeconomic significance of this is hard to overstate. It may be that headline catching estimates, such as the saving of USD \$12 trillion (Way et al 2022) end up being underestimates of the value of this transition to the global economy.

The range of innovations in energy, storage and distribution are leading to new opportunities to have the right sort of high quality energy available in the right place at the right time.



The energy transition is already reshaping the global competitiveness landscape.

Those that don't act early will be left behind, while early movers are already gaining a comparative advantage (e.g. China and Germany; Mealy & Teytelboym, 2022). The transition presents countries with the opportunities to grow competitive advantage in a vast array of green products, components and services. The extent to which a country (or company) is competitively positioned to generate export income from the low-carbon transition will vary and may differ from the status quo. Appendix includes a green comparative advantage analysis. Relevant benefits associated with pursuing green growth opportunities include: expanding exports in growing markets, securing foreign investment, and boosting employment opportunities, while mitigating material fiscal risks and risk of industry, job and export losses as they fail to compete internationally (O'Callaghan et al., 2022).

The scale of the green growth opportunities is vast:

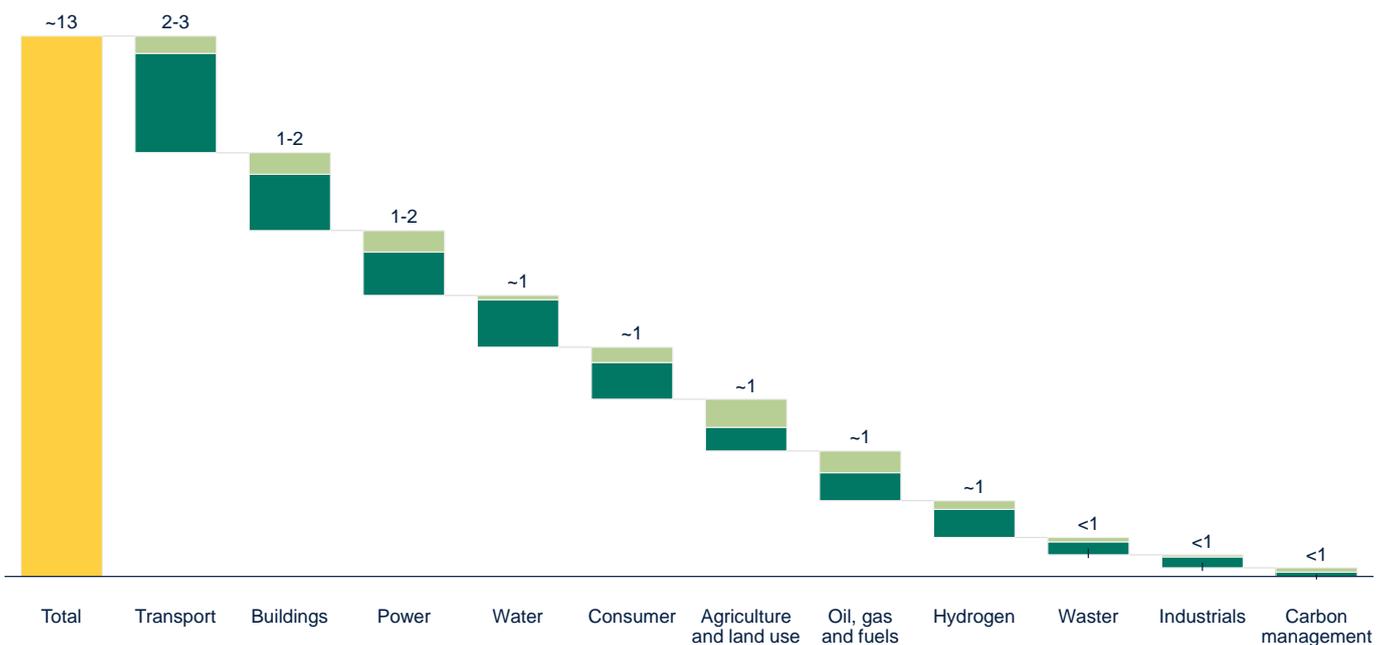
figure 6 illustrates that eleven of the highest potential low-carbon technology revenue pools were estimated to generate more than £9 trillion of annual sales by 2030 (McKinsey, 2022), roughly 10% of the global economy. One driver of this is the continued growth of technologies that are already penetrating global markets (e.g., renewable energy and electric mobility). For example, solar and wind generation is expected to comprise ~70% of power globally in 2050 (IEA, 2021a) and demand for batteries is expected to increase 14-fold between 2021 and 2030 (EU, 2022). Another driver will be the rapid emergence of technologies that are less currently commercialised (e.g., green hydrogen-based fuels). Figure 6 illustrates estimated market sizes for both these more nascent technologies and those that are more mature.

Eleven of the highest potential low-carbon technology revenue pools were estimated to generate more than £9 trillion of annual sales by 2030 (McKinsey, 2022), roughly 10% of the global economy.

Figure 6:

Estimated 2030 addressable market size of low-carbon technologies (McKinsey & Company, 2022)

Estimated 2030 addressable market size of low-carbon technologies, selected categories, USD Trillions



Source: McKinsey & Company (2022)

Section C

Ministries of Finance are vital to delivering that future



“Finance Ministers hold the keys to accelerating climate action. They know most clearly the risks posed by climate change, and recognize how taking action could unlock trillions in investments and create millions of jobs through 2030.”

(Coalition of Finance Ministers for Climate Action, forthcoming)

MoF have both the incentive to act to drive climate action to achieve their primary objectives and are uniquely placed to drive it (Coalition of Finance Ministers for Climate Action, forthcoming). The transition requires an enormous, system-wide technological and economic shift that will create new risks and challenges at all levels of the economy, distributed unevenly. Figure 7 outlines the most salient risks and opportunities and their relevance to MoF’s core objectives.

Despite these crises, the opportunity for MoFs to offer visionary leadership is enormous. There is a track-record for many MoFs in demonstrating visionary, innovative and adaptable leadership in times of crisis and to galvanise economic transitions: for example, in response to the COVID-19 pandemic MoFs responded with rapid financial support (amounting to ~USD19tn² on vaccine innovation and livelihood protection.

² by mid-2022

Figure 7:

Core inflation and its distribution across countries (recreated from IMF World Economic Outlook, 2022)

Relevant risks and opportunities to the core objectives of Ministries of Finance

Non-exhaustive

Relevant

		Objectives of Ministries of Finance			
		Stable and fair fiscal regime	Balanced budget	Competitive nation	Well-managed national assets
Opportunities	Collapse of energy trilemma				
	New dimensions of competitive advantage				
	Creation of new jobs				
	Reform of fiscal regime				
Risks	Increased climate damages				
	Reduced competitiveness				
	Ineffective use of public funds				
	Write-down of stranded assets				
	Increased risk of climate litigation				

MoF are uniquely placed to drive and shape a sustainable economic transformation given their soft³ powers within government and beyond, along with their broad policymaking mandate (Coalition of Finance Ministers for Climate Action, *forthcoming*). Together these hard and soft powers give them varied policy intervention levers to stimulate large investments in innovation and technological deployment to rapidly drive climate mitigation and adaptation (*ibid*):

- **The majority of interventions required fall under MoF’s direct remit⁴:** macro-fiscal and regulatory interventions needed to create markets for a sustainable transition and to balance distribution of benefits and costs are typically under MoF’s core functions (see figure 8 below).
- **They are typically responsible for government expenditure:** ~30% of the global economy is under their remit (*ibid*).
- **They usually have a central role in government:** positioned at the nexus of cross-government policy, typically with a degree of oversight or budgetary control over other line ministries, central banks, state-owned enterprises and the financial sector.
- **They are the designers and owners of cross-government tools:** often MoFs are responsible for tools used across government departments. These include economic impact assessments and macroeconomic forecasting.

Figure 8:

MoF functions and transition-relevant levers within their remit (inspired by Coalition of Finance Ministers for Climate Action, *forthcoming*)

Functions of Ministries of Finance and transition-relevant levers

Adapted from Coalition for Finance Minister for Climate Action (*forthcoming*)

Core function	Function description	Transition-relevant tools
Budget management (expenditure and investment)	Raising, steering & blending government expenditure and private capital via design and implementation of:	<ul style="list-style-type: none"> • Annual budgets (whole-of-government and gate-holder to departments) • Mobilisation of domestic capital (e.g., national investment banks) • Public investment strategies • Public procurement strategy and guidelines • Policies to leverage other sources of finance, such as blended
Macro and fiscal policies (tax and debt)	Setting macro economic and fiscal policy	<ul style="list-style-type: none"> • Taxation (including carbon-pricing, future-proofing tax income, distributional impacts) • Debt instruments • Regulation (e.g., subsidy reform)
Regulation and oversight	Governing and/or having budgetary control over other government departments, state-owned enterprises and central banks	<ul style="list-style-type: none"> • Mobilization of domestic capital via greening state-owned enterprises, development banks, central banks, sovereign wealth funds • Mobilization of private capital via greening national financial sectors
Accounting and reporting	Defining national accounting approaches, defining and ensuring compliance with policies and compiling financial reports	<ul style="list-style-type: none"> • Development of accounting standards, rules and guidelines including <ul style="list-style-type: none"> – Policy appraisal tools (e.g., cost-benefit analysis) – Climate performance standards and disclosure requirements – New national accounting approaches
National economic strategy	Shaping long-term national strategies	<ul style="list-style-type: none"> • Industrial strategy • Climate action strategy • Nationally Determined Contributions

Only within remit of Ministries of Finance in particular geographies

Source: Coalition for Finance Ministers for Climate Action (*forthcoming*)

³ Often indirect and rely on influencing partners. ⁴ Stern (2022) notes that the decarbonization transition includes a large number of market failures, including the externality of greenhouse gas emissions, the externalities of RD&D investments, imperfections in risk and capital markets, a variety of network externalities, lack of information, and health and environmental co-benefits. These failures are so numerous that a bold approach to structural change is needed. Rather than fixing markets “one failure at a time”, MoFs and governments need to create a new framework to accelerate the creation of more sustainable markets.

Although there is geographical variation in the mandate, governance and culture of MoF, they share core attributes, making them critically important to national transitions.

The appropriate role for MoFs (and governments more broadly) **evolves as the net zero transition reconfigures our economies.** This is because each phase of a transition (from invention to mainstreaming of a new technology) is characterised by different market failures and challenges. The simplest conceptualisation of the transition is a 3-part systems transformation framework: splitting the transition into phases of emergence, diffusion, and systems reconfiguration as summarised in Figure 4 (Victor et al., 2014; Geels et al., 2019). We use this framework in the rest of this report as a simple way to highlight the different challenges that arise in each phase, and the policies that can overcome them.

This framework makes it clear that the **government plays a critical role from the beginning until the end (ibid).** In the early stages, governments must give a strong impetus to low-carbon R&D, nurturing a flourishing innovation system focused on low-carbon technologies, since the private sector does not have the right incentives to do so alone. In later stages, governments can protect fledgling technologies by nurturing niche markets, help them compete by removing fossil fuel subsidies, encourage consumer behaviour change, and ramp up regulatory policies such as carbon pricing. They then play an orchestrating role in system reconfiguration, by coordinating actors who can ensure that complementary investments and learning in upstream and downstream sectors, in skills and in infrastructure will allow a technology to be deployed at scale. Given that many key sectors are globalised,

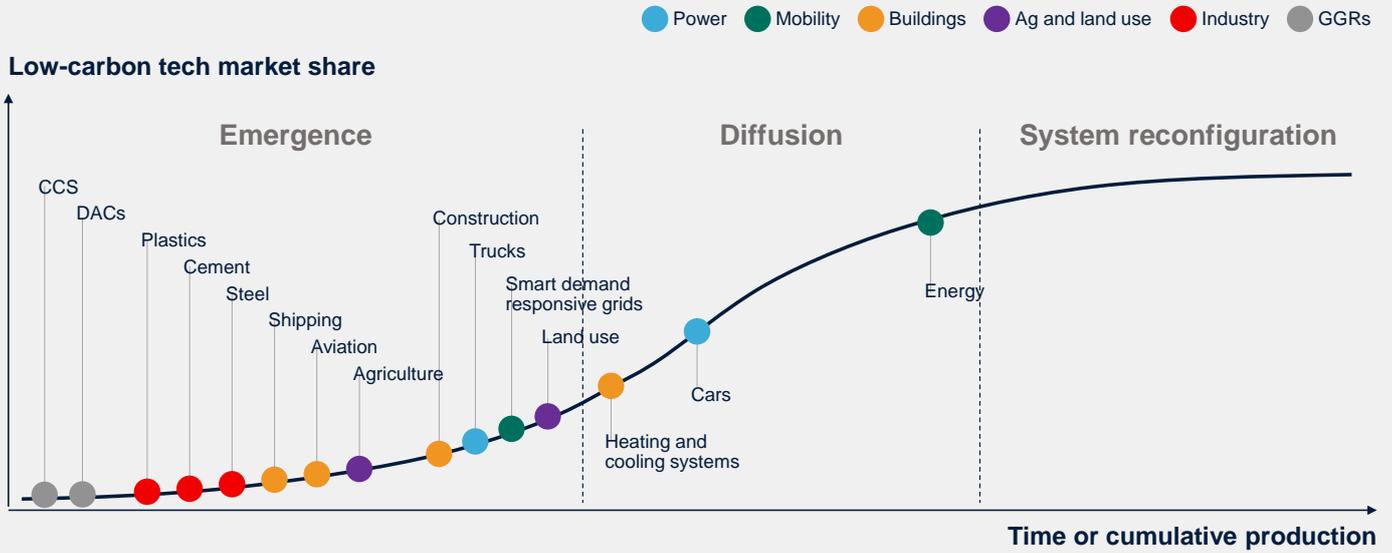
this effort also needs cooperation between governments, to ensure national policies reinforce each other and technological learning happens as quickly as possible. In a nutshell, MoFs, with the rest of the government, must develop a committed mission-led industrial strategy for low-carbon transformation in cooperation with other countries.

Individual governments must regularly assess individual technologies' position within the low-carbon transition. Figure 9 provides an illustration of the average stage of key sectors. Yet, this is highly dynamic and there is a large degree of geographical variation because, in some countries, past and on-going policies have successfully pushed forward some technologies along the transition curve. For example, in 2021 fifty countries had more than 10% of their electricity generation from wind and solar. Meanwhile Denmark, Uruguay and Luxembourg exceeded 40% (Jones et al., 2022), and are thus clearly already in the system reconfiguration phase of their power sector. This shows that the speed at which sectors can move through these transition phases depends in large part on policies and **government support is needed both to discover breakthroughs (emergence), and to scale existing technologies.** The IEA estimates that 50% of reductions in CO₂ required through 2050 may have to come from technologies that are still at the emergence phase. Consistent with this, Figure 10 shows that the technological transformation of most sectors is still in the emergence phase (technological solutions that are still at the prototype stage). For example, technologies in the emergence phase include utility-scale long-duration energy storage, electrolysers, hydrogen fuel-cells, demand-responsive smart grids, synthetic fuels, sustainable bioenergy and greenhouse gas removal technologies.

The IEA estimates that 50% of reductions in CO₂ required through 2050 may have to come from technologies that are still at the emergence phase.

Progress of selected technologies' low-carbon transitions

Adapted from Victor et al., (2019)



Source: Victor et al. (2019)

Figure 9:

Different sectors and technologies are more or less advanced in their net zero transition, but all must reach the destination (based on Victor et al., 2019)

Policy sequencing over the course of a technology transition is key (Acemoglu et al. 2016; Meckling et al. 2017).

Indeed, early innovation policy creates solutions and lowers the cost of low-carbon technologies. Once low-carbon substitutes exist, it becomes technically and politically feasible to regulate the market, by, for example, gradually ramping up carbon prices and/or phasing-out dirty technologies. Thus, given the early stages of many of the technologies required, a clear focus is needed on funding R&D nurturing a flourishing innovation system.

Evolution of role of government across simplified technological transformation

Adapted from Geels et al. (2019)

Figure 10:

The appropriate role for MoFs (and governments more broadly) evolves as the net zero transition reconfigures our economies (based on Geels et al., 2019)

	Emergence	Scaling	System Reconfiguration
 <p>Phase description</p>	<p>Discovery and development of novel technologies. Achieved by public and private labs deploying scientists to engage in testing, fast learning, and the creation of niche applications.</p>	<p>Commercially available technologies, which are not yet cost competitive with incumbents, start to penetrate markets. Learning processes improve via economies of scale; behaviours and attitudes start to shift in favour, and complimentary investment, skills, infrastructure, and standards begin.</p>	<p>New technologies achieve widespread adoption (e.g., clean energy technologies replacing incumbent fossil fuel technologies).</p>
 <p>Rationale for government intervention</p>	<ul style="list-style-type: none"> Develop the novel technologies that are considered critical enablers of the low-carbon transition in most pathways that are otherwise underfunded by the private sector, as firms are unable to capture positive spillovers Make existing technologies more cost competitive Overcome barriers to entry, (e.g. economies of scale) and create material opportunities for new products, firms, and countries to enter markets and win competitive advantages 	<p>Overcoming the technology “valley of death”</p>	<p>Reduced need for direct policy support yet broader system reconfiguration support required for complementary technologies, infrastructure and/or user behaviour. Indirect support required to:</p> <ul style="list-style-type: none"> Avert “locking in” incumbent technologies domestically (e.g., legacy infrastructure, legal standards) and internationally (e.g., supply chains) Ensure adequate welfare support to mitigate regressive effects of system change
 <p>Exemplar interventions required</p>	<ul style="list-style-type: none"> Initially provide technology-push policy support via public R&DD funding for early stage experimentation and, later, demand-pull support to bridge the ‘valley of death’ Define and enforce reliable regulatory structures that reward innovation and entrepreneurialism, via supporting startups and new entrants Nucleate and nurture consortia and channels that cultivate knowledge sharing and collaboration, for example partnering on regulatory support advocacy (e.g. Hydrogen Council) Apply a portfolio approach, accepting that funds must be applied to a wide range of technologies over a long period of time to ensure results (Grubb, 2013) 	<ul style="list-style-type: none"> Support the development of infrastructure to accelerate the uptake of new technologies (e.g., EV recharging networks). Coordinated public procurement Coordinate international definitions and standards Mandates (e.g., banning ICE vehicles; green building codes) Subsidies for purchase of low-carbon technologies purchase Commence phase out of existing subsidies on carbon-intensive goods/services 	<ul style="list-style-type: none"> Provide stimulus for supporting infrastructure Reform technology standards and legal requirements, both at the national level and internationally across global value chains Subsidies on high-carbon technologies should be gradually removed Complete phase out of existing subsidies on carbon-intensive goods/services Mitigate unintended consequences for members of societies most vulnerable to systems-scale transitions. Examples: skills transition programmes, regional innovation policies)

Source: Geels et al., 2019; SSEE (2022)

Section D

10 recommendations for how Ministries of Finance can drive and shape the transition



The nature of the challenges and opportunities associated with the low-carbon transition will need MoF to rethink their unique position over the economy to accelerate and shape it.

MoFs need to reform their core macro and fiscal functions to reconfigure the subsidy pot in a way that accelerates the transition and distributes its costs and benefits. In particular, there is an urgent need to reallocate capital into strategic low-carbon investments from both public and private sources. In order to do this, MoFs will need to reform their ways of working: some of the tools and approaches used will need to be adapted to meet the scale of the transition required. Those that respond to this era-defining challenge can be at the forefront of the transition to a lower-carbon, resilient world. This section outlines ten non-exhaustive

recommendations that seek to inspire MoF to develop smart portfolios of mutually reinforcing strategies, policies and capability measures that drive low-carbon innovation to accelerate the transition.

These are general principles that require tailoring to particular economic contexts:

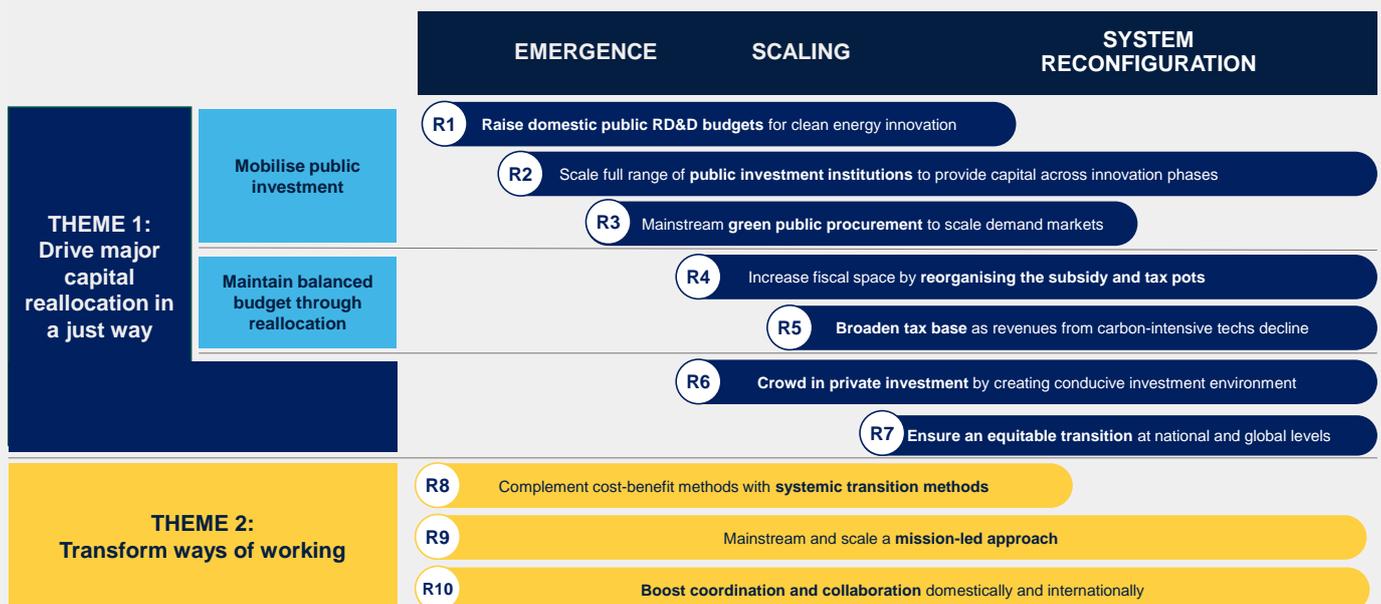
key factors will be the precise remit of the MoF, the existing innovation ecosystem, the fiscal space and the comparative advantages. They are intended to provide general guidance, based on practitioners' expert perspectives and a synthesis of the most up-to-date research on technological transitions and economic policy. Individual governments should incorporate the principles in ways most suited to their economic context.

Figure 11:

Ten recommendations for how MoF can drive delivery of the low-carbon energy transition in a fair way

10 recommendations for how Ministries of Finance can drive and shape the transition

Framework of principles to better drive and shape a low-carbon transition



Further raise domestic public R&D budgets for clean energy innovation

What it is:

Increasing government spend on the transition is one of several ways to close the incremental investment gap. Although this is expected to comprise a relatively small share of the total incremental investment: indeed McKinsey (2023) estimates that ~20% of the incremental cost would be government-funded if the investment conditions are sufficiently conducive to the private sector.

Public funding will be required for a multitude of applications, including research and development, demonstration projects, providing subsidies to low-carbon products or services that are not yet cost competitive, and welfare support for vulnerable groups negatively impacted. This public funding can be delivered through a range of mechanisms through which this could be delivered (e.g., grants, loans, subsidies, tax credits to name a selection).

This report argues that there should be a quadrupling of strategic direct R&D investment in earliest stage innovations most vital for the low-carbon transition

over 10 years. This funding currently stands at 0.035% of GDP and only 5% of overall public R&D (IEA, 2022), Recommendations 4 and 5 outline strategies for funding this. This remains an area of public underinvestment: it is less than 2% of clean energy deployment funding and is only half of the figure in the 1970s (IEA, 2022; Dechezlepetre, 2019). Whilst such funding has historically followed a boom-and-bust cycle linked to oil prices, there is a need for longer-term commitment and directional clarity to provide clear signals to invest in the appropriate research capabilities.

R&D investments should:

- Fund a decentralised innovation system, across multiple regions and cities, supporting both basic and more applied public research: the pool of ideas can be diversified and learning accelerated by using cities as laboratories of research.
- Be directed competitively to a wide range of public and private actors, including new entrants and start-ups. It expands the search for solutions, limits the chances of rent-seeking, and stimulates further innovation by stimulating competition (Aghion et al. 2015). It may also increase the chances for more transformative innovations and new business models, beyond simple substitution of an existing technology (e.g. innovative modal shifts beyond the individual car).
- Although the bulk of R&D investment should be directed to both technology discovery and development, a smaller portion should be earmarked for social sciences. Funding the latter can help inform why much of society is operating well below the possible production frontier (e.g., domestic heating systems).
- Linked to other financing policies targeting deployment and commercialisation (detailed in the next set of principles). As these investments are aiming at structural change (transforming whole technological systems), it is essential that different financing policies reinforce each other over the course of the full innovation chain.

Role of public R&D in developing solar

Public R&D has played an instrumental role in most of the key technologies that structure our economy, including the internet, smartphones, breakthrough drugs, or biotechnology (Mazzucato, 2011) documents that. Solar is no exception. Public R&D is one of the key ingredients in the history of solar's success. In the 1970's, the US government developed an ambitious programme to develop solar applications, improve performance and lower costs, injecting USD 1.7 billion⁵ in R&D over the period 1974-1981. This investment was accompanied by the Block Buy programme, the first public procurement programme designed to pull demand. During this period, scientists and engineers

developed 14 of the 20 most important breakthroughs in the history of solar, and costs were reduced by a factor of 5 (Nemet, 2017). According to Nemet (2017), this period was very fertile in training numerous scientists, creating rapid international learning and enabling new, viable companies. The US continued to fund solar R&D for the following 30 years, but at a much lower level, along with Japan and, later on, China. Public R&D programmes have had enduring effects: they have created codified knowledge (in the form of reports) and created institutions and international communities of practitioners, which have persisted after budgets were cut.

Challenges addressed: Insufficient funding for low-carbon technologies.

Public investment in innovation and demonstration of low-carbon technologies is estimated to be USD 34 billion (IEA, 2022). This must increase to generate enough innovations and rapid progress on promising low-carbon technology solutions still in the emergence phase. This early-stage public investment will gradually crowd in more private investment. Beyond closing the financing gap for low-carbon innovation, national innovation institutions should assume a mission-oriented role, with clear investment directionality to tackle major economic or societal challenges (recommendation 9).

Role of MoF: MoF have direct oversight for governmental department budgets: they oversee the expenditure of all main government departments. This gives some degree of direct or indirect control over public spending (which amounts to one-third of global GDP) and positions them in a crucial cross-governmental coordination role.

Tangible Actions:

- Commit to steady annual increases in low-carbon R&D funding: an indicative figure would be to bring it to ~20% of public RD&D (four times its current value) over the next 10 years.
- Communicate medium-term funding plans to explain the evolution of allocation of funds and what other costs are being displaced.
- Target funding towards technologies and components for which a country has a comparative advantage. Conducting regular analyses to identify in which technologies or component parts the country has a comparative advantage can help policymakers to strategically target areas in which they are best placed to compete and trade in. This should be based on natural resources, adjacent trade strengths (exemplified in appendix) and the policy landscape.
- Ensure funds irrigate a decentralised network of public and private actors, including new firms.
- Overall, this funding must be closely coordinated with other financing tools (recommendations 2, 3, 4) and to a mission-led approach (recommendation 9), and with other departments and countries (recommendation 10).

⁵ 2017 USD

Establish and scale full range of public investment institutions that provide conditional capital across innovation phases

What it is:

Beyond R&D funding, the earliest stage technologies require patient capital to help them establish and bridge the valley of death and therefore public investment is key. MoF can influence public investment institutions to increase their low-carbon investment and ensure that there is an ecosystem of public investment institutions servicing a range of capital types to deploy across the evolution of the innovation phases.

The strategy of individual MoFs will vary according to the existing public investment institutions already in place. Firstly, MoFs will choose to use a public investment entity with an economy-wide thematic remit (e.g., national investment bank, strategic investment fund) and give it a wide-ranging green mandate or to use a separate investment entity solely dedicated to green investment (e.g., green investment bank or venture fund). Secondly, MoFs must decide the geographical remit of each public investment entity: ranging from regional to national or multilateral (e.g., Israel's Yozma vs EU's European Investment Bank). Thirdly, MoFs need to ensure that there a range of risk appetites are covered by the public investment institutions: for example,

the UK is launching the Advanced Research & Invention Agency to funnel investment into early stage innovation in a way that complements its lower-risk UK infrastructure bank. Other relevant public investment institutions are national development banks and publicly controlled firms (in particular utilities, 50% of which are nationally owned (Mazzucato & Penna, 2016). Examples of successful public investment institutions include Germany's KfW, US Department of Energy's ARPA-e, China's CDP Capital and Sweden's Almi Invest Green Tech fund whilst green investment banks have been set up at national (e.g., Australia, UK), state (e.g., California, Connecticut) levels.



Section D

R2

Government funding should be conditional on behaviour change within organisations gaining access to that funding (Mazzucato, 2022). This should include financing from public investment institutions and also be incorporated into procurement requirements (recommendation 3) and R&D budgets (link to recommendation 1). Conditionality can be used to drive behavioural change in many areas and most relevant here is directing green transition change. They could be applied to, for example, ensuring emissions intensity reductions via investment in sustainable production methods or green procurement. More broadly, conditionality can be used to ensure equitable and affordable access to products and services, improvement of working conditions, reinvestment into R&D and/or profit sharing (e.g., ending the use of extraction tools like share buybacks). Conditionality is critical in aligning public-private partnerships with bold policy goals, ensuring that the rewards of investments are shared equitably. They can reverse value extraction from the real economy and instead channel investment into productive economic activities that are aligned with critical policy goals.

Challenges addressed: Insufficient funding for low-carbon technologies. These investment institutions can scale up capital available to fund low-carbon innovations. The variation in risk appetite of such institutions means they can cover a broad range of capital types.

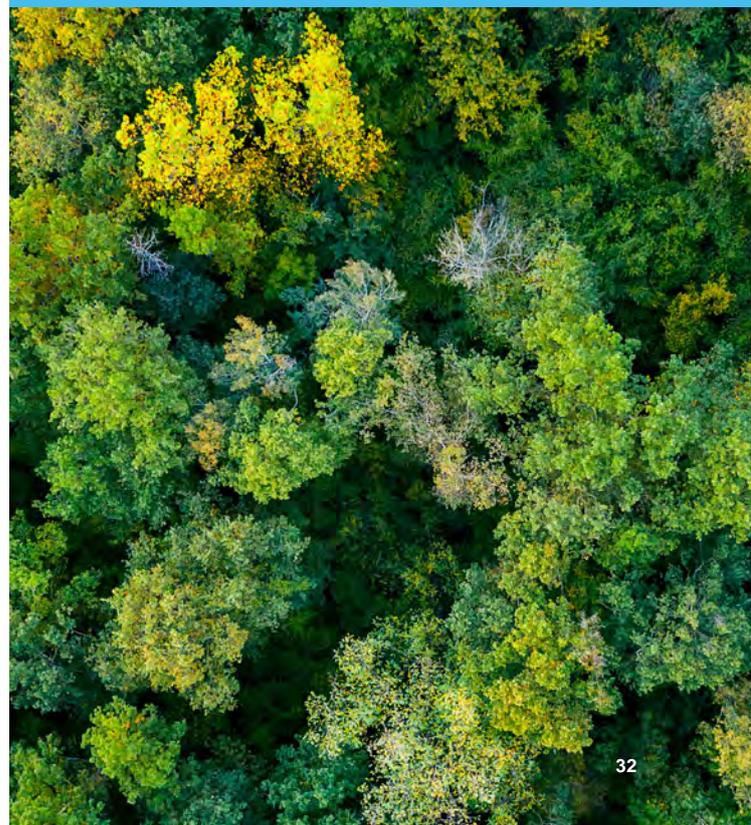
Role of MoF: Since MoFs typically have some degree of oversight of public investment institutions and state-owned enterprises, MoFs can (in)directly influence these organisations to increase investment towards low-carbon innovation, including in energy. Although the role of MoF with respect to public investment institutions varies internationally, as major stakeholders they have tools at their disposal including creating, or aligning, mandate to fit to government policy, providing governance oversight and/or coordinating with various public institutions (e.g., UK's ARIA set up as a differentiated public investment body with higher risk appetite than the UK Infrastructure Bank).

“Government funding should be conditional on behaviour change within organisations gaining access to that funding.”

(Mazzucato, 2022)

“For example, while the UK government mindlessly lent \$683 million to EasyJet with no strings attached, France made its pandemic-era loans to Air France and Renault conditional on emissions-reduction commitments.”

(ibid)



Germany's KfW use of conditionalities to drive innovation and economic activity towards environmentally preferable technologies (Mazzucato, 2022)

Germany's state-owned KfW - the world's second largest development bank - has utilised conditionalities several times to shape investment decisions relating to green transition initiatives. Between 2002 and 2020, the EU Directive on Energy Performance in Buildings (EPBD) was adopted in Germany: it required all new buildings to be close to zero energy. KfW introduced a dedicated Loans and Grants Programme to support SMEs seeking finance for refurbishment and construction of nonresidential buildings. Loans were available for up to EUR

10 million per project and the loan amount and terms were conditional on meeting KfW standards (based on the EPBD). These loans and their associated conditions were designed to promote buildings with higher energy efficiency: the higher the standards met, the higher the repayment. It is estimated that the programme reduces borrowers' investment costs by about 5.1%. For example, a less energy efficient KfW 40 Plus house would be eligible for a 10% repayment whereas KfW 40 house would be eligible for 15% repayment.



Tangible Actions:

- Create and nurture an ecosystem of public investment institutions that span a range of risk appetites: constituent parts could include venture funds and infrastructure funds.
- Ensure low-carbon transition is an explicit part of the mandate of public investment institutions using supervisory powers.
- Introduce clear conditionalities aligned to environmental goals to ensure that public investment institutions with access to public funds also invest in sustainable technologies consistent with the country's transition ambitions. These should be consulted extensively before introduction.

Mainstream green public procurement to create niche markets and drive economies of scale

What it is:

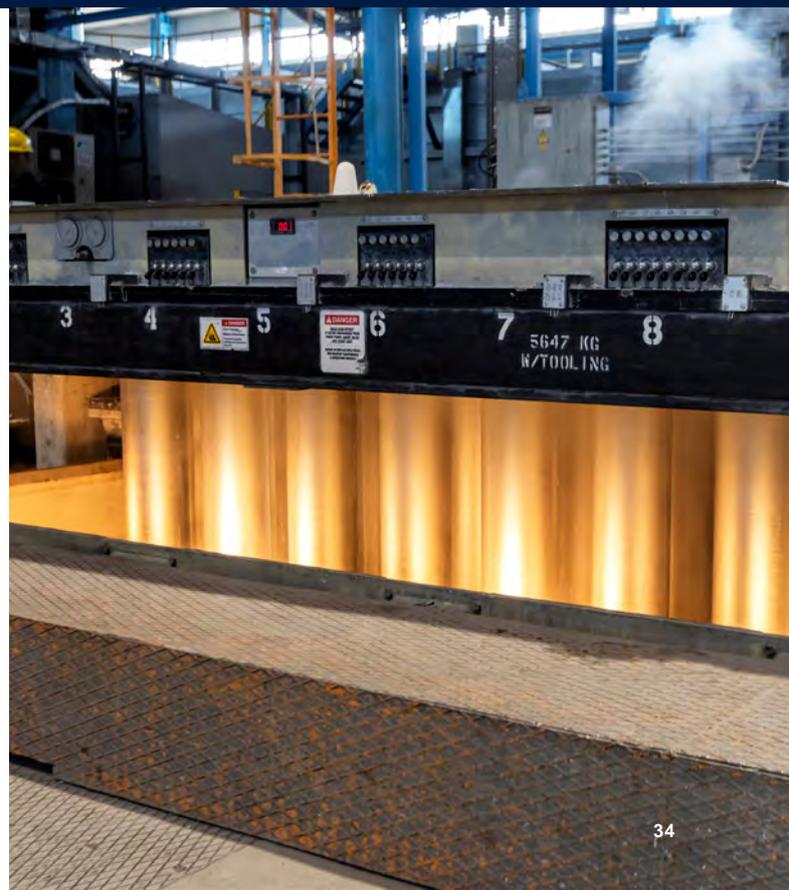
Procurement budgets can play two important roles: to support creation of niche low-carbon markets (in)directly through the emergence phase and to accelerate adoption through the diffusion phase. These niche markets are firstly critical to allow innovators to improve a technology and further reduce its costs and later an important lever in scaling the demand market.

This is particularly relevant for earlier-stage technologies, such as ultra-high density batteries for utility-scale storage, capacitors, battery recycling, hydrogen-based fuels, green building solutions, scaled composting for natural gas generation, low-carbon steel, electrolysers and fuel cells (Victor et al., 2019). Directly, they send a greater share of public investment towards mission-relevant low-carbon technologies (Bosio & Djankov, 2020; Mazzucato, 2020). This is reinforced by indirect effects of crowding in subsequent private investment and it has a signalling and catalytic effect, creating

a lead market as the public uptake of specific innovations can raise awareness for the private market, providing grounds for demonstration (Rothwell, 1984). During the diffusion phase, public procurement policies and mandates create sustained demand and induce economies of scale and learning spillovers, by incentivising manufacturers and reducing market risk and uncertainty (Victor et al., 2019). Domestic demand is a key source for enhancing region and business competitiveness (Porter, 1990).

Challenges addressed: Insufficient funding for low-carbon technologies. Procurement budgets are a powerful tool to partially service increased investment needs, due to the scale of government procurement budgets at ~12% of global GDP (in some countries higher), as well as MoF's proactive role in policy design and budgetary oversight of government departments and agencies (World Bank 2020).

Role of MoF: MoF are typically largely responsible for designing policy and legal frameworks for national public procurement. They can design frameworks aligned to governmental low-carbon objectives, set procurement budgets and coordinate cross-departmentally.



Vancouver's procurement of the first hydrogen bus (Adamson, 2004; Koppel, 1999)

Cities can serve as a laboratory for experimenting with new technologies using local procurement policies. In particular, many cities around the world have used public procurement of buses and car fleets to help demonstrate new vehicles. For example, in 1998, Chicago and Vancouver demonstrated the first buses using Ballard Power Systems hydrogen fuel cells, which gave assurance that fuel cells would become viable technologies for heavy transport. Nine cities in Europe followed suit (through awards by the EU Commission), as well as Beijing, Perth, Reykjavik, Aichi in Japan. These cities formed an international forum to share experience with the technology.

These cities formed an international forum to share experience with the technology.

Tangible Actions:

- Create a policy framework for green public procurement linked to national transition plans and low-carbon innovation objectives. In particular, identify areas of procurement that can stimulate innovation and select project bidders on the basis of their willingness to experiment with new decarbonisation solutions.
- Develop, and roll out, a procurement training programme and guidelines across relevant government departments and agencies to boost colleagues' abilities to design contracts aimed at achieving public policy aims beyond a sole focus on cost optimisation. The EU has produced a Guidance on Innovation Procurement and established the Procur2Innovate programme, a network of competence centres to support public procurers in using procurement budgets to support innovation and facilitate joint procurement across borders.

Bogotá's procurement of electric buses to scale domestic market (Sustainable Bus, 2022)

Bogotá has the highest number of electric buses in circulation in South America (as of October 2022), attributed to successful public procurement of large electric bus fleets via a-bus-as-a-service setup up with Enel (Sustainable Bus, 2022). The procurement programme is part of a delivery programme to achieve the city's aim of 100% zero emissions buses by 2035. It is thought to have driven a 10% reduction in the city's PM2.5 concentrations since 2020 while achieving "savings of almost 37 billion pesos for the local budget" (ibid).



Increase fiscal space by reorganising the tax and subsidy pots

What it is:

MoFs can use macro and fiscal policy levers to free up capital that can be reallocated to invest in the low-carbon transition. Overall, such reforms to the subsidy and tax pots should better align them to the low-carbon transition objectives. For example, the continued deployment of direct (and indirect) fossil fuel subsidies constitutes an implicit subsidy and impedes the energy transition by distorting the cost competitiveness of fossil fuels versus renewable sources. This report outlines three options below yet the Coalition of Finance Ministers for Climate Action (forthcoming) will explore a broader range.

First, **MoFs should gradually phase out direct fossil fuel subsidies.** Sustained subsidisation of fossil fuel production and consumption hampers low-carbon technology scaling and system reconfiguration. Sometimes it cannibalises the impacts of low-carbon subsidy support. Indirect fossil fuel subsidies alone have been estimated by the IMF at ~7% of GDP in 2020, or ~\$6 trillion (Parry et al, 2022), and this is approximately double the annual investment in clean energy⁶ (not just innovation) required to achieve Net Zero emissions by 2050 estimated by the IEA (2021). Taken together, these numbers show that a major reorganisation of the “subsidy pot” is needed. (Parry et al., 2021).

Second, **pricing for negative externalities should increase gradually.** Specifically, carbon prices should be increased such that energy sources are taxed in proportion to their carbon content.

The current implicit tax on most energy sources is well below the social cost of carbon (Blyth, 2018). These taxes are thus very distortionary. Thirdly, **taxes on rents and excessive consumption should be established, increased and/or expanded** in scope (e.g., wealth taxes, financial transaction taxes, of which stamp duty was the first imposed on the LSE in 1694 (Dieter, 2003); land taxes; windfall taxes).

A clearly communicated long-term plan is essential to carefully manage the fact that subsidy and fiscal reforms can create winners and losers. International experience with fossil fuel subsidy reform indicates that a clearly communicated gradual plan, accompanied by proactive education of the public and using the savings to support vulnerable households and businesses can enable a successful transition (Altenburg and Assmann, 2017).

⁶ IEA (2021) estimates low-carbon clean energy investment must triple to \$4 trillion by 2030

Challenges addressed: Direct and indirect support for fossil fuels hamper effectiveness of public support for low-carbon technologies.

Timely, strategic carbon intensive subsidy removal is needed to promote and lock in low-carbon technologies. This must be coordinated with broadening of the tax base (covered next).

Role of MoF: MoFs generally have direct control over a wide range of macro-fiscal policy functions. Subsidies and taxes are typically within this remit. Thus, MoF can reform subsidies supporting incumbent carbon-intensive goods and services via clearly communicated long-term plans. Such plans provide clear signals to the private sector, public and rest of government; this enables putting adequate coordinated support (e.g., just transition plans, covered next) in place.



Does the UK have fossil fuel subsidies?

As a result of there not being a globally agreed definition for fossil fuel subsidies, estimates vary substantially by author because of differences in definitions and calculation methodologies. The UK government defines these subsidies as government action that “lowers the pretax price to consumers to below international market levels” and asserts that it has “no fossil fuel subsidies” (DECC, 2015;

House of Lords, 2021). However, other sources disagree: OECD estimates that the UK has fossil fuel subsidies of around £10bn per annum (OECD, 2021). Tax breaks and RD&D support for exploration have been cited as major spend categories. Furthermore, in 2022 the UK introduced its Energy Profits Levy which has been described as an “effective fossil fuel subsidy” (Walsh et al., 2022)⁷.

⁷ The Levy was introduced with an investment allowance – i.e. an allowance generated on investment expenditure of 80%, which could be used immediately by companies to reduce the amount of profits subject to the Levy. The Levy was introduced with an investment allowance – i.e. an allowance generated on investment expenditure of 80%, which could be used immediately by companies to reduce the amount of profits subject to the Levy. The most contentious part of the Levy from a net zero point of view is that it lacks a comparable incentive for investment into low-carbon technologies, including intermittent renewables, storage, and green hydrogen.

Morocco's phase out of fossil fuel subsidies

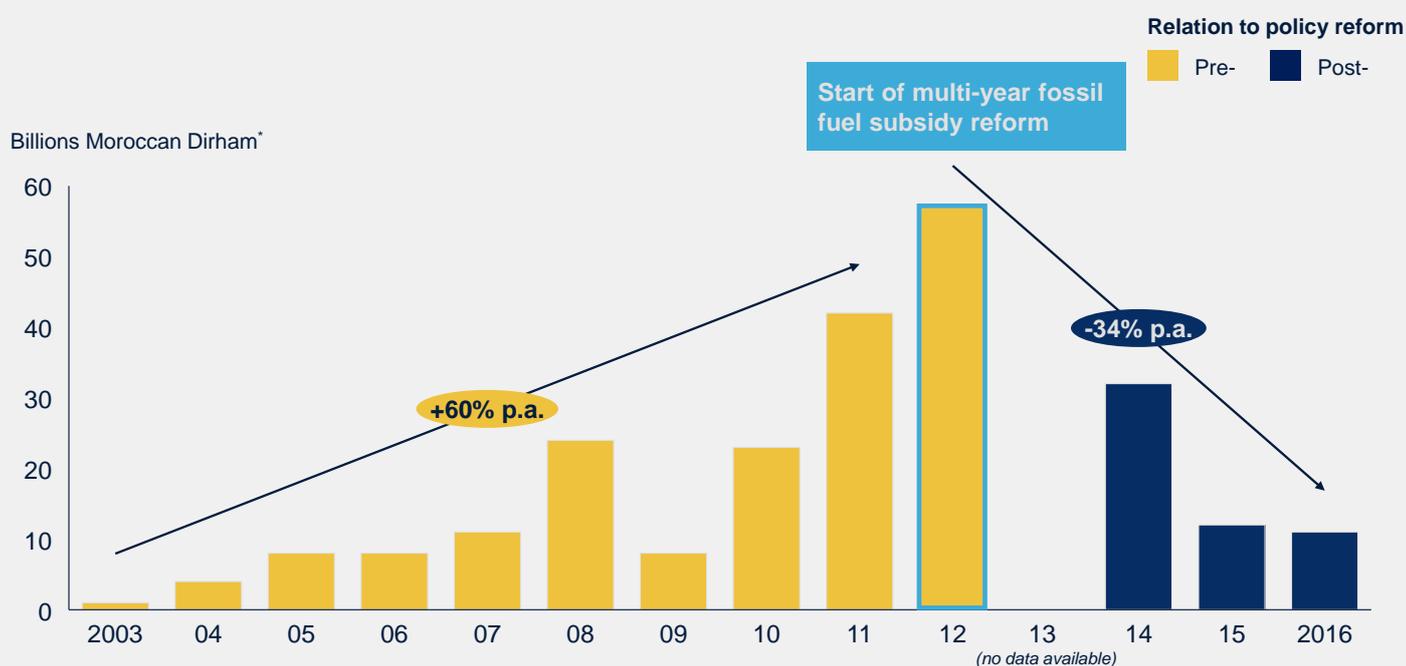
Over 5 years from 2012, Morocco introduced a multi-step fossil fuel subsidy reform. Fossil fuel subsidy spending decreased from ~5% of GDP in 2012 to ~1% of GDP in 2016 (WRI, 2021). The policy has been praised for the planned phase out over time to manage impacts, good intergovernmental coordination, clear communication to domestic and international stakeholders, and measures taken to

manage distributional impacts (ibid). For example, remaining fossil fuel subsidies were prioritised to protect lowest income groups: butane remains subsidised as it enables cooking and lighting in disproportionately rural populations.

Figure 12:

Evolution of Morocco's fossil fuel subsidies between 2003-2016

Moroccan government spending on support for fossil fuels 2003-2016



* Morocco dirham is 0.097USD (as of early 2023)

Source: Ministry of Energy, Mines, Water and Environment of Morocco, 2013, "La nouvelle Strategie Energetique Nationale Bilan d'etape" and Innovation for Sustainable Development Network, 2019, "Removing fossil fuel subsidies in Morocco"

Tangible Actions:

- Quantify and annually report fossil fuel subsidies, taking into account all forms of support including investment support, tax breaks, reduced-rate VAT. Unpaid externalities should also be calculated using a defined carbon price and included in the analysis.
- Plan on using part of the revenues to mitigate regressive distributional effects identified.
- Develop, legislate and communicate long-term implementation plans for the phase-out of direct subsidies and the gradual increase in carbon taxation, providing indicative dates and phase-out plans to allow time for individuals, businesses and other governmental agencies to adjust accordingly.

Broaden the tax base as revenues from carbon-intensive technologies decline

What it is:

The evolution of the taxation base is necessary as economies undergo low-carbon transitions in different sectors and income from fossil fuel production and/or consumption declines. While technologies in the emergence and/or scaling phases will require supportive subsidies and regulations, once established they will eventually need to become a source of tax revenue to fill the gap left by carbon-intensive technology revenues.

This process will have to proceed in stages since the taxation base will evolve gradually in response to several mechanisms: 1) Increase in the carbon price which will in the medium-term create a net increase in revenue, but as decarbonisation proceeds, will gradually shrink; 2) The short-fall in revenue from fossil fuel consumption excise taxes (mostly in road transport) which will depend on the rate of adoption of low-carbon technologies; 3) The short-fall in revenue from the production of fossil fuels in resource-rich countries. The figure below shows an illustrative scenario of the pace and timing of these changes.

In the short-term, the phase-out of fossil fuel subsidies will provide some additional revenue, as will the increase in the price of carbon outlined in recommendation 4. Turning to the transport sector, shifting from taxes on fuels to taxes on distances driven will deliver a more sustainable tax policy, as it will replace revenue from fuel taxation and will price externalities associated with road use

(congestion, wear of roads, biodiversity impacts...). Maintaining total transport tax revenue may not be the foremost objective of a sustainable tax policy strategy for the transport sector. Instead, aligning transport taxes with the externalities of transport is best.

The greatest challenge lies in diversifying the economies of resource-rich countries. For fossil fuel exporters, economic diversification is more important than ever before, and must be done in a way that is consistent with a low-carbon economy. Some countries that are currently fossil fuel exporters may be able to become significant exporters of renewable energy, thereby replacing fossil fuel as a source of fiscal revenue. In these contexts, fiscal discipline and fiscal planning focused on medium- and long-term horizons is more important than ever to channel capital into the low-carbon economy. Leveraging sovereign wealth funds and strategic investment funds as described in recommendation 6 is a particularly important complementary strategy to fiscal reform for countries that need to diversify.

Slovenia's road pricing (OECD, 2019)

In the report, they evaluated the tax income impacts of different electronic vehicle take-up scenarios. Later, they analysed the tax income impacts of different tax policy reforms against their original scenarios. Three categories of tax reforms were looked at: fuel taxes, vehicle taxes (including one-off registration fees and annual fees) and distance-based taxes.

A key conclusion was that the tax system should gradually transition to a more distance-driven based tax system to better reflect the external costs of driving further.

Challenges addressed: Eventual erosion of tax revenues from fossil-fuels.

Development and communication of a strategy and implementation plan for replacing tax revenue from carbon-intensive sectors will both fill the eventual gap in revenue and ensure businesses and individuals are forewarned of changes. The low-carbon transition can be seen as a constructive opportunity to re-prioritise long-term fiscal health and sustainability of government revenue. It is estimated that the potential revenue raised by carbon tax reform could average over 3% of GDP (IMF 2021).

Role of MoF: Taxation is within MoF's core fiscal remit and responsibility for designing and implementing tax base evolution lies with this.



Tangible Actions:

- Develop a long-term tax strategy for Net Zero: this should include identification and evaluation of future potential tax revenue streams from low-carbon goods and services where in the medium- to long-run economic rents are to be expected.
- Incorporate a Net Zero tax audit into existing frameworks to evaluate the consistency of the tax system with the Net Zero transition.
- Mandate that just transition considerations be considered for all decisions regarding tax policy changes. Where effects are considered particularly regressive, supporting measures to mitigate impacts on low-income households must be included in the policy.

Crowd-in private finance by creating a conducive investment environment

What it is:

MoFs must create and sustain a financial environment in which private financial institutions increase their financing flows towards transition-consistent investments. Private investors can be the biggest deployers of capital into the transition: in a supportive policy environment, they are expected to provide ~55% of the incremental capital investment required annually (McKinsey, 2023). The private investors include banks, pension funds, private equity and capital markets.

MoF can crowd private finance in by providing patient capital for early stage innovations (recommendations 1 and 2) or scaling niche markets through public procurement (recommendation 3). Later in the innovation process, MoF can crowd-in private finance by issuing and/or scaling green debt instruments (e.g., bonds, loans), steering the greening of the overall financial system to raise long-term funding for infrastructure investments required in scaling and system reconfiguration phases. MoF can increase long-term policy certainty

on the direction of travel through coordinating a clear cross-party transition mission (recommendation 9) with long-term regulatory policy (e.g., UK banning the sale of diesel engine passenger cars sent a clear signal). All existing financial instruments can be green to have a short-term green equivalent (e.g., sovereign green bonds and sustainability-linked bonds) and eventually all financing instruments should be green. Aside from long-term and consistent policy, MoF can reduce a private investor’s policy uncertainty by blending public and private finance.

Private financial institutions could finance about 55 percent of net-zero investment needs

Average annual investment needs for low-emission assets, 2022-50, \$ billions

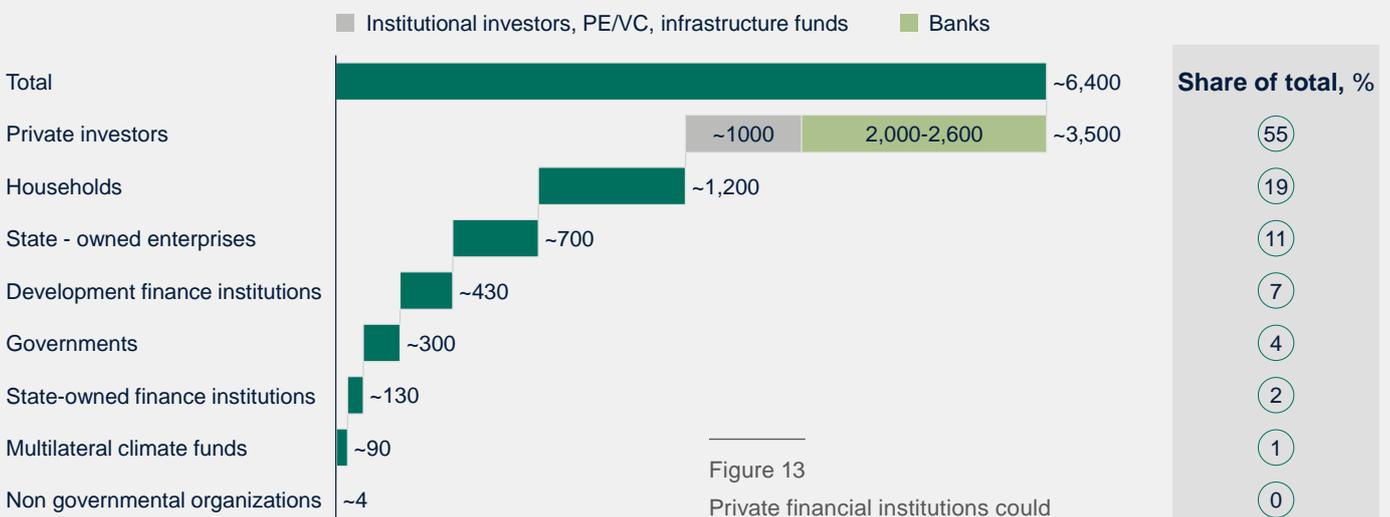


Figure 13
Private financial institutions could finance about 55 percent of net-zero investment needs

Source: McKinsey & Company (2023)



Challenges addressed: Insufficient funding for low-carbon technologies. Crowding in private financial flows will play an important role in closing the existing financing gap (McKinsey, 2023).

Role of MoF: MoF lead the establishment of a national Net Zero coalition that develops: green finance strategy, roadmaps for greening the financial system and potentially a green taxonomy (or another region's could be utilised).

Tangible Actions:

- To green the financial sector, instigate a multi-stakeholder coalition or taskforce to support the development and execution of Green Finance Strategy, Green Finance Roadmaps, Green Taxonomies. This group should convene representatives from the MoF, central bank, capital markets, regulators, philanthropists, public and private investment institutions.
- To mainstream green financial instruments, introduce and/or scale sovereign green bonds, loans and other green debt financing instruments to invest in a resilient low-carbon transition. MoF would be responsible for leading design and implementation with other government departments (particularly identification and communication of a pipeline of eligible expenditures that are consistent with the transition).
- Work with sub-national governments to support the establishment of sustainable debt at the regional or city level.



Ensure an equitable transition at regional, national and global scales

What it is:

At a domestic level, MoFs will need to evaluate and introduce measures to manage two broad types of impacts. First, the concentrated loss of local economic activity and employment opportunities (sectoral or regional). Second, the regressive impacts on consumers, especially the risk of energy poverty and insecurity for households at the lower end of the income distribution (Green and Gambhir, 2019). Such negative impacts will be unevenly distributed across regions, sectors and individuals. MoFs in developed countries have a critical role to play in supporting mitigation efforts in developing countries (although out of scope of this report, they also have a critical role to play in supporting and financing loss and damage, adaptation and resilience in developing countries too). More constrained fiscal space, insufficient private finance and much higher costs of capital exacerbate the challenges for such countries.

At a national and regional levels, MoFs will be responsible for coordinating social protection and coordination of housing, migration, retraining, and social support policies to mitigate negative consequences arising from an economic transition of this scale. Compensation to directly affected workers in the form of redundancy payments and/or early retirement benefits is often part of a fair work transition. However, this is not sufficient to ensure the long-term economic health of affected regions. Thus, policies are required to support reallocation of skills and capabilities via skills transitions and local economic development. Such action needs to be anticipatory and through a deliberative approach that engages those affected (e.g., workers unions, employers, educational institutions).

At the international level, MoFs in developed nations must help address the existing challenges impeding mitigation deployment in developing countries: these include highly constrained fiscal space, a lack of private finance and much higher costs of capital (Bridgetown Initiative, 2022). MoFs in the global north should actively engage with the developments proposed by the Bridgetown Initiative (and also the United Nations 2010 Stiglitz Report), including the proposed funding of a USD 500 billion Global

Climate Mitigation Trust through unused Special Drawing Rights (SDRs) issued by the IMF. “SDRs are international reserve assets allocated to IMF members that allow for each member to borrow from one other’s central bank reserves in case of distress. Importantly, borrowing costs are kept well below market value, currently at 2.4%” (ibid). An interesting characteristic of the proposal is that its loans would be counted as the assets of the fund and would not be a country’s liability. “The loans will be the funded projects’ liability and will therefore constitute a type of ‘third debt’” (ibid). Parallels have been made to the NextGenerationEU fund that has components funded by EU debt that doesn’t constitute a national debt for an individual country”. Irrespective of whether 2023 will see a global recession and demand imbalances, with an eye on global inflation such a structure could in due course be deployed to fund the necessary investment in the transition.

Note that the scope of this report is focused on mitigation but there is, of course, an important role for MoFs in the global north to support the global south with financing for loss and damage, adaptation and resilience as well. The Coalition for Finance Ministers on Climate Action report (forthcoming) will be broader in scope and address these issues.

Challenges addressed: Risk of an unjust transition with regressive impacts.

Implementation of welfare measures can ensure distribution of positive and negative impacts - and perception of this - is equitable. There is a moral obligation to do this but MoFs must also recognise that failure to deliver a transition that is perceived as fair risks major backlash from those groups disadvantaged. Distributional impacts will vary: policymakers must protect individuals and regions that may be most vulnerable to negative impacts. Negative impact examples are energy poverty and insecurity, loss of decent employment opportunities and loss of local tax revenue. In the medium- to long-run, low-carbon technologies such as electric cars and renewable energy are projected to be cheaper than current fossil-fuel based technologies and will therefore benefit all households (Way et al., 2022). However, in the short- to medium-run, the low-carbon transition can have regressive impacts, as new technologies enter the diffusion and system reconfiguration stages. First, in many countries, the direct effects of carbon prices on household consumption are estimated to be slightly

regressive (Wang et al. 2016), although this varies by country and may be offset by progressive impacts via changes in factor prices (Dorban et al. 2019, Feindt et al. 2021). Second, and most critically, technology or emission standards, which promote newer but more expensive technologies, are likely more regressive (Davis and Knittel, 2019, Metcalf 2019). These distributional impacts need to be addressed for equity reasons, as well as to ensure the transition is acceptable to different constituencies.

Role of MoF: The MoFs are the budgetary gatekeepers and thus the gatekeepers of the foreign assistance budgets and welfare support measures to support a fair transition at the national level. Additionally, domestically, their cross-government soft powers to coordinate structural change across a country's entire economy position them well to oversee regional distributional impacts of a low-carbon energy transition. Furthermore, they are well placed to identify sectors that could be competitive with green comparative advantage (Mealy & Teytelboym 2020).

“Climate justice underscores the unfairness of countries and groups that have contributed the least to climate change being most at risk.” (Thomas, 2021)

US Inflation Reduction Act 2022: range and scale of actions (US Congress, 2022)

Beyond wide-ranging policies incentivising investment in the low-carbon transition, the Act includes just transition components. There has been significant emphasis on environmental justice and support for disadvantaged communities and there are several provisions to ensure that fossil fuel industry workers are not left behind. Exemplar provisions:

- Support for regions with intensive fossil fuel industry via a range of mechanisms including:
 - (a) tax credits for renewable energy projects are subject to a 10% increase if located in communities that have historically been reliant on fossil fuel
 - industry for a significant proportion of local employment and (b) solar and wind projects sited in low-income communities, on indigenous-owned land, or as part of a low-income building project are also eligible for bonus credits.
- Provision of reparations for legacy pollution via \$6bn for Environment and Climate Justice block grants and Neighbourhood Access and Equity plants.
- Introduction of tax credits for the purchases of the electric vehicles that are only available to families below a threshold income level.

Spain's stakeholder engagement process

Spain has spearheaded the use of Just Transition Agreements – a transition contract between government and local stakeholders ahead of closures of high-carbon facilities. The government and unions signed the first contracts ahead of closing 26 uncompetitive coal mines in 2018. Now, these transition contracts will be used more broadly as part of Spain's Just Transition Strategy to phase-out coal mining and coal plants. These contracts are developed in a participatory negotiation process

involving the government, unions, local authorities and companies such as energy providers. The negotiation process covers all aspects of a just transition plan, from determining the territorial boundaries covered by the agreement, assessing the job losses, the challenges and opportunities in the region, to developing and assessing potential projects for the affected areas (World Resources Institute, 2021).

Tangible Actions:

- At an international level, MoFs of developed countries must convene via multilateral agencies to develop strategies and tools with which to offer financial support to developing countries. Examples include: development of an annual issuance of Special Drawing Rights at the UN-level, debt cancellation and concessional conditional finance for low-carbon projects.
- At all levels, introduce conditionality into the use of public funds, mandating that organisations accessing such funds ensure that public investments have a public return.
- Assess the national and regional distributional implications of major fiscal and budgetary change for the transition and identify appropriate supportive measures such as revenue recycling. Such supportive measures should coordinate with relevant departments (detailed below) and with affected stakeholders.
- As the owner of the national financial and economic forecasting, MoFs will be best placed to create economy-wide scenario-based labour market projections. Thus, they will have a critical cross-government coordination role (further noted in recommendation 10):
 - Departments of Business, Energy and/or Industry to identify jobs with high skills crossover.
 - Department of Education to ensure national school curricula align with needs, more novel jobs are advertised and universities cater to demand for new skills.
 - Department for Employment to develop social compensation policies.
 - Department of Infrastructure and Planning to identify infrastructure needs in line with regional long-term plans (to allow more commuting, or support new sector development).

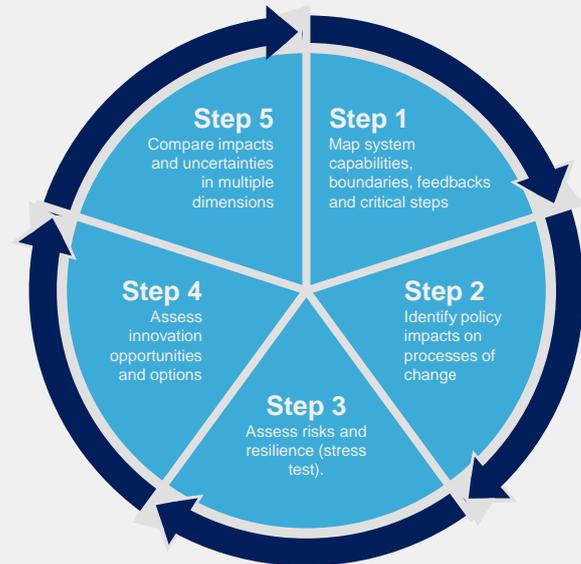
Complement cost-benefit analysis with systemic transition methods

What it is:

Use of alternative policy appraisal tools to either replace - or at least accompany - the typical tool of cost-benefit analysis can mitigate the inaction bias associated with the traditional tool (challenges associated with the typical tools are detailed below). Such tools include cost-benefit analysis and randomised control trials to evaluate impact of emerging policy ideas at small-scale (Mercure et al., 2021; Serin et al., 2022). New decision-making tools could initially be used in conjunction with traditional cost-benefit analyses before potentially replacing them. One such example is the risk opportunity framework that is put forward by Anadon et al. (2021; a simple illustration is available in figure 14).

Steps of the emerging risks and opportunities framework

Mercure et al. (2021)



Source: Mercure et al. (2021)

Figure 14

Steps of the emerging risks and opportunities framework
Mercure et al. (2021)

Challenges addressed: Limitations of standard cost-benefit policy appraisal. Low-carbon technological transitions require strategic investments – that is investments that transform technological opportunities and create new markets. Such investments reshape the technological frontier and the optimising decisions of actors. However, tools currently used for policy decisions, in particular traditional cost-benefit analysis are not well suited to assess strategic investments (Anadon et al. 2021). Indeed, they take the current technological frontier as given to assess trade-offs at the margin. Specifically, they are likely to steer MoFs away from supporting the right public finance decisions because of:

- **Their inability to assess transformational change:** traditional static cost-benefit analysis is designed to assess marginal system change. It is not fit for measuring transformational change (Dietz & Hepburn, 2013; UK HMT, 2022). The complexity of climate change, and the non-linearity of technological progress over long-term horizons, violates the underlying assumption of this traditional static approach, which assumes no significant uncertainty, nor changes in products' cost, price or availability.
- **Their failure to account for benefits beyond market rewards:** market failures extend beyond the negative externality of greenhouse gases to other benefits such as health and biodiversity that are not reliably monetisable. This creates an inaction bias as they are excluded from the calculation (Grubb et al., 2021).

UK offshore wind

Analysis of the UK offshore wind industry exposes the limitations of the application of static cost-benefit analysis in assessing the 'effectiveness' of a low-carbon transformation (Mercure et al., 2021). UK offshore wind policy, including sustained government support, resulted in offshore wind becoming cost-competitive with fossil fuel generation. A critical contributing

element to this success was that decisions were not made on a cost-benefit basis, but in line with broader EU commitments. Offshore wind was seen as a strategic investment. Indeed, the major successes of the low-carbon transition have been achieved despite traditional cost-benefit analysis, which could suggest such investments were not 'cost effective' (ibid).

Role of MoF: MoF's role with respect to policy evaluation can vary internationally. They are often responsible for wide-reaching tools and approaches, including: macroeconomic forecasting, economic impact assessments and guidance on investment appraisals that shape other departments' spending decisions. In the case of the UK, the overall Government's current guidance on policy appraisal and evaluation is contained within the Treasury's Green Book (HM Treasury, 2022). In the case of the US, this would lie within the Office of Management and Budget.

Tangible Actions:

- Adapt the measurement and accounting frameworks used to account for economic value – at both the micro and macro levels – to assign a proper value to parts of the economy in which prices do not fully reflect their economic and societal contribution.
- Commission project into developing and then sandboxing novel policy decision-making tools, particularly public investments, suitable for a low-carbon transition context. Tools should target better:
 - Spillovers that occur with bold policies
 - Dynamic price trajectories
 - Benefits beyond monetary rewards (e.g., biodiversity, health)
- Introduce randomised controlled trials to test promising policy ideas
- Introduce a fund - akin to the UK's Business Basics fund - that uses an experimental approach, by supporting trials of different ideas that encourage small and medium-sized enterprises (SMEs) to adopt productivity-boosting technologies and management practice.



Mainstream and scale up a mission-led approach

What it is:

MoFs shape the government's overall strategy and way of working by forming a mission-led mindset, framework and narrative that brings all departments together. Mission-oriented cross-governmental industrial policies provide growth direction to accelerate innovation and transformational change via strategic investments in many sectors inducing technological, social and behavioural spillovers, and increase macroeconomic stability (Mazzucato, 2018).

Such missions entail shifting the market towards desired outcomes - in this case, spurring innovation to accelerate the low-carbon energy transition. This means challenging and reconceptualising policy's role, not as an intervention to fix market failures, but as part of the market-shaping process (Mazzucato, 2018). This framing challenges traditional pervasive thinking that the government's role is to fix market failures, instead of proactively shaping markets and enabling sectoral and system-wide transformations (Mazzucato, 2018).

Mission oriented innovation policy is broader than R&D policy: it can address interconnected objectives (e.g., energy security, climate change, and economic competitiveness) and typically requires systems-level innovation (Geels et al, 2017). When it comes to low-carbon energy technologies, coordination is especially key given technological change in one area or sector often impacts technological change in other areas (Aghion et al., 2009). The clean energy transition is an example of a sociotechnical transition, gaining most momentum when "multiple innovations" link to reconfigure the broader system (Geels et al, 2017).

Challenges addressed: Insufficient government coordination. The structural change associated with the low-carbon transition will require a whole-of-government approach, including horizontal policy coordination. All relevant policies (macroeconomic, structural, industrial, innovation, skills, labour market, energy, and other policy frameworks) must work strategically with supporting institutions to drive requisite economic recovery and structural change.

Role of MoF: MoF can play a vital role in scaling up mission-led innovation and industrial policy, intervening at various stages of the low carbon innovation cycle via a portfolio of policy tools, discussed in this section.

Tangible Actions:

- Create a mission-setting body, ideally at the Cabinet level, with a clear mandate to work across ministries and sectors to define missions that (a) are bold and inspirational, (b) set a clear direction, (c) are ambitious but realistic, (d) encourage cross-disciplinary and cross-sectoral innovation and action, and (e) involve multiple, bottom-up solutions (Mazzucato & Gibb, 2019).
- When defining missions, ensure that a wide range of stakeholders, including citizen groups, labour organisations, and businesses, are at the heart of the discussions in agreeing on investment priorities and objectives. This is crucial to connect public spending to issues that matter to people (Camden Renewal Commission Report).
- Invest in the capabilities of the Ministry of Finance and other public financial bodies so civil servants have the confidence and tools to experiment with public policy, measure and evaluate public spending in new ways, and negotiate with the private sector (Mazzucato et al., 2021).

Strengthen domestic and international collaboration to accelerate transitions

What it is:

At a domestic level, MoFs must invest time as active contributors to cross-governmental commissions and coordinate across line ministries and policy agencies. On the latter, MoF can harness its cross-economy view to engage the relevant institutions to drive requisite structural change. Exemplar policy areas requiring domestic coordination include: macroeconomic, structural, industrial, innovation, skills, labour market, energy. Although this sounds intuitive, implementation in practice is challenging and often falls short.

At an international level, MoF should engage with international efforts to accelerate low-carbon innovation and diffusion (Anandon et al., 2021). CleanTech for the Nordics is a consortium recently formed (with the help of Breakthrough Energy) that seeks to “pioneer globally competitive industries that can slash carbon emissions, while also increasing energy security across the Nordics” (CleanTech Scandinavia, 2022). Benefits of international coordination include knowledge sharing in early R&D phases (e.g., steel, cement, aviation, shipping) to catalyse innovative processes. Knowledge spillovers between international firms drove cost

declines for solar PV (Nemet et al, 2019). Furthermore, aligning definitions (e.g., carbon intensity threshold for green hydrogen) and standards (e.g., battery electric vehicle sockets) can reduce, or eliminate, the threat of international competitiveness loss, creating an international level playing field. Major economies coordinating to adopt minimum standards for domestic and imported goods would eliminate the threat of domestic companies being undercut by firms not meeting standard’s thresholds. A recent example of this is the EU’s coordinated ban on internal combustion engines from 2035.

“International collaboration will be critical to success, given the global scale and fast pace of change required. Action by governments and businesses individually is necessary, but not sufficient. Well-targeted international collaboration can make low carbon transitions faster, less difficult, and lower cost.”

(Breakthrough Agenda, 2022)

Challenges addressed:
Insufficient government coordination. Centrally-defined and agreed roles, mandates and responsibility distribution between relevant government bodies avoids duplicative or potentially non-complementary policies. Furthermore, weak international cooperation has hindered the deployment of clean energy technologies thus far (IEA, 2021a).

Section D

R10

Role of MoF: MoF are in a key strategic position within government to coordinate structural change across a country's entire economy, understand other ministries' needs, and mitigate coordination, and directionality failures. They can harness this role to increase intergovernmental coordination.

Furthermore, MoF can utilise their existing mandate to allocate budgetary resources aligned in a targeted, and predictable way, particularly for education and skills development, and infrastructure, both critical enabling aspects in accelerating the low-carbon transition (Stiglitz & Greenwald, 2014). For example, France created a National Observatory for Jobs and Occupations of the Green Economy (Cedefop,

2018a). Ministries of Finance can play a key role in enabling cross-departmental coordination and allocating capital for targeted policy and programme interventions aligned with the overall direction of the sector(s).

Internationally, MoF are well-positioned to collaborate and encourage coordination on learning and knowledge spillovers across government and internationally, systematically advancing green innovation. MoF can leverage their soft powers, coordinating domestically between government departments, on technologies, definitions and standards, and with international counterparts.

The Coalition of Finance Ministers for Climate Action is a potential forum for this coordinated collaboration.



Tangible Actions:

- Bring together existing growth and green innovation strategies to create one coherent strategy with low-carbon and resource-efficient innovation embedded throughout.
- Identify areas requiring coordination and collaboration related to climate change across the key functions related to national development and climate strategies, investment planning, macro and fiscal policy, financing; and other key capabilities, including them into the internal climate strategies or plans.
- Develop governance and stakeholder maps with clear mandates for MoF along with other line ministries and agencies to ensure clear responsibilities and work division.
- Establish a Net Zero innovation entity at a senior level of government (e.g., The Cabinet Office in the UK).
- Strengthen collaborative relationships between MoF and Ministries of Environment, including via recognising mutual differences in backgrounds, relative strengths and constraints. Potential ideas include informal working sessions, perspectives and sending joint delegations to international conferences.
- Establish, align and apply minimum standards to imported goods (in line with domestic standards).
- Actively participate in - or initiate - regional discussions creating definitions of new low-carbon products, for example the definitions for low-carbon products (e.g., hydrogen) based on carbon intensity. Align policy to these regional standard.

Appendix

Green competitiveness by country and technology

Opportunities will exist for all countries but green competitiveness is currently unevenly distributed by geography, sectors, and companies. The low-carbon transition has the potential to alter the global competitive landscape: the transition will cause demand surges in some goods and services whilst dissipating demand for carbon intensive ones (Fankhauser et al., 2013). The extent to which a country (or company) is competitively positioned in the low-carbon transition will vary and may be different to the status quo.

Current green competitiveness varies by country and by technology: figure 15 shows the inter-country variation in the competitive export of certain complex renewable products by sector. Other work has

consistently shown that the regions most competitively exporting green products are Western Europe, North America and East Asia; whereas Africa, Australia and parts of South America rank lowest (Mealy et al, 2017). This existing imbalance underlines the need for support to establish and scale Global South countries low-carbon industries (as outlined in recommendation 9). The aggregate Green Complexity Index (GCI) captures the number and complexity of green products that a country is currently exporting competitively (Mealy et al, 2017). Germany is consistently well-placed across the products examined, consistent with a recent report’s conclusion that across all green complex products “Germany stands out as a strong leader in the production of green, complex products” (Mealy & Andres, 2021).

Green complexity index by technology and by country

Using methodology of Mealy & Teytelboym (2022)

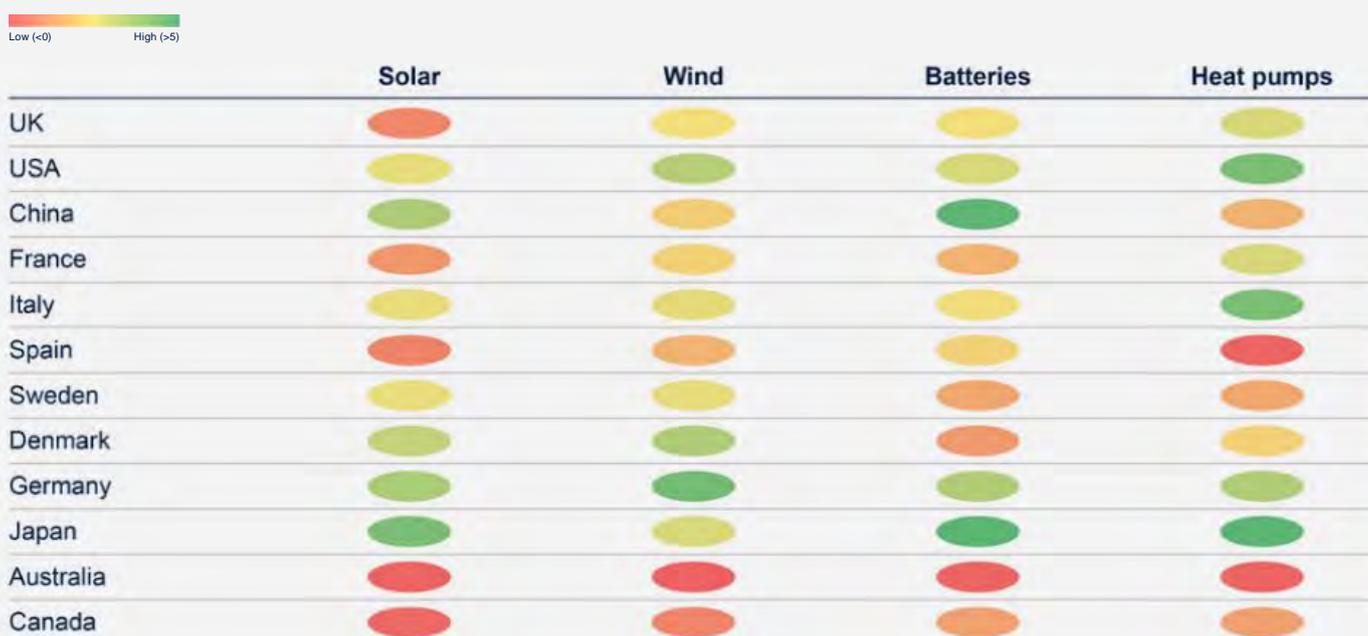


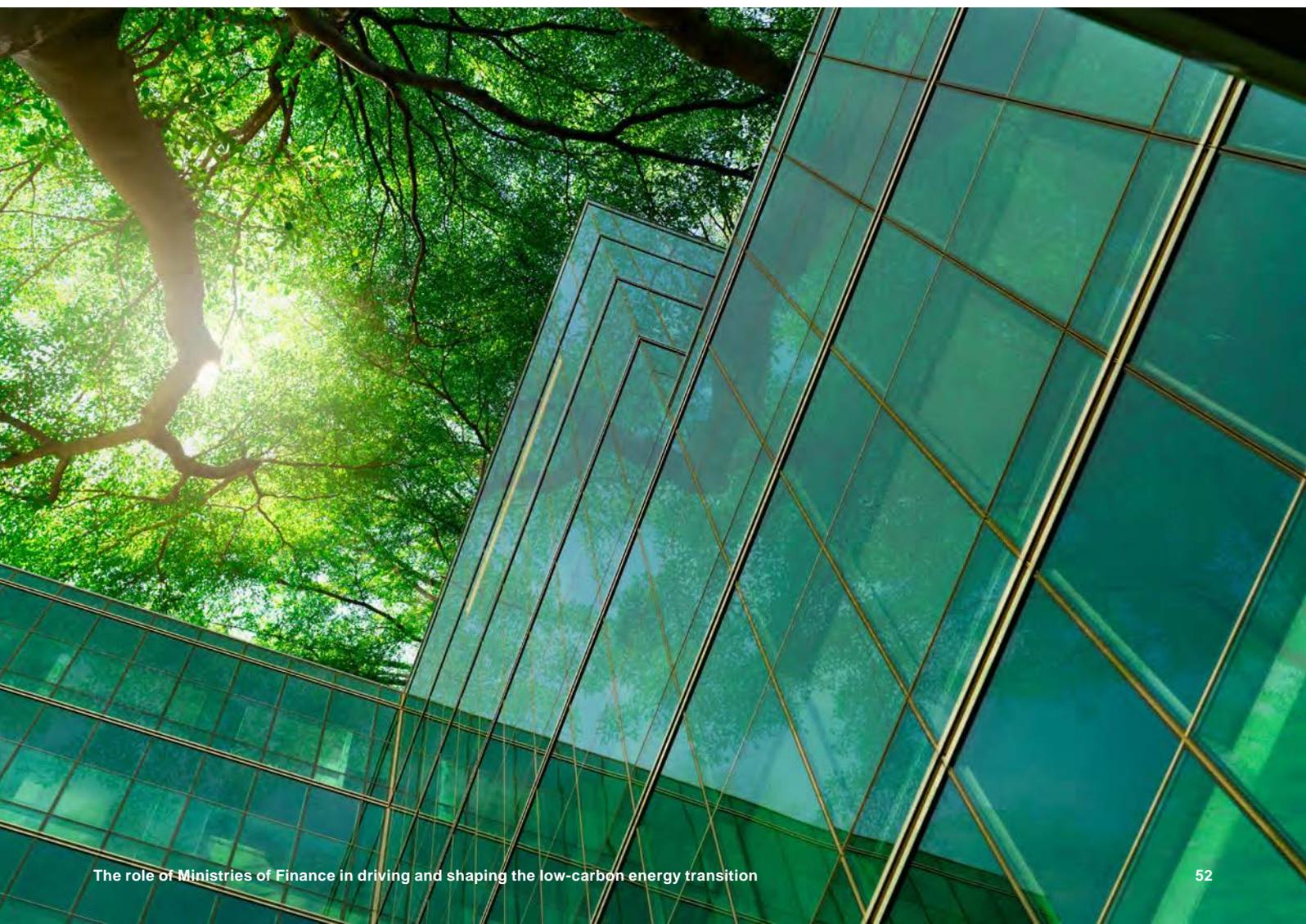
Figure 15: Green complexity index, by country and technology category

Appendix

Methodology: Evaluating green complexity

The green complexity index (GCI) is a measure of a country's current competitiveness in green technologies. It can also be predicted for the future using a measure called the green complexity potential (GCP) that is not covered here. The measure "aims to capture the extent to which countries are able to competitively export green, technologically sophisticated products, and allow us to estimate which countries are likely to be leaders and laggards in the green economy." (Mealy and Teytelboym, 2022).

While the GCI is typically compiled across the entire product set in the green technology space, our team led by Kevin Tang introduce a modified index compiling the technological products specific to each green technology in figure 15. For each technology, a subset of green products that are specific inputs to each category are evaluated by country according to current and potential country competitiveness. The subset of products in each technological category only accounts for those that are considered green.



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