

Aligning short-term recovery measures with longer-term climate and environmental objectives





A background report prepared by the OECD for the
2021 G20 Presidency of Italy

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Executive Summary

The COVID-19 crisis is an enormous challenge to economies and societies across the world. It has exposed our vulnerabilities to global shocks and underlined the importance of improving environmental health and societal resilience. Early in the pandemic, economic rescue measures had the priority of providing relief to workers and businesses. But the economic stimulus packages and recovery plans that governments are now putting in place have the potential to create a recovery that is both green and inclusive while achieving global climate goals.

A green and inclusive recovery has the potential to create opportunities for income, growth and quality jobs, and at the same time accelerate action on medium and long-term environmental goals, both national and global. Such a recovery will also significantly enhance the resilience of economies and societies in the face of accelerating environmental challenges that may come on top of existing stressors. For example, climate impacts are likely to be non-linear due to strengthening feedback loops that amplify the effects of global warming and the increasing likelihood of cascading tipping points in the climate system that can lead to irreversible climate change.

The current decade is crucial to achieve mitigation at the levels needed to reach long-term goals for climate action. In addition, the decisions made in the coming years on infrastructure, equipment and systems in which we invest will affect the climate for decades to come. Therefore the choices governments are making in shaping their recovery packages will determine countries' capacity to reach their climate objectives and comply with the Paris Agreement. In order to meet climate goals, recovery plans made for the immediate term need to be aligned with objectives set at the international and domestic levels, for the near (2030) and long term (2050 and beyond).

Innovation – the creation and diffusion of new ideas, products, processes and methods – is fundamental to the transition to a cleaner global environment and to the issue of ensuring alignment between short-term goals and actions and long-term strategies and objectives. Major innovation efforts are vital in this decade so that the technologies necessary for net-zero emissions reach markets as soon as possible. The pandemic has underlined the importance of science in preparing for and reacting to upcoming crises. The recovery from the COVID-19 pandemic provides an opportunity to boost green innovation, but governments need to strengthen their efforts to overcome barriers limiting the development and diffusion of new cleaner technologies in order to ensure appropriate alignment.

This report has been prepared in support of the G20 Presidency of Italy and provides guidance to countries in designing green recovery packages, aligning recovery packages with climate objectives, establishing effective evaluation and monitoring frameworks, and strengthening innovation and R&D.

1 Reaping the benefits of a green recovery

How green is the recovery so far?

Overall, stimulus packages still lean towards a business-as-usual approach

Data from the OECD Green Recovery Database¹ suggests that countries covered in the database (which includes all G20 members except for Argentina and Saudi Arabia²) are pursuing climate and environmental objectives as part of their recovery plans, although on aggregate these actions are counteracted by an equivalent number of measures with a negative or mixed impact. Country-specific measures with a likely positive environmental impact total around USD 336 billion, as shown in Figure 1.1. By contrast, measures marked as having negative or mixed environmental impacts total around USD 334 billion. This result suggests that, so far, funding for environmentally positive measures is almost matched by funding allocated to negative and mixed measures. This is broadly in line with results presented in tracking tools published by other organisations (Box 1.1).

It is important to see this result in the context of wider overall stimulus packages. The spending tagged in the OECD database as environmentally positive accounts for only around 17% of total recovery spending, using an estimate of the total spending from (O’Callaghan and Murdock, 2021^[1]). The small percentage of measures tagged as “green” implies that total stimulus packages overall still lean heavily towards investments in business as usual type activities, rather than the transformational investments required.

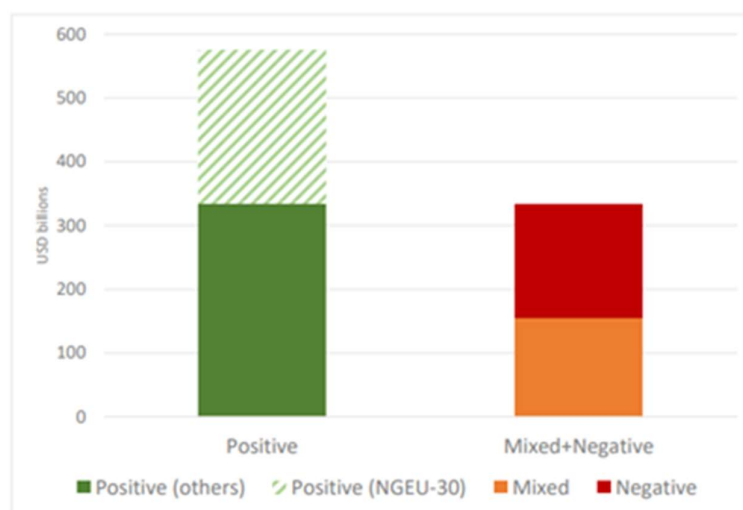
The picture will continue to evolve. An important additional factor is EU-wide funding announced through the Next Generation EU programme. This has not yet been included in the total of environmentally positive spending, because it was not yet allocated at the time of analysis. However, the hatched green bar in Figure 1.1. reflects the fact that the

¹ The OECD Green Recovery Database compiles policies related to economic recovery from the COVID-19 crisis that are likely to have positive, negative or mixed implications for the environment for 43 countries. The database does not, however, aim to comprehensively cover all COVID-19 related spending measures that do not have clear environmental implications. The results presented include data up until 1 March 2021. For an overview of the database methodology, please refer to Box 1.1.

² Please note that the measures included in the database for South Africa have been independently compiled by the OECD Secretariat and have not been endorsed by the Government of South Africa.

Recovery and Resilience Facility and the React EU facility have targets of 37% for climate-related investments. Care has been taken to avoid double-counting EU and national allocations, but it is still possible that some overlap exists at this stage. Internationally, further recovery packages and plans are being announced on a rolling basis – such as the American Jobs Plan proposed by President Biden in March 2021, not included in these numbers – and these will continue to shape the balance of funding relating to environmental impacts, once and if approved.

Figure 1.1. Total funding allocated by environmental categorisation



Note: NGEU-30 = Next Generation EU, the EU recovery fund. The funding indicated here represents the fact that the Recovery and Resilience Facility and the React EU facility have targets of 37% for climate-related investments. Note that the NGEU funding is available to all EU27 countries, some of which are neither OECD members nor accession/key partners and so are otherwise not covered in the database.
Source: OECD Green Recovery Database.

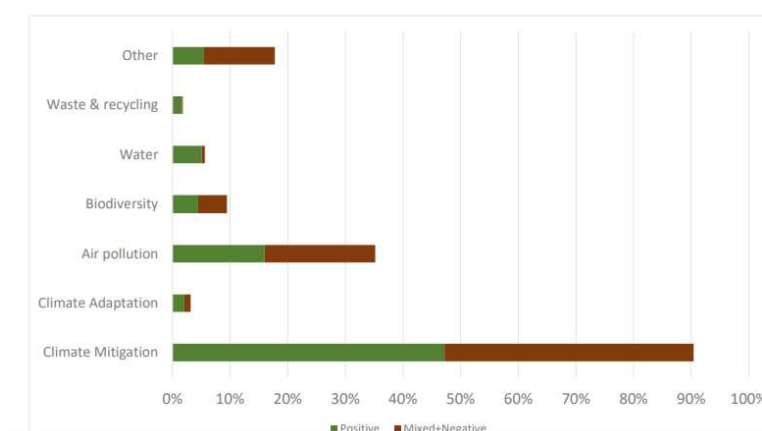
While these results provide a helpful overall picture of the likely impacts of recovery packages, caution is required when interpreting these results. Only 80% of measures reported in the database have funding totals or monetary values allocated, and those that do are not necessarily comparable (e.g. due to timeframe differences, inclusion of loan guarantees, etc.). Furthermore, the database likely under-reports the level of funding allocated towards measures with potentially harmful environmental outcomes.³ Crucially, even where large sums have been allocated towards environmentally positive measures, this does not necessarily mean that the overall packages will be aligned with longer-term climate change plans, such as targets for net-zero emissions, or other important environmental objectives (OECD, 2021^[1]). A discussion on alignment between recovery

³ There is a likely bias towards reporting of environmentally positive measures compared to negative measures both in terms of total numbers of measures (as the “green” measures are often more visible) and in terms of funding (because funding is reported for a higher proportion of positive measures (85%) than for negative measures (70%), meaning that negative measures contribute less to reported funding totals).

measures and near-term (2030) as well as long-term (2050) climate objectives is provided in Chapter 2.

Climate change mitigation is by far the most common environmental dimension targeted by the recovery measures that have been tracked (Figure 1.2). Nearly 90% of funding allocated is for measures tagged as having clear implications for GHG emissions, roughly evenly split between measures that reduce emissions and those likely to increase emissions. The next most common dimension impacted is air pollution (with around a third of total funding, again evenly split). In many cases, measures are tagged as being beneficial to both climate change and air pollution, as the two often go together. For example, investment in electric vehicles and active mobility both reduce CO₂ emissions and local air pollutants. In contrast, other environmental dimensions feature much less strongly. For example, measures affecting biodiversity account for less than 10% of the funding allocated, water only accounts for around 8% of funding. Other important dimensions such as waste and recycling, and climate change adaptation, have so far also received a very small proportion of total funding.

Figure 1.2. Funding allocated to measures affecting different environmental dimensions



Note: recovery measures can be tagged as targeting more than one environmental dimension (such as reducing GHG emissions and air pollution).

Source: OECD Green Recovery Database.

Some G20 countries are effectively greening their stimulus packages

Almost all of the G20 countries assessed in the database have at least some environmentally positive recovery measures. However, the proportion varies widely across countries. Positive examples include green infrastructure investment in renewable energy and energy efficiency, investment in sustainable transport modalities, green conditions attached to financial support, and programmes to support the creation of green jobs. The Next Generation EU recovery package includes targeted measures to reduce dependence on fossil fuels, enhance energy efficiency and invest in natural capital.

Importantly, the regulation establishing the Recovery and Resilience Facility, provides that no measure included in a Recovery and Resilience Plan should lead to significant harm to environmental objectives within the meaning of Article 17 of the Taxonomy Regulation⁴.

In contrast, some G20 countries have made only limited efforts to integrate environmental considerations in recovery packages. This was done, for example, through unconditional bailouts of airline companies, support for the fossil fuel industry without environmental conditions and, in general, through economic stimulus measures that locked in a business-as-usual approach (Buckle et al., 2020^[2]).

Box 1.1. Methodology of the OECD database and other tracking tools

The OECD Green Recovery Database was initially developed in July-August 2020 and subsequently updated in late 2020 and in March-April 2021. The database was shared with countries in multiple occasions via the delegates of the OECD Environment Policy Committee and their updates were reflected in the database.

The database currently contains around 680 measures with environmental relevance spread over 43 countries and the EU. A further 170 measures are classified as indeterminate for environmental impact and are not included in the analysis. While some sub-national measures are included, coverage focuses on national-level measures, which may skew results for some countries. Measures include tax reduction or other subsidy (not R&D); grant or loan (including interest-free loans and guarantees); regulatory change; skills and training; R&D specific subsidies.

The database focuses on measures related to COVID-19 recovery efforts that are likely to have a clear positive or clear negative environmental impact across one or several environmental dimensions (Figure 1.2). This means that the data cover not just measures targeted at environmental improvements, but also capture more general policy measures that may have negative environmental consequences.

Positive measures are those expected to have clear positive environmental impact for one or more environmental dimension, while not having major negative impacts on other environmental dimensions. In contrast, negative measures are those likely to have clear negative impacts on one or more environmental dimensions. “Mixed” measures are those that have clearly discernible positive and negative impacts, whether i) a clear positive environmental benefit on one dimension, but significantly negative impacts on at least one other dimension; or ii) the measure is very broad and contains some elements that will have strong positive implications but other elements that are likely to have clear negative implications (whether along the same environmental dimension or across several environmental dimensions). Measures that do not have clearly discernible environmental impacts are not the focus of the database, but those which have been included are categorised as “indeterminate”.

The categorisation used here draws on existing and emerging classification systems for environmental effects, such as the EU Taxonomy for Sustainable Activities, and OECD assessments of those methods already published (e.g. (OECD, 2020^[3])). Nevertheless, the categorisation is a high-level assessment and

⁴ Sustainable finance taxonomy - Regulation (EU) 2020/852, <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32020R0852>.

is intended to be used for aggregate analysis. It is not meant as a definitive judgement or assessment of the likely impacts of individual policy measures.

The results of the OECD database are both complementary to and broadly in line with other tracking exercises. None of the other trackers has the same scope (for example in terms of countries) nor method (for example in how environmental impacts are classified and tagged). Other prominent tracking tools include the following:

- The [Greenness of Stimulus Index](#) by Vivid Economics combines the flow of stimulus into five key sectors (agriculture, energy, industry, waste and transport) with an indicator of each sector's environmental impact. The impact indicator assigns a greenness value (positive or negative) to each sector for every country. The index covers G20 countries and ten other economies.
- The [Energy Policy Tracker](#) collects publicly available information on public money commitments for different energy types, and other policies supporting energy production and consumption. The Tracker currently covers more than 30 major economies and the Multilateral Development Banks.
- The [Green Recovery Tracker](#) assesses the contribution of EU member states' national recovery plans to the green transition. The assessment is based on a quantitative and qualitative analysis conducted in partnership with local experts.
- The [Oxford Global Recovery Observatory](#) tracks and assesses every individual COVID-19 related fiscal spending policy announced by 50 leading economies for potential impacts on the environment and the socio-economy.

Source: OECD (2021), *Green Recovery: Database of recovery measures with environmental implications*, [https://one.oecd.org/document/ENV/EPOC\(2021\)5/en/pdf](https://one.oecd.org/document/ENV/EPOC(2021)5/en/pdf).

Learning the lessons from past crises

The economic crisis caused by the COVID-19 pandemic is, of course, not the first global crisis caused by a shock in the recent past. The global financial crisis (GFC) of 2007-08 also triggered a major recovery effort that also had a strong focus on green stimulus in many countries. This section highlights some of the key findings from the experience of the GFC, drawing on a recent OECD report (Agrawala, Dussaux and Monti, 2020^[4]).

Green stimulus measures are beneficial for growth and well-being

Analysis conducted on green stimulus packages that were introduced in response to the GFC demonstrates that the implementation of sufficiently large, timely and properly designed green stimulus measures, which are well embedded into domestic policy settings, can deliver economic and environmental benefits. There are a number of examples of green stimuli that led to strong economic growth shortly after their implementation, including the creation of quality jobs.

The current crisis, triggered by a global pandemic, is fundamentally different to the GFC. It has been accompanied by a very significant loss of human life, a tremendous strain on public health infrastructure, and significantly higher economic and social consequences

worldwide. An immediate priority, therefore, is to deal with the public health aftermath of the crisis and its continued toll on society. In this context, green measures should have a “do no harm” orientation and include maintaining vigilance on any rollback of environmental standards, ensuring that any scale-back or suspension of environmental management activities is temporary, and making sure that support measures put in place to restart the economy do not inadvertently exacerbate environmental damage and do not lock in carbon-intensive technologies.

As economies begin to pick up at different speeds and move from rescue to recovery response, societal priorities could undergo a significant change as a result of the aftermath of COVID-19. The nexus between public health and the environment, for example, will likely be a much higher public policy priority now compared with previous crises, especially given the emerging evidence of links between COVID-19 vulnerability and air pollution or biodiversity loss. Concern about the social and distributional consequences is also likely to be paramount as this crisis has exacerbated inequality and unemployment. Much more so than in the case of the GFC, to recover from the COVID-19 crisis, policy objectives towards a “just transition” and co-benefits of the health-environment nexus should be considered in green stimulus packages.

As growth rebounds, governments will also have to ensure fiscal consolidation. In this context, they should tailor tax and spending policies to support the attainment of emission targets and address environmental challenges more broadly. Taxing emissions and polluting activities is a way to dis-incentivise these activities, as is the further phasing out of fossil fuel subsidies. Pricing mechanisms need to provide long-term investment signals, but should be timed and phased-in carefully (OECD, 2020^[5]). Spending measures may need to be deployed to offset the negative, unintended effects of environmental policies and improve their acceptability. Green budgeting, through a set of tools including green budget tagging, can ensure that spending integrates climate and environment related considerations. In addition, adaptation may require additional spending to increase resilience to extreme climatic events that occur with increased frequency and intensity (e.g. hurricanes, floods, large-scale forest fires) (OECD, 2020^[6]). Green public procurement is also an important policy instrument of budget allocations directed towards the private sector (OECD, 2019^[7]).

COVID-19 is unfolding in a policy environment that is significantly different from 2007-08. The costs of key renewable energy technologies such as solar and wind have fallen dramatically since 2010 compared to other energy sources, making large scale financing more economically attractive. At the same time, measures such as green public R&D support can target technologies that complement renewables but might be further from the market, such as energy storage. Another development since the GFC is the heightened attention to improving resource efficiency and the transition towards a more circular economy. Shifting away from unsustainable natural resource use would not only reduce environmental impacts and supply risks, it could also create job opportunities, for

example in recycling, processing of secondary materials and repairing goods. These developments offer new impetus and possibilities for greening the COVID-19 recovery.

There are however potential trade-offs between competing economic, environmental and social policy objectives. For example, in many cases investments aiming to improve energy efficiency were successful at maintaining economic activity in the construction and in the automobile sector but they suffered from rebound effects and delivered little net environmental gain. Conversely, the support to renewable energy generation was successful at reducing the cost of renewable energy technologies but had little impact on economic growth. These trade-offs call for policy coherence, public participation, whole-of-government co-ordination and establishment of clear criteria to identify and mitigate potential divergence in the achievement of different policy objectives within recovery packages.

Design of green stimulus measures: the need for evaluation frameworks and monitoring

Stimulus measures need to be developed on the basis of evaluation frameworks with clear criteria and robust methodologies to assess the environmental effectiveness and economic efficiency of stimulus measures. There are several examples from the GFC of green stimulus measures that were implemented without evaluation frameworks and thus did not achieve the desired results. For example, scrappage payments removed inefficient vehicles from the road but in some cases encouraged the purchase of cars emitting more nitrous oxide and bigger cars. A more general lesson from the GFC is that proper policy design is critical to prevent rebound effects, limit market distortion, and ensure additionality of public funding.

Therefore, it is important to ensure proper incentives within governments for building efficient and effective *ex ante* evaluation of measures, both in terms of their expected impacts, as well as where policy misalignments may exist. *Ex ante* evaluation mechanisms will also increase the transparency around recovery and stimulus plans and help governments orient current and future policy decisions towards more sustainable outcomes (Agrawala, Dussaux and Monti, 2020^[4]).

The increased use of green budgeting in OECD and other countries can help to enhance such transparency around public expenditures, linking recovery measures to crucial yearly budgeting exercises. Public sectors of OECD countries are not yet widely analysing and publishing the climate effects and environmental footprints of their direct operations, including delivery of public services. As governments are producing financial accounts and statements, a similar effort on climate and environmental accounts of the public sector could offer valuable incentives for reducing the environmental burden from the side of the public sector (OECD, 2021^[1]).

Monitoring the impact of recovery and stimulus measures on environmental outcomes through measurable, comparable, timely and transparent indicators is key to ensuring

that the green recovery is well targeted and effective in its execution. To contribute to this effort, the OECD is currently preparing a high-level dashboard of indicators to guide a strong, resilient, green and inclusive recovery (Table 1.1). It will consist of a small set of indicators that could be used to monitor four aspects of the ongoing crisis and recovery (i.e. strong, inclusive, green and resilient). In line with the OECD approach to measuring well-being and the Sustainable Development Goals, the dashboard will include both traditional economic indicators such as GDP and employment, as well as indicators related to sustainability, inclusion and well-being (OECD, 2021^[8]).

Table 1.1. Preliminary selection of indicators for high-level dashboard to guide a strong, resilient, green and inclusive recovery

Recovery dimension	Theme	Indicator
Strong	Economic activity	GDP growth
Strong	Employment	Job quantity in terms of volume of hours worked
Strong	Household income	Real (inflation-adjusted) household disposable income per capita
Strong	Business dynamism	Number of enterprise exits
Strong	Health risks	COVID-19 related deaths
Inclusive	Income inequality	S80/S20 ratio of household disposable income nowcasted estimates
Inclusive	Labour underutilisation	Number of unemployed persons, inactive people who wish to work and are available but may not have looked for work during the past 4 weeks, and employed people who work fewer hours than they would like, as a percentage of the labour force, seasonally adjusted.
Inclusive	Youth employment and training	Share of youth (aged 15-24) not in employment, education or training, percentage
Inclusive	Financial insecurity	Share of people that are finding it difficult or very difficult to live on current household income
Inclusive	Low life satisfaction	Share of people reporting a level of life satisfaction of 4 or below on a 10-point scale
Green	Climate change	CO2 emissions
Green	Green energy	Renewable energy in the energy mix
Green	Circular economy	Domestic material consumption
Green	Biodiversity	Natural and semi-natural vegetated land cover (tree-covered area, grassland, wetland, shrubland and sparse veg.) as % of total land area
Green	Environmental quality	Share of population exposed to 10g/m3 of PM2.5
Resilient	Fiscal sustainability	Institutional sector debt
Resilient	Investment	Gross fixed capital formation
Resilient	Digital transformation	Households with broadband Internet access at home
Resilient	Trust in government	Share of people reporting confidence in the national government
Resilient	Health resilience	An appropriate indicator needs to be explored; such as Multiple Chronic Conditions, work absenteeism, health spending, or other indicator that measures broad physical health of the population.

Source: (OECD, 2021^[8])

Opportunities and challenges of the green recovery

There are a number of challenges that governments face to achieve a green recovery. Ultimately, however, the recovery is an opportunity to “build back better”, combining an

emphasis on restoring growth and creating jobs with the achievement of environmental goals and objectives.

Some common **challenges** are the following:

- Governments' imperative is to get economies recovering quickly and to see positive results in employment. This will often be based on known investment plans and technologies, reflecting a certain degree of inertia in the system, a **business-as-usual approach**, a lack of understanding on the factors behind unsustainable growth, and a lack of information on alternative, sustainable options. Another challenge is the temptation to relive financial pressure on firms by relaxing environmental standards and regulation temporarily, and this should be avoided as it exacerbates existing environmental challenges and fails to provide incentives for firms to transform to more resilient business models. Similarly, where direct support to firms is essential to maintain viability it can be made contingent on environmental improvements, which can also help ensure the future viability of companies in a net-zero world.
- The green recovery poses a particular challenge for **developing countries**, and especially those **rich in non-renewable resources**, notably fossil fuels and minerals. Developing countries often have strained public finances combined with limited access to finance and high cost of capital. They often have less strong institutional capacity and larger informal sectors. For fossil fuel-exporting countries, falling demand for fossil fuels, in combination with policy pressure to reduce GHG emissions, would increase the urgency to diversify the economy away from fossil fuels toward cleaner energy forms. For mineral-rich developing countries, the abatement of emissions from this sector could contribute significantly to overall emissions reductions. To achieve such objectives, countries rich in non-renewable resources will need to develop targeted policies in areas including fiscal and tax policy, financial, energy, and mining sector regulation, and low-carbon technology, while keeping a strong focus on equity aspects of the transition.

The challenges are more than counterbalanced by numerous **opportunities** offered by the green recovery:

- The green recovery is an opportunity to undertake wider reaching and fundamental restructuring of critical sectors and activities in order to **support the transition to net-zero emissions**, driving towards climate-resilient and resource-efficient economies in socially inclusive ways. Not only would this be in line with national and international commitments made under the Paris Agreement, Sustainable Development Goals and other international environmental agreements, such as the Aichi Biodiversity Targets⁵, but increasing evidence points to green measures having strong fiscal multipliers, making them key drivers of growth and jobs (Coalition of Finance Ministers for Climate Action, 2020^[9]). In addition, they would also support improving the well-being for all over the near and medium to longer term. Environmental degradation disproportionately affects the most vulnerable groups and households in society. For instance, low-income households are more vulnerable to air pollution and climate change (OECD, 2021^[10]).
- The OECD Green Recovery Database indicates that a number of governments are using the post-COVID measures to **accelerate actions that were already envisaged under existing**

⁵ The Aichi targets include: Strategic Goal A: Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society; Strategic Goal B: Reduce the direct pressures on biodiversity and promote sustainable use; Strategic Goal C: To improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity; Strategic Goal D: Enhance the benefits to all from biodiversity and ecosystem services; Strategic Goal E: Enhance implementation through participatory planning, knowledge management and capacity building. More information available at <https://www.cbd.int/sp/targets>.

environmental plans and proposals. To capitalise on this effect, it will be important that plans are accompanied by clear and strategic regulatory frameworks pertaining to the long-term transition to a net-zero emissions economy, beyond the specific recovery programmes announced.

- **Carbon pricing** can support green recovery by shifting investment incentives and boosting public revenue, provided that it is designed in a progressive manner. OECD analysis (OECD, 2019^[11]; OECD, 2016^[12]) shows that current carbon prices are too low to incentivise deep decarbonisation for most energy users. Around 60% of energy-related CO₂ emissions from advanced and emerging economies in the 44 OECD and G20 countries are entirely unpriced and some of the most polluting fuels remain among the lowest priced (OECD, 2021^[13]). Lowering taxes on labour and capital, in favour of taxing environmentally harmful consumption and production, can stimulate job creation and investment, improving economic efficiency. Governments can complement support for green technologies with carbon price trajectories that provide guidance to consumers and producers without the need to raise carbon prices immediately when the economy has yet to recover from the crisis. In addition, some evidence suggests that higher-income households may be more likely to benefit from certain incentives to adopt greener technologies (e.g. incentives to buy more expensive EVs, or invest in home-renovation since low-income households are less likely to own housing) (OECD, 2021^[10]). It is crucial that energy tax or carbon pricing reforms, as well as green incentives are designed to avoid increasing the share of “energy poor” and rising inequalities, as adequate access to energy services is essential for ensuring decent standards of living (OECD, 2020^[14]).
- Similarly, **reform of fossil-fuel subsidies** can provide an opportunity for governments to redirect some of the half a trillion dollars spent annually supporting fossil fuels into sustainable investments including low-carbon energy. Government support for the production and consumption of fossil fuels totalled USD 468 billion in 2019, according to analysis by the OECD and the IEA of 81 economies (OECD, 2021^[15]). Beyond encouraging wasteful consumption, fossil fuel subsidies are an ineffective way to support low-income households compared to targeted benefits and tend to favour wealthier households that use more fuel and energy. Money spent supporting coal, oil and gas could instead be invested in sustainable energy infrastructure, research and job training. In the COVID-19 climate, subsidies drain resources that could be spent strengthening health system preparedness and resilience, for example.
- The significant amounts of money being focused on infrastructure as part of the stimulus packages highlight the opportunity to invest in **better alignment of infrastructure plans with longer-term goals on climate**, biodiversity, water and waste management, and resource efficiency. This is particularly the case for investments in electricity generation systems as well as major transport-related infrastructure, such as road systems, public transport, railways, and ports, as these will have major implications for future environmental outcomes. More in general, public resources committed to green measures must be strategically leveraged to mobilise capital from private sources.
- Innovation, through the **creation and diffusion of new products, processes and methods** is fundamental to creating new businesses and jobs, increase productivity and drive progress towards the green recovery. There are major opportunities for green innovations, which include, among others, technologies for renewable energy, energy storage, heating and cooling in buildings, electric, hybrid and fuel-efficient vehicles, and carbon capture, storage and use technologies. Despite some progress, the current level of innovation is not sufficient to reach ambitious climate and environmental objectives. Stimulus measures represent an important opportunity to bolster funding for innovation, though government involvement in innovation goes well beyond public funding for R&D. Typical innovation barriers include financing, information asymmetries, uncertainty of future policy strategies, and trade barriers. A broader discussion on R&D and innovation is provided in Chapter 3.
- Recovery measures aimed at achieving environmental objectives, including tackling climate change, also need to have a strong focus on **creating lasting, quality jobs**. One estimate suggests a green recovery could create 395 million jobs by 2030 globally (World Economic Forum, 2020^[16]).

Various green sectors and activities offer significant prospects for job creation. For example, renewable energy, notably solar PV, employs more people per unit of investment and energy than fossil-fuel generation (IEA, 2020_[17]). The International Renewable Energy Agency (IRENA) estimates that renewable energy could employ more than 40 million people by 2050 and that total energy sector employment can reach 100 million by 2050, up from around 58 million today, should the international community utilise its full renewable energy potential (IRENA, 2020_[18]). Energy efficiency also offers significant opportunities for rapid job creation, with the IEA estimating potential of up to 2.5 million new jobs per year as part of recovery efforts. However, there are considerable regional disparities in job creation in the energy sector with job gains in some parts of the world outpacing losses in others. In addition, some population groups, notably ethnic minorities and women, do not have the same access to newly-created jobs. Enabling a just transition that ensures social inclusion, protection and decent work is crucial to achieve a green recovery. The identification of policies that balance the impact of the transition while maximising socioeconomic opportunities is key for a more inclusive transition that supports the most vulnerable groups of society. Comprehensive measures for vocational training and reskilling can improve transferability across firms and sectors, thus enhancing ability to successfully relocate as needed.

- Nature-related jobs are also an important potential source of employment in the green recovery. To give just one example, ecosystem restoration in the US already provides direct employment for 126 000 people, and a further 95 000 indirect jobs, and generates USD 9.5 billion in economic output annually – with benefits for climate change as well as biodiversity. Organic agriculture also offers good potential for job creation. A number of studies have found that labour requirements per hectare on organic farms are higher than their conventional counterparts given that they have more labour-intensive production activities (e.g. complex rotation systems, mixed farming), that there is a higher share of labour-intensive crops (e.g. fruit and vegetables), less mechanisation, and more on-farm processing and trading (OECD, 2020_[19]).

2 Aligning recovery packages across different dimensions

The COVID-19 crisis has come on top of major global challenges that countries and governments have been struggling with for the last decades, with climate change being the most prominent (but by no means the only one). The global recession caused by COVID-19 has barely affected concentrations of greenhouse gases (GHG) in the atmosphere, which are likely to keep rising as the economy picks up. With G20 countries accounting for around 80% of global emissions, stronger action on reducing emissions needs to be a major focus of the recovery. Building resilience and adaptation will also be needed, to deal with inevitable climatic changes already locked in.

The short term policy responses to the COVID-19 crisis must be well aligned with longer-term climate objectives if they are to be met effectively and efficiently. This requires that governments build integrated strategies to address the different timeframes over which the impacts and policy responses will unfold. Bridging short-term policy responses and long-term objectives is a key challenge for both G20 and non-G20 governments. Such bridging can be considered through three inter-related channels:

- Aligning recovery packages with short and long term climate objectives;
- Aligning recovery packages to other well-being goals; and
- Aligning public and private financial flows to enhance the effectiveness of recovery packages.

Aligning recovery packages with short and long term climate objectives

The choices governments are making now when shaping their recovery packages will determine their countries' capacity to reach their climate objectives and comply with the Paris Agreement. Recovery packages are a unique opportunity to invest in climate mitigation given the sheer size of the funding underpinning the packages. Crucially, recovery plans made for the immediate term need to be aligned with countries' climate objectives, set at the international and domestic levels, for the short (2030) and longer term (2050).

According to the Intergovernmental Panel on Climate Change (IPCC), limiting warming to 1.5°C above pre-industrial levels implies reaching net-zero CO₂ emissions globally around 2050. Under the Paris Agreement, countries have to submit Nationally

Determined Contributions (NDCs) to communicate how they plan to reduce their GHG emissions. With the pledges submitted originally under the Paris Agreement, climate action by 2030 is not sufficient even to limit global warming to 2C, let alone 1.5°C, even if these pledges are supplemented with significant increases in the scale and ambition of mitigation after 2030 (IPCC, 2018^[20]).

Countries are also voluntarily invited to communicate by 2020 long-term low greenhouse gas emission development strategies (LT-LEDs) to 2050. These strategies represent an opportunity for countries to develop a roadmap for a deep, economy-wide transformations needed to achieve low emissions by mid-century. In turn, long-term strategies have the potential to guide shorter-term action and thus feed into the next rounds of NDCs. While a number of countries (around 30) have submitted LT-LEDs, few of these strategies have explicit linkages to the shorter-term NDCs (Falduto and Rocha, 2020^[21]).

More than 100 countries to date have pledged to get to net-zero emissions in the next 30 years (Net Zero Tracker, 2021^[22]). Net-zero emission strategies are sometimes embedded in national laws (e.g. Denmark, Sweden, France, New Zealand and the United Kingdom), but these countries account for less than 5% of global emissions. Some countries have set intermediate targets in the short term to ensure that emissions pathways' are consistent with long-term objectives (Box 2.1). But for most countries, there remains the task of actually developing strategies for and implementing their net-zero objectives.

The alignment between short and long term climate objectives is even more important in the current economic crisis. This is because such alignment can ensure more effective policymaking, more efficient use of resources and may also promote stronger well-being benefits associated with a mitigation strategy; all of these factors will be key in governments' response to the climate change challenge amidst and post the COVID-19 crisis. Recent OECD analysis used past examples to outline some guidance principles on the way to align those different timeframes (Falduto and Rocha, 2020^[21]):

- Countries need to **properly identify the risk of locking-in GHG emissions** in the long term. They need to anticipate now the actions that could hamper long-term mitigation goals, although they might contribute to reduce GHG emissions in the short term (such as a broad investment in technologies and infrastructure with lower carbon intensity than previous technologies, but which are not climate neutral may last for decades). One option is to systematically consider longer-term effects of climate actions. The LT-LED of Costa Rica, for instance, identifies lock-in risks for various sectors of the strategies, like investments for private vehicles at the expense of public transport or the development of 'transitional technologies' that are less emitting than the existing ones but not carbon neutral.
- Countries need to **identify the actions needed now for longer-term mitigation of GHG emissions**. The setting of sectoral pathways and targets in the short and long term can be helpful. Reducing GHG emissions in certain sectors without threatening people's quality of life or livelihoods might require broad changes in technologies and behaviour that cannot be made overnight. It is particularly true in the transport sector, where carbon pricing is often not enough to mitigate the use of internal combustion engine vehicles for private use. In addition, some measures launched

immediately will only be fruitful in many years or decades, requiring a longer-term vision from policy makers. This is particularly the case for land use change measures, crucial for our future climate stability, as the potential of soils to sequester carbon requires work and time.

- A **clear sequencing of action** will more effectively foster the development of the needed technologies and innovations for mitigating GHG emissions in the long-term by providing the signals to both public and private actors in the short to medium term. For example, by following such sequencing in an explicit fashion, Denmark is building a development track that will better focus efforts on research and innovation (Box 2.1) (Danish Council on Climate Change, 2020^[23]). Sequencing is likely to be particularly important for technologies such as Carbon Capture, Use and Storage (CCUS), which so far is not mature enough to be scalable at the levels potentially needed for limiting global climate warming to an increase of 1.5°C or even 2°C at the end of the century.
- The development of coherent and aligned policies and priorities for the short- and long-term can be facilitated by specific mechanisms for promoting policy coherence and appropriately **co-ordinated institutional arrangements** across relevant services and institutions. Recent OECD analysis highlights that establishing an inter-ministerial committee may be beneficial in the context of climate change, as aligning short and long-term goals requires co-ordination from different ministries (OECD, 2020^[24]). To increase the effectiveness of institutional arrangements, clear roles and mandates to anticipate and resolve policy divergences and to prevent and mitigate impacts on future generations should be established and guided by leadership from the top. In addition, they should ensure co-ordination at the horizontal (i.e. between different ministries) and vertical (i.e. between national and sub-national stakeholders) levels.

Box 2.1. Case studies of recovery packages integrating climate and well-being considerations

Italy's Relaunch Decree introduced a 110% tax deduction (Superbonus) for costs incurred to improve energy performance and/or earthquake protection work of residential buildings, including social housing, with the possibility of transferring the relative tax credit to the supplier. This applies to expenses incurred from 1 July 2020 to 31 December 2021 for thermal insulation work and other measures to improve energy efficiency. In addition to residential housing, the renovation bonus can be used by social housing institutions (Ministero dell'Economia e delle Finanze (MEF), 2020^[25]). The Superbonus was subsequently extended, in May 2021, until 31 December 2022 for condominiums and until 30 June 2023 for social housing.

France took the opportunity of the recovery plan to address energy efficiency in private buildings. Although a large part of social housing, benefitting low-income households, have been suffering from low energy efficiency, the costs of deep retrofits hamper the implementation of an ambitious plan. The French recovery plan includes a EUR 500 million plan (covering the two-year period 2021-2022) to support retrofitting works in up to 40000 dwellings (Buckle et al., 2020^[2]) (Gouvernement Français, 2020^[5]).

Aligning recovery packages to other well-being goals

Recovery packages can also be focused on a range of other goals in addition to climate goals. Broadening the range of goals can help governments to identify and exploit synergies with climate objectives. For example, measures to improve air quality will generally have strong impacts on reducing GHG emissions. More indirectly, but of particular significance in the current circumstances, measures to pursue biodiversity goals are an example where there may often be strong synergies with climate policies

(e.g. in terms of reducing land degradation). Nature-based solutions have been shown to support multiple goals including reduced GHG emissions (compared to grey infrastructure), increased biodiversity, and improved resilience to climate-related shocks, as well as presenting economic benefits such as job creation and recreational use (OECD, 2021^[26]). Bringing a broader range of environmental and other goals into the alignment challenge can also help to bridge the short-term / long-term nexus on climate by enhancing the political acceptability of recovery spending measures by focusing on the overall welfare of populations.

Such an approach lies at the core of the OECD well-being framework (OECD, 2020^[27]), which looks at people's material conditions and quality of life in eleven dimensions, including material dimensions, life quality, such as health and the safety of the place people live in, the environment, and social integration (Figure 2.1). In recent years, the OECD well-being approach has been applied to the economic country reviews of Austria, the US and Mexico, as well as to the issue of climate and the linkages with the COVID-19 recovery (Box 2.2).

The well-being approach requires that policymakers:

- Take an integrated policy approach to enhance people's lives, enhance synergies between policy areas and identify and address trade-offs; and
- Identify new levers of policy action for climate that may not have been considered previously.

Box 2.2. Three stylised pathways to frame a recovery strategy relative to climate

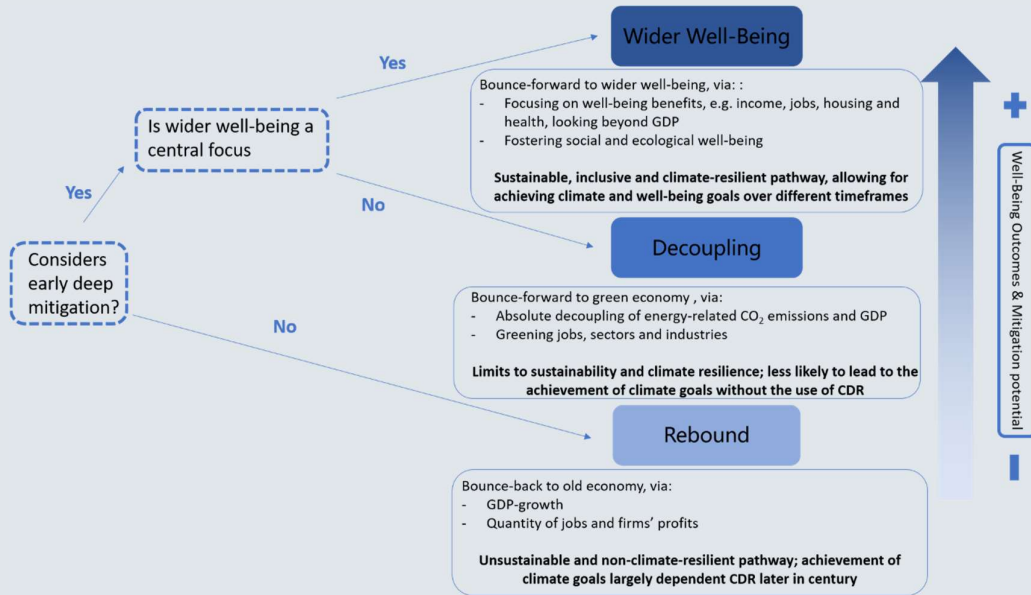
A recent OECD report outlines three stylised approaches to address climate concerns in recovery plans: by focusing purely on generating an economic rebound, with little or no specific recognition of climate challenges; by implementing measures to decouple GHG emissions from economic growth; and by implementing a well-being approach (Buckle et al., 2020^[21]).

A *rebound pathway* follows a bounce-back rationale and aims at putting the economy back on track as fast as possible, the way it was before the COVID-19 crisis. Climate and the environment are neither an objective nor a constraint. Measures following such a strategy include unconditional support to industries, including for fossil fuel production.

A *decoupling pathway* aims at fostering economic outcomes, reaching employment at pre-pandemic levels (or beyond), while reducing the impact on climate and the environment. It could consist or instance in support measures to promote electric vehicles to households, allowing mobility and supporting the industry with low GHG emissions. A decoupling strategy does not necessarily address the ambitious actions needed to reach the Paris Agreement goals, and bears the risk of locking in harmful structures and behaviours.

A *wider well-being pathway* consists of aiming for ambitious climate action together with other well-being outcomes, as defined by the OECD well-being framework. More particularly, it allows to integrate equity issues when implementing climate policies in a context of economic and social crisis.

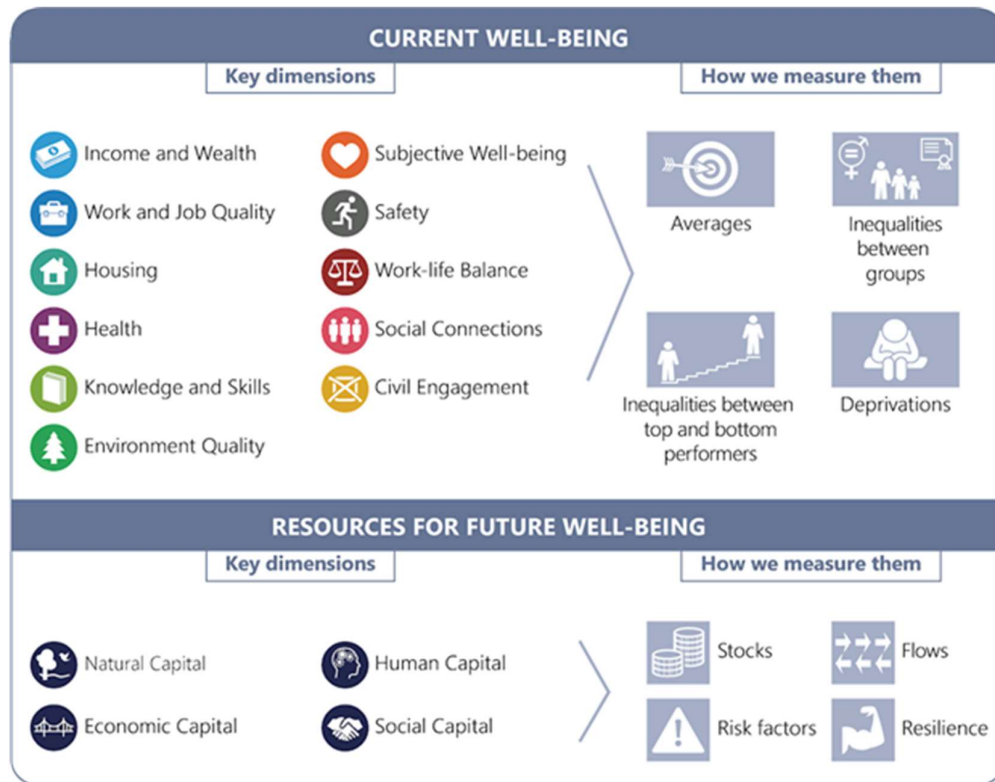
Figure. Stylised recovery pathways from the COVID-19 crisis



Note: CDR stands for Carbon Dioxide Removal. By CO₂ emissions, this discussion document refers to fossil-fuel related CO₂ emissions, as measures assessed in this document relate to those tackling those emissions specifically. This discussion document acknowledges that CO₂ emissions from non-fossil fuel related sectors (e.g. from the land use sector) as well as other greenhouse gas emissions from fossil-fuel combustion (e.g. CH₄ from fugitive emissions) and in other sectors (e.g. N₂O and CH₄ from agriculture) are important greenhouse gas emissions and need also to be tackled by specific measures during the recovery and beyond.

Source: (Buckle et al., 2020_[2])

Figure 2.1. The OECD well-being framework



Source: (OECD, 2020^[27])

There are a number of actions that governments can consider when developing a well-being approach into recovery packages (OECD, 2019^[28]). These include:

- **Enhanced strategic planning mechanisms** that will enable policy makers to integrate the many dimensions of well-being. Committing to clear objectives will help actors and citizens to anticipate policies, which could in turn encourage green investments by households and firms.
- A set of **relevant indicators** can make public action more effective, by helping policy makers to monitor progress, and possibly adjust action if progress is not sufficient. These indicators need to cover a broad set of objectives, clearly identify and measure cross-benefits between objectives, and to be widely available to allow comparisons between countries and across time. For instance, indicators on energy poverty could help build effective climate strategies to improve the comfort of low-income households and reduce energy consumption, as well as improve the material and economic conditions for low-income households.
- **Strengthened governance and institutions** to overcome the perennial challenge of policy coherence and horizontal government coordination. Many governments still tend to work in silos and there is a need to carefully consider the appropriate mechanisms to enhance coordination (e.g. a stronger central role for government, or structured coordination mechanisms). Sectoral ministries should also systematically integrate climate and well-being considerations in their activities.
- The **vertical mainstreaming** of well-being objectives across levels of government (i.e. between national, regional and local levels). For example, the role of municipalities in managing transport systems and emissions is crucial to addressing not just climate goals, but also goals linked to local air quality, congestion and commuting time, housing affordability, etc. Coordination between

neighbouring cities can also be significant, for example by using planning processes to mitigate potential leakage effects (a shift of congestion from one city to another) and make the case for shared investment in public transport.

Aligning financial flows to climate objectives

In order to build back better we need green recovery packages that build the foundations for the investments required to reach net zero by mid-century. It is therefore important that the financial system is aligned with the goals of sustainable growth, climate action, and responsibilities towards the environment and biodiversity.

The Paris Agreement (Article 2.1c) acknowledges the dependency of the climate mitigation and adaptation goals to “Making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development” (UNFCCC, 2015^[29]). This formulation contributed to the development of the concept of alignment of finance with climate goals used in the financial sector (banks, institutional investors), businesses, and public institutions (development banks, public budgets). As illustrated by OECD country-sector pilot studies (e.g. (Jachnik and Dobrinevski, 2021^[30])), the alignment of finance with climate goals requires assessments across all types of investors and finance providers in both the public and private sectors, which in turn requires reliable data and robust assessment methodologies.

The amount of resources devoted to climate-friendly objectives in recovery packages is a significant indication of countries climate ambitions, as shown by the OECD Green Recovery Database and other tracking exercises presented in Chapter 1. Analysing the share of budget dedicated to green and climate spending can help countries build recovery packages with consistent and ambitious green strategies. Green budgeting, i.e. the climate and environmental impact assessment of budgetary choices can be a useful tool to inform policy makers on the alignment of recovery packages with their climate and environmental strategies. In most cases, green budgeting consists in tagging the different budget measures according to their impact (positive, negative or neutral) on different criteria. France used this approach to frame its recovery plan in September 2020, in which 30% of budget was allocated to green measures, following six environmental objectives (climate adaptation, climate mitigation, biodiversity and sustainable land use, circular economy and risk prevention, water resources management and pollution abatement) (OECD, 2020^[31]).

The potential of green budgeting in supporting climate and environmental objectives highly depends on how it is framed and implemented. The OECD’s Green Budgeting Framework highlights the building blocks needed for this approach to be effective: i) a strong strategic framework for climate and the environment, ii) tools for evidence generation and policy coherence, iii) reporting to facilitate accountability and transparency and iv) an enabling budgetary governance framework (OECD, 2020^[32]). As

impact assessment is crucial *ex-ante* to anticipate the effect of measures that are not implemented yet, *ex-post* assessment can deliver the tools to monitor the effects and potentially adjust the measures throughout the exercises of public budget. Spending reviews, which consist in considering both the impact and efficiency of spending can also help to prioritise investments that support a low-carbon economy (OECD, 2020^[31]). An inventory of expenses and tax expenditures would also allow countries to identify budget lines that should be phased-out in order to reduce GHG emissions, such as support to fossil fuel and related industries.

A considerable part of the recovery spending will be carried out through public procurement. There is a great potential for green public procurement (GPP) in supporting climate and environmental objectives. In 2015, the OECD developed an analytical framework for successful green public procurement, consisting in the following steps: (1) setting up a legal and policy framework to assist public buyers in incorporating green aspects in their procurement procedures; (2) planning green public procurement, including understanding market capacity and available technical solutions, as well as assessing green public procurement costs and benefits; (3) introducing environmental standards in the technical specifications, selection and award criteria, as well as in contract performance clauses; (4) professionalising GPP and increasing GPP know-how and skills; (4) raising awareness of GPP solutions and their benefits with buyers, businesses and civil society; and (6) monitoring the results of GPP and providing a feedback loop into policy and regulation (OECD, 2015^[33]).

As the economy recovers, private actors have a key role to play in driving the transition to a net-zero economy, and the financial sector is an important driver of change in the real economy. Financial markets need clear, comprehensive, high-quality information on the impacts of climate change. This includes the risks and opportunities presented by rising temperatures, climate-related policy, and emerging technologies. The Financial Stability Board created the Task Force on Climate-related Financial Disclosures (TCFD) to improve and increase reporting of climate-related financial information.

Previously, the OECD presented evidence that while a significant increase in infrastructure investment was needed to meet development objectives, making new infrastructure aligned with the Paris Agreement would require only a 10% marginal increase in yearly investment (going from USD 6.3 trillion to USD 6.9 trillion) (OECD, 2017^[34]). In 2017, private investors only accounted for 17% of total investment for infrastructure. The investment of private actors, and particularly institutionalised investors, stands as a major opportunity for green finance.

Common barriers preventing greater flows private finance into climate-aligned infrastructure include the general economic and environmental context (the lack of clear carbon pathways, the support allocated to fossil fuels, and the lack of ambitious climate strategy). Other barriers concern the structure and regulation of financial markets, or

specific issues with some projects (lack of national planning, insufficient risk mitigation, etc.) (OECD, 2020^[35]). Despite the great increase in appetite for Environmental, Social, and Corporate Governance (ESG) investing, recent OECD work found that the wide array of standards being used was hindering transparency and leading to mixed performance on the environmental side (OECD, 2021^[26]).

Policy makers can enhance private investment in climate through three main strategies. Public-private partnerships offer a great opportunity for the development of green finance, by providing guidance and a clear horizon to investors and by mitigating risks. This type of collaboration is at the basis of the development of offshore wind energy in Denmark. Governments can also stir private investment for green infrastructures by greening mandates. Clarifying fiduciary duties for green investment and the link between investment flows and climate and environmental outcomes is an option chosen by the European Union when defining its sustainable finance taxonomy. Finally, governments can provide a regulatory framework for securitised financial products that are specific to green infrastructure (OECD, 2020^[35]).

Finance flows towards developing countries should also be enhanced. The COVID-19 pandemic has greatly affected developing countries, which see their economies battered, face mounting debt and at the same time have lost large amounts of remittances sent home by their citizens working abroad. The \$100bn commitment of climate finance directed to developing countries from 2020 has not been met according to latest data. Total climate finance provided and mobilised by developed countries for developing countries reached USD 78.9 billion in 2018, up by 11% from USD 71.2 billion in 2017. This represents a slower growth rate than the 22% rise from 2016 (USD 58.6 billion) to 2017. Within this total, public climate finance provided by developed countries increased, while private climate finance mobilised stabilised (OECD, 2020^[36]). The consequence is that some of the most vulnerable countries are left without the means to cope with the intensifying impacts of climate change, let alone direct investment in recovery plans towards a low-carbon future.

3 Innovation as a key pillar of a durable green recovery

A green recovery will require directing R&D and innovation towards longer-term climate and environmental objectives

The COVID-19 pandemic has underscored the importance of long-term investments in R&D and innovation to being both prepared and reactive to external shocks. The speed with which public research groups and biopharmaceutical firms are developing COVID-19 vaccines builds on years of basic research investment, as well as supply-side and demand-side incentives to business R&D and innovation including public procurement, regulations, R&D tax credits and direct grants.

On an aggregate basis, business investments in research and innovation are pro-cyclical, and thus prone to contracting in times of crisis. Green recovery packages will need to include measures to channel direct public support to climate and sustainability goals as well as incentives for business to invest in green R&D and innovation. Governments should revisit their “policy mix” in support of business innovation to ensure an appropriate balance indirect measures, such as R&D tax incentives which are technology neutral, and more targeted approaches such as “mission oriented” innovation grants that direct innovation efforts towards specific challenges such as climate, clean energy, air and water pollution or the preservation of biodiversity. Furthermore, just as the COVID-19 pandemic is a global problem that requires international co-operation in R&D, governments should consider scaling up international collaborative R&D platforms, infrastructures, and networks that will improve countries’ abilities to jointly respond to climate challenges and risks.

Innovation for the green transition: a brief overview

Innovation – the creation and diffusion of new ideas, products, processes and methods – is fundamental to the transition to a cleaner global environment. For example, the low-carbon energy transition relies on a rapid diffusion of at least four broad types of technologies: renewable energy, energy efficiency, large-scale energy storage, and carbon capture and storage. While mature technologies (e.g. onshore wind, solar PV) can be further improved, there is room for breakthrough innovations in geothermal energy, concentrated solar power, high-energy-density storage and CO₂ capture (IEA, 2017^[37]).

Beyond climate change, all other global environmental challenges – including air pollution, access to clean water, biodiversity loss, and waste management – also require innovation. Reducing human exposure to air pollution in cities implies switching to electric vehicles, where innovation is needed both in established lithium-ion technologies and in emerging technologies, such as ultra-super-capacitors or hydrogen fuel cells. Access to clean water requires the improvement of membrane treatment and of other nature-based purification techniques. Advances in sensors are necessary to improve the accuracy and productivity of automatic sorting of waste and the quantity and quality of recovered material fractions available for recycling. In parallel to technological innovation (new processes and products), other forms of green innovation are needed, such as organisational innovation (e.g. environmental management) or business models innovation for the new circular economy (OECD, 2019^[38]).

Importantly, the green transition requires innovation in many “enabling” technologies that are not strictly speaking “environmental”. This includes in particular digital technologies such as artificial intelligence (AI), 3D printing, the Internet of Things (IoT) and blockchain (OECD, 2020^[39]). In industry, smart appliances, energy consumption feedback devices and energy management are already effectively reducing energy demand and associated GHG emissions. AI - machines performing human-like cognitive functions - can contribute to a greener economy through multiple channels (OECD, 2019^[40]), for example by catalysing smart grid management and intelligent transport systems. 3D printing or additive manufacturing can produce products in layer by layer fashion, on demand and directly from digital 3D files. This can reduce the amount of scrap materials and yield significant energy and resource savings. Data-driven solutions can enable predictive maintenance, prolonging infrastructure life, while the use of drones can enable more targeted, less invasive interventions that can reduce the cost and consumption of building materials (OECD, 2021^[26]). The Internet of Things (IoT), which comprises devices and objects whose state can be altered via the Internet also presents new opportunities to solve environmental problems. Buildings could adapt in real time to weather conditions and prices, thus increasing energy efficiency (OECD, 2015^[41]). ‘Smart’ traffic lights can adapt to traffic flow, reducing air pollution and increasing energy efficiency of transport. Finally, the main strength of blockchain (a decentralised and disintermediated technology that facilitates economic transactions and peer-to-peer interactions) could be managing the distributed grid as it facilitates decentralized consumer-to-consumer selling of electricity and balancing supply with demand without needing a third party.

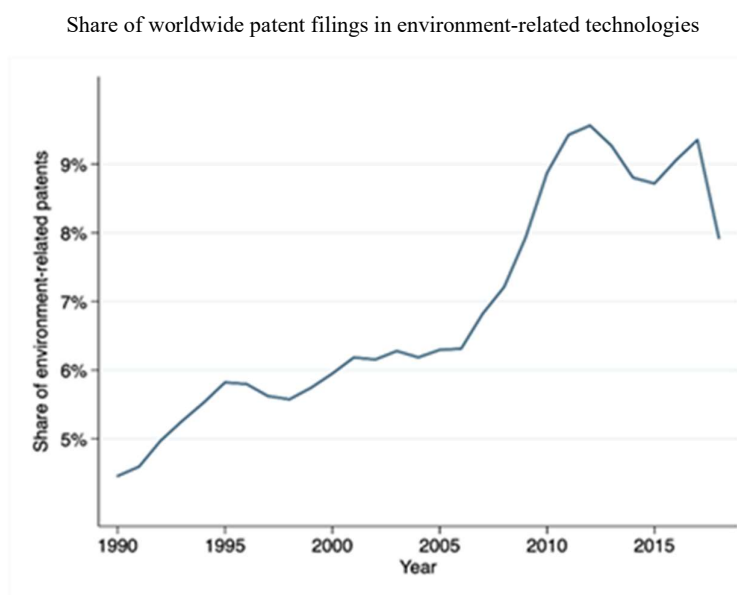
In short, digital technologies can be a key enabler for the green transition, both by directly improving firms’ environmental performance and by allowing governments to more accurately monitor environmental progress and implement decentralized policies. However, there are concerns about the carbon and material footprint of digital technologies themselves (e.g. energy use of data centers, challenges of recycling electronic equipment) which need careful consideration.

Recent trends in global green innovation

The pace and progress of environmental innovation can be measured by looking at global patenting activity in related technologies. Figure 3.1 shows this activity between 1990 and 2017 (the last reliable year of data) for a range of environment-friendly technologies. The combined data cover most of the technologies available today to mitigate greenhouse gas emissions, but also technologies related to air pollution control, waste management, water management, adaptation to climate change, soil remediation and environmental monitoring. The full set of technologies covered is listed in Box 3.1. Because growth in environment-related patenting could reflect the general growth of patenting in all technologies, Figure 3.1. indicates environment-friendly inventions as a *share* of environment-related inventions in all technology areas. This indicates the *direction* of innovation toward green technologies.

The main message is that, following two decades of uninterrupted growth, innovation efforts in environmental technologies have declined recently. Between 2006 and 2012, the number of new environment-related inventions patented globally grew at an annual rate of almost 10%: more than double the rate of innovation of all technologies. However, environmental innovation efforts as a share of global innovation efforts started to peak and decline around 2010. This downward trend in environment-friendly innovation efforts is concentrated in technologies related to climate change mitigation such as renewable electricity, low-carbon transportation and energy efficiency. A primary objective of a green recovery from the COVID-19 pandemic would be to reverse this worrying trend in global green innovation efforts, particularly in low-carbon technologies.

Figure 3.1. Global environmental innovation efforts, 1990-2017



Source: Based on data from the Global Patent Statistical Database (available through the OECD MicroData Lab).

Box 3.1. Environment-related technologies covered in patent data

- Low-carbon electricity production, for example renewables, nuclear, biofuels, smart grids, energy storage and carbon capture and storage.
- Low-carbon transportation, for example fuel efficiency technologies, electric, hybrid and fuel cells vehicles, and lighter materials.
- Energy efficiency in the buildings sector, for example energy-efficient lighting and heating, and insulation.
- Energy efficiency in the manufacturing sector, for example energy-efficient industrial processes, and material recycling.
- Air pollution control technologies, for example purification of waste gases (e.g. engine exhaust gases), smoke purifiers, dust collectors, and catalytic converters.
- Adaptation to climate change, for example, sea walls, tidal barriers, flood forecasting, reforestation, storm shelters, and medical treatment of waterborne diseases.
- Water pollution abatement, for example wastewater or sewage treatment, fertilisers from wastewater, and oil spill clean-up technologies.
- Waste management, for example solid waste collection, material recovery, recycling and re-use, fertilisers from waste, and energy recovery from waste incineration.
- Water saving technologies, for example indoor water conservation (aeration of water, dry toilets), greywater reuse, drip irrigation, drought-resistant crops, leakage monitoring in pipes, rainwater collection and replacing steam power generation by photovoltaics and wind turbines.
- Other environmental technologies, such as remediation of contaminated soil and environmental monitoring.

Note: See <https://www.oecd.org/env/indicators-modelling-outlooks/green-patents.htm> for OECD's green patents analyses.

The potential for innovation to reignite economic growth and reduce emissions at the same time

Innovation is the main source of modern economic growth. As such, the development and rapid diffusion of technologies that improve environmental outcomes is not only a necessary condition for the green transition, it also opens up a vast range of economic opportunities and can be a source of jobs, productivity improvements and growth. The structural transformation of the economy made necessary by the green transition – like all previous industrial revolutions that the world has undergone – presents market and business opportunities across all sectors (Fankhauser et al., 2013^[42]). There is evidence that the green economy is already growing at a fast rate across numerous countries and sectors and this trend will likely only become stronger in the years ahead (Georgeson and Maslin, 2019^[43]). New green revenue data from global listed firms (covering 98% of global market capitalisation) shows that revenues from environmental goods and services is growing rapidly and totalled USD 1.6 trillion in 2016, representing around 4% of turnover (Kruse et al., 2020^[44]).

There are two main channels through which environmental innovation can positively impact firms' environmental and economic performance at the same time: the cost channel (whereby firms reduce input costs through improving material or energy efficiency and mitigating risk) and the revenues channel (whereby firms increase revenue by developing new, cleaner products in response to changing customer preferences) (Ambec and Lanoie, 2008^[45]).

On the cost side, there is ample empirical evidence that green innovation leads to reduced costs by improving energy efficiency or productivity (Dechezleprêtre and Kruse, 2018^[46]). An example is through adoption of digital technologies, which monitor and analyse the efficiency of machines and optimise their operations. This can simultaneously improve material and energy consumption and raise productivity. The potential of digital technology adoption as a way to achieve economic and environmental objectives jointly has been highlighted by the COVID-19 pandemic, as technologies allowing remote work and reducing manual labour input have ensured continued production in some sectors and firms, while reducing emissions related in particular to transportation (OECD, 2020^[47]). At the macroeconomic level, it has been shown that resource productivity improvements can create net positive additional employment (Laubinger, Lanzi and Chateau, 2020^[48]). There is also evidence that greener firms are able to attract more productive employees (Nyborg and Zhang, 2012^[49]) and face smaller costs of capital (Cheng, Ioannou and Serafeim, 2013^[50]). On the revenue side, it has been shown that moving into green activities (by increasing the share of revenue generated from the sale of green goods and services) is associated with higher operative profit margins (Kruse et al., 2020^[44]).

Finally, it is worth mentioning that many innovations that improve environmental quality lead to better health, which in turn translates into productivity improvements. For example, there is empirical evidence that reductions of polluting emissions translate into higher economic growth at the regional level (Dechezleprêtre, Rivers and Stadler, 2019^[51]). This is a more indirect way in which green innovation leads to better environmental and economic performance at the same time.

Integrating innovation for the green transition into recovery packages

Challenges to directing R&D and innovation towards climate and environmental goals

Many of the technologies needed for keeping global temperature rise well below 2°C already exist. Many more, such as digital tools, promise to advance low-emissions technologies even further, provided there are sufficient incentives for public and private investment in R&D. Despite this, many existing solutions are not yet deployed at scale: for example, only four out of 38 low-emissions technologies fundamental to achieving the 2°C target are on track to penetrate markets sufficiently: PV, lighting, data centres and networks, and electric vehicles (IEA, 2018^[52]). The recovery from the COVID-19 pandemic provides an opportunity to boost green innovation, but there are a number of

barriers limiting the development and diffusion of new cleaner technologies. A well-designed green recovery should seek to address these barriers jointly.

- First, a key feature of the green transformation is that – at least until green technologies become cost-competitive with fossil-based technologies – the demand for green goods and services depends on public policies to create the relevant markets. Unregulated emissions or misaligned fiscal policies favouring fossil-based technologies (such as government subsidies for the consumption of fossil fuels) reduce the size of the future market for green technologies, which in turn reduces innovation. In other words, private investment in green technologies will increase if the demand is large enough, so policies need to align the private costs with the public (environmental) costs. Many public policies can foster and reward green innovation, including fiscal policies which incentivise people to make sustainable consumption choices, green public procurement, norms and performance-oriented standards (Veugelers, 2012^[53]).
- Second, it is well established in the economic literature that R&D activities provide not only private returns to inventors, but also additional returns to the society, which are not captured by inventors. These “knowledge spillovers” result in a large wedge between private and social rates of return to R&D. Since firms make investment decisions based on their private returns, socially beneficial research opportunities are ignored by firms because they are unable to fully capture the rewards of such innovations. Research has shown that knowledge spillovers are 60% larger for low-carbon technologies and other radically new technologies such as AI, nanotechnologies or robots, compared with traditional fossil-based technologies (Dechezleprêtre, Martin and Mohnen, 2017^[54]). This provides evidence that – compared to innovation in fossil-based technologies – innovation in clean and enabling digital technologies require higher public subsidies.
- New technologies require new skills to enable the technologies to be developed and diffused, and new infrastructure to be deployed. Thus, a successful green recovery entails gearing up educational institutions and firms to provide the skills that are required for new occupations and sectors that will emerge from the green economy. This is particularly the case for the diffusion of enabling digital technologies, which are fast changing the nature of jobs and the skills that workers need to possess to perform them (OECD, 2017^[55]; Squicciarini and Nachtigall, 2021^[56]).
- Strong innovation capabilities are also required. This includes not only the training of researchers, but a well-functioning innovation ecosystem. In particular, the financing of R&D and innovative activities is notoriously difficult in a freely competitive market, because the primary output of resources devoted to invention is the knowledge of how to make new goods and services, and this knowledge can be easily appropriated by competitors. Lack of adequate financing along the entire innovation chain is one of the main obstacles in the commercialisation of science, especially for early-stage companies whose products are not finalised and therefore cannot obtain seed funding (Hall and Lerner, 2009^[57]).
- Barriers to a dynamic business environment, such as limitations to competition, can slow down the adoption of greener technologies. Encouraging the entry of new, adventurous firms, is important as new firms are often the vehicle through which radical, game-changing innovations enter the market (Andrews, Criscuolo and Menon, 2014^[58]). Lack of business dynamism means that low-emissions innovations may not overtake fossil fuel-based incumbents and secure their place in mainstream markets, even if they are more efficient. Concentration of market power means that long-term investors (e.g. asset-heavy banks, institutional investors) may favour incumbents because of perceived stable returns.
- Poor access to infrastructure can be a key barrier for technologies characterised by the presence of network effects. For example, diffusion of low-emissions vehicles is hindered by the lack of a charging network in cities and along motorways. The pervasiveness of high-carbon infrastructures means that technologies can be subject to lock-in or dominant design that prevents other technologies from emerging.

- Social barriers may result from lack of public acceptance and engagement with new technologies (e.g. due to lack of information, habits, or perceived negative health and safety consequences). Communicating, preventing, correcting and mitigating adverse effects is important for the deployment and diffusion of new low-carbon technologies which challenge the social norms and activities they have fostered throughout society.
- Political and institutional barriers result from governance and co-ordination failures due to incoherence or inconsistent timing across policy areas. Misalignments can be horizontal (i.e. between innovation policies and sectoral policies), vertical (i.e. between ministries and implementing agencies) or multi-level.

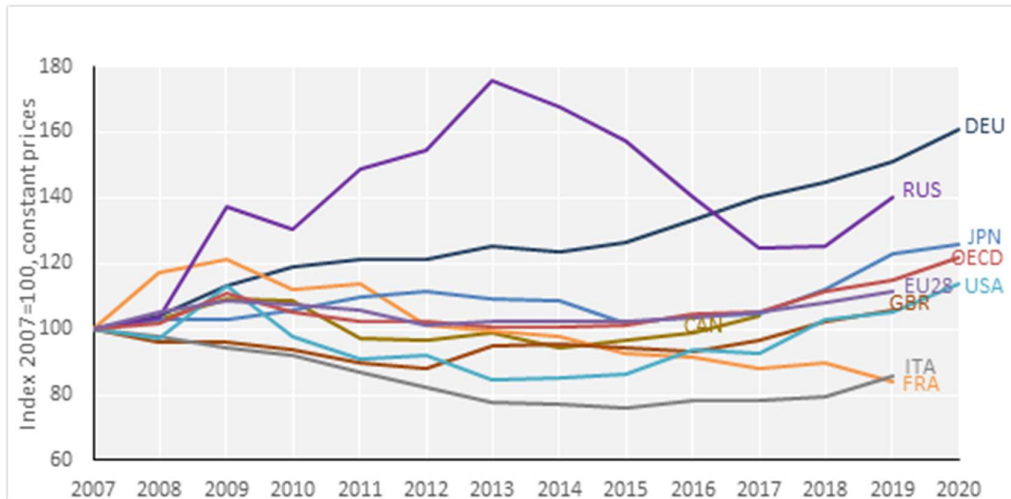
Support to public and private R&D, demonstration and technology diffusion as part of a green recovery

The first (necessary, but not sufficient) component of an innovation-oriented green recovery is public investment in R&D and technology diffusion, with a focus on innovations with a potential to foster and accelerate the green transformation, including technologies with a direct environmental benefit and enabling digital technologies.

Government support to public R&D remains essential, both to understand the science behind climate as well as to conduct high-risk research that the private sector would not fund. Government support generally takes the form of institutional "block" funding to universities and public research institutions, competitive research grants for specific research fields/topics, technology transfer and commercialisation policies, and cluster or eco-system policies that aim to link public research to industry.

Prior to the onset of the COVID-19 crisis, government R&D budget indicators for the OECD area, which present the amounts allocated by governments for R&D rather than actual expenditure reported by R&D performers, showed an upward inflection in 2018: budget allocations for R&D surpassed their previous 2009 peak. This was principally explained by growth in budgeted R&D support in Germany, Japan, the United Kingdom and the United States. Preliminary estimates also suggest a significant but more moderate increase in R&D budgets for 2019 (+2.47%). Growth in US R&D budgets came to a halt in 2019. R&D budgets in France, Italy and Spain were in 2019 still below 2007 pre-crisis levels. The United Kingdom and the United States only just emerged from this position in 2018 (Figure 3.2).

Figure 3.2. Government R&D budget trends, selected economies, 2007-20



Source: OECD Main Science and Technology Indicators (MSTI) Database, 19 April 2021 <http://oe.cd/msti>.

The outlook for public R&D funding in the recovery phase remains uncertain but the government response to the pandemic has underlined the importance of science in preparing and reacting to upcoming crises, possibly translating into stronger and more lasting support for public research. For example, the United States and the United Kingdom have pledged new funding for research for the coming years. The announced US federal R&D budget for 2021 shows a 6% increase over the fiscal year (FY) 2020 budget. Meanwhile, the United Kingdom remains committed to raising public R&D expenditure to GBP 22 billion by FY 2024/25 and increasing its total R&D expenditure to 2.4% of gross domestic product by 2027. Korea also announced a new science and technology policy initiative “post corona, science and technology policy direction for a new future” that identifies 30 promising technologies which will have high priority for government R&D funding (OECD, 2021^[59])

Because R&D is increasingly reliant on data and digital tools, it is important that the outputs of publicly funded research be made widely available to other scientists as well as potential innovators (i.e. academic entrepreneurs and SMEs) who may face difficulty in access public research results (e.g. publication and research data) due to the high cost of scientific journal subscriptions or the lack of qualified personnel.

Public support to private R&D in firms can take the form of grants, tax credits or innovation prizes, but can also be delivered through demand-side policies such as regulations and public procurement (OECD, 2011^[60]), (OECD, 2017^[61]). OECD countries and partner economies have increasingly relied on R&D tax incentives to spur business innovation, with tax support representing around 56% of total government support across OECD countries in 2018, compared to 36% in 2006. Yet, while such measures are effective in incentivising business innovation, they are indirect and untargeted, and tend

to generate incremental innovations. Well-designed direct measures, such as contracts, grants and awards, may therefore be better suited to supporting longer-term, high-risk research, and to targeting innovations that generate public goods or large knowledge spillovers (OECD, 2021^[59]). Public support to private R&D efforts should continue to support the development of pre-competitive technologies that are still far from the market, such as hydrogen, energy storage or carbon capture and storage.

Such support could put a particular emphasis on academic spin-offs and start-up firms. A rapid shift towards a low-carbon economy requires radically new innovations on top of incremental improvements in existing technologies, and young firms tend to be major drivers of such radical innovation. Therefore, facilitating the entry and growth of innovative start-ups will be crucial for the development of low-carbon innovations. This is all the more important as both young and small firms are likely to be much more severely affected by the COVID-19 crisis compared to larger or incumbent firms, as they have poorer access to capital required to smooth over transitory shocks (Calvino, Criscuolo and Menon, 2016^[62]).

There are two notes of caution on public R&D support. First, any increase in funding needs to be gradual, because the supply of researchers is fixed in the short run and expanding research in clean technologies involves training new scientists to avoid crowding out other socially valuable R&D. Second, the impact of R&D activities takes time to materialise. Therefore, while public R&D support may be particularly fruitful as a longer-term recovery strategy to the COVID-19 crisis, it is not necessarily destined as recovery stimulus per se, and should therefore be combined with other standard short-term policy measures to revive the economy.

While R&D is important, green innovation policy also requires a strong emphasis on the deployment and diffusion of already close-to-market green innovations. Immature but potentially transformative low-emissions innovations must often compete against hefty incumbent technologies in markets with high barriers to entry and exit, which makes them risky for innovators. Governments can help to break path dependence in these circumstances – as has been the case for renewable electricity (Climate Finance Study Group, 2016^[63]). The rise in global investment in renewable power capacity was driven in large part by significant support to technology deployment through targeted incentives (e.g. fixed prices and guaranteed purchase for renewable electricity) electricity (Climate Finance Study Group, 2016^[63]; FS-UNEP and BNEF, 2016^[64])).

The design of technology adoption support policies needs to carefully take into consideration countries' domestic settings (level of development, talents, skills, firms and infrastructure). Previous green recovery packages focused on demand side policies which are critical to create markets for green products (feed-in tariffs, car rebates) but paid little attention to the supply side and to the development of global supply chains.

Matching green technology support to the skill base of the local economy matters for the success of such programmes (Chen et al., 2020^[65]).

To achieve persistent behavioural changes so that the decline of emissions observed during the 2020 lockdowns can become permanent, targeted investments for the diffusion of digital technologies and the upgrade of communication networks should be part of a green recovery package, provided measures are taken also to reduce the environmental footprint of digital technologies (OECD, 2020^[66]). In particular, more permanent teleworking arrangements that can induce emission reductions from transportation will only be feasible if high-speed internet access is widely available. On average across OECD countries, the share of high-speed fibre internet in total broadband is less than 30%, although large differences exist, with Korea and Japan having around 80% and Italy, Austria, Germany or Greece less than 10% (OECD, 2020^[67]). Investing in high-speed internet technology can generate jobs and support economic development – particularly in rural areas which have often been left behind in access to digital technologies. Widely-available access to high-speed internet also reduces distributional disparities between regions and income groups and allows rural economies to benefit from emerging technologies and improves their competitiveness. Such measures may need to be accompanied by new regulation that facilitates and encourages behavioural changes over the longer term, which may include flexible working arrangements or a right to work from home when feasible.

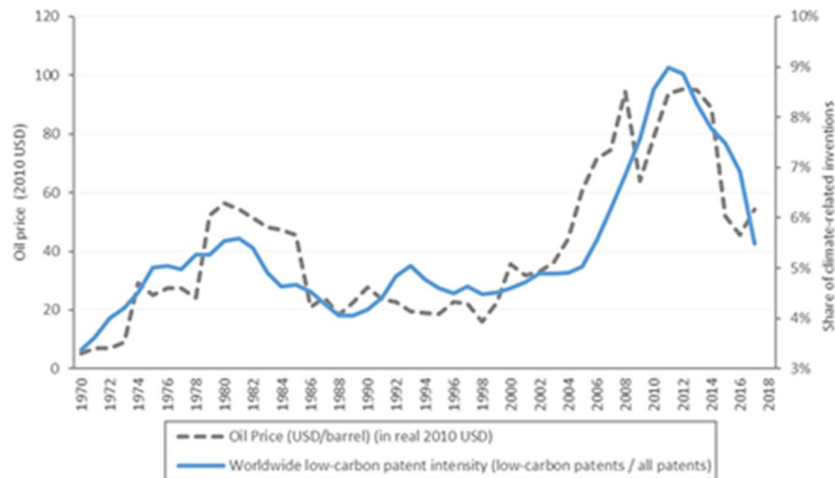
Beyond technology support: creating favourable conditions for green innovation

Innovation happens in a wider socio-economic, technical and institutional environment, and an important lesson learnt from previous green recovery packages is that investment support for technology development and diffusion is not sufficient. Following the Great Financial Crisis (GFC), over half a trillion US dollars was committed worldwide as part of green stimulus packages. Yet, emissions recovered after the GFC, and continued on an upward path. This is because green stimulus packages often lacked the important longer-term signals provided by carbon prices. As a result, investment support during the GFC did not benefit from a clear commitment to long-term carbon pricing trajectories that can render low-carbon investments more viable. For example, the American Recovery and Reinvestment Act of 2009 provided USD 2 billion to develop CCS technologies for coal-fired power plants. Similarly, in 2009 the European Energy Programme for Recovery dedicated EUR 1 billion to co-finance CCS projects. All such CCS projects were later abandoned as low carbon prices rendered it difficult to attract private financing (Parry, Pittel and Vollebergh, 2017^[68]). We risk being in a similar situation – across 44 OECD and G20 countries, over 75% of emissions are priced below EUR 30/tCO₂, a conservative estimate for the social cost of carbon (OECD, 2018^[69]).

As a consequence, green recovery packages need to be accompanied by clear trajectories of gradually increasing carbon prices over the next decades and removal of

harmful fossil fuel subsidies which undermine the business case for low-carbon technologies. There is ample evidence that energy prices (inclusive of taxes) are one of the main determinants of patenting activity in low-carbon technologies (Dechezlepretre et al., 2011^[70]), as shown in Figure 3.3.

Figure 3.3. Worldwide low-carbon patent filings and energy prices



Source: Based on data from the European Patent Office’s Global Patent Statistical Database and Oil price data from the World Bank.

The use of carbon pricing policies with clear price trajectories – based on the social cost of carbon – would allow forward planning for businesses and households, and incentivise green innovation. The Swedish carbon pricing policy provides a good-practice example, where carbon prices were implemented nearly 30 years ago and have risen gradually from about EUR 23 per ton to EUR 110 per ton of carbon emissions. The policy has achieved significant emission reductions, while maintaining economic growth (Government Offices of Sweden, 2020^[71]; Andersson, 2019^[72]). Lessons learnt from the successful introduction of the British Columbia carbon tax, where the higher carbon tax is combined with labour and business income tax reductions, could be applied to other countries (Harrison, 2013^[73]). Alongside carbon pricing, increased disclosure of carbon emissions and better climate-related taxonomies can help making such pricing mechanisms more effective and better align private investments in innovation with climate goals.

Emissions pricing on top of direct R&D and technology diffusion support are only one aspect of environment-friendly mission-oriented policies. Technology adoption can be strongly encouraged by other demand-side policies, such as regulation and performance standards, and public procurement (OECD, 2017^[61]). Governments can also use public funds or policies to leverage private finance (e.g. the European Investment Council). For example, in Turkey, policy support coupled with investments from multilateral

development banks (MDBs) and the Clean Technology Fund (CFT) helped to leverage private sector capital, and transformed Turkey's renewable energy and energy efficiency markets from a virtually non-existent to one that could be financed on commercial terms over 2009 to 2014 (World Bank, 2015^[74]). Budgeting processes can also be used to help attain environmental objectives. The Paris Collaborative on Green Budgeting promotes the use of the policy tools of budgeting (taxes, financial outlays, and co-ordination) to promote the alignment that is essential to meet environmental goals (OECD, 2018^[75]).

Governments can promote collaborative innovation networks – which may matter more than a traditional menu of fiscal measures for de-risking innovation (Bennett, 2018^[76]). Dedicated platforms that foster cooperation between researchers, companies and governments can enhance innovation performance and help fund it. Illustrative examples are the Fraunhofer Institute in Germany, the Environmentally Sound Technology (BEST) Cooperation Platform for Brazil, Russia, India, China and South Africa (10th BRICS Summit, 2018^[77]), or the Innovation for Cool Earth Forum (ICEF) hosted by Japanese government.

Beyond environmental policies, policy makers face the need to develop a vision of what future sustainable systems will look like, including what technologies are likely to play important roles in the future system, what infrastructures will be needed, and how business models and patterns of behaviour will need to change. One major implication from this systemic innovation approach is that innovation policies will need to be aligned with policies in other areas affecting the rate and direction of innovation (OECD, 2015^[78]; Ang, Röttgers and Burli, 2017^[79]). These include:

- Education and labour market policies, to help people prepare for the change by equipping them with analytical expertise and the skills necessary to contribute to and benefit from innovations (e.g. STEM degrees, entrepreneurship skills, communication skills, digital literacy).
- Investment policies, to support not only physical investment in clean technologies but also complementary investments in process-based innovations and knowledge-based capital (e.g. software, data, organisational capital).
- Competition policies, to promote open markets for the exchange of knowledge and innovations beyond sectors and jurisdictions in order to enable exit of fossil-based business models and allow for experimentation with new ideas, technologies and business models. For example, easing trade barriers and services regulation is relevant in the context of global value chains.
- Fiscal policies, to encourage business R&D (e.g. through contracts, grants, awards, tax credits) with a focus on social returns and international good practices (e.g. the G20 peer review process of inefficient fossil-fuel subsidies that encourage wasteful consumption, the Green Budgeting Initiative and BEPS).
- Framework policies, such as intellectual property rights (IPRs). The infrastructure for collaboration between research institutes and firms needs to be continuously adapted to support the entry and growth of innovative firms – and facilitate the exit of those with climate-unsustainable business models. Existing IPR policies are not always well suited to the fast-changing nature of innovation and firms that tend to privilege trade secrecy and confidentiality agreements for protecting their intellectual assets (Agrawala et al., 2019^[80]).

Creating robust innovation ecosystems to drive transformational change and a green recovery: insights from case studies from G20 countries

Since the signing of the Paris Agreement in 2015 and the adoption by the United Nations of the Sustainable Development Goals (SDGs) there has been an acceleration in efforts to mobilise R&D and innovation ecosystems to drive the green transition. But even before the SDGs emerged as a global agenda for sustainable development, many countries have been mobilising science, technology and innovation policies to address social and environmental challenges at the national and sub-national levels. Innovation policy for sustainability relies on a variety of policy instruments:

- Public support to R&D and innovation or incentives to lower the cost of R&D in universities, research laboratories, or firms (supply-push)
- The implementation of policies to increase the rewards to innovators by creating or shaping markets for new innovation such as regulations, feed-in-tariffs, tax credits, carbon prices, lead market initiatives, public procurement (demand-pull)
- Promoting private-public R&D and innovation partnerships (mix of supply-push and demand-pull)
- Strengthening innovation policy governance arrangements through greater stakeholder involvement in setting priorities and in the co-design of innovative solutions (linking bottom up and top-down initiatives).

A meta-evaluation by the OECD of case studies of innovation policies in selected G20 countries (Table 3.1) finds that innovation policies for sustainability differ significantly from innovation policies aimed at increasing the economic performance of existing systems with unchanged, even growing resource demands (Machado, 2019^[81]). Traditionally, innovation policies have focused on increasing the rate of innovation – increasing R&D budgets, the number of high tech companies – with a view to promoting competitiveness and structural change in the economy. However, the transition from a fossil fuel based energy system to one based on renewable and low carbon energy sources requires a focus also on the direction of innovation and not only on the rate. Many of the R&D and innovation policies target specific sectors with high levels of GHG emissions such as energy, agriculture, building and construction and transport.

Table 3.1. Supporting research for sustainable development: Overview of case studies

Policy initiative	Country	Type	Period	Annual budget	Main objective
Australia's smart cities and suburbs plan	Australia	National initiative Supply-side	2017-2020	AUD\$50 million over three financial years	Encourage local government agencies and bodies to deliver collaborative smart city projects that improve the liveability, productivity and sustainability of Australian cities, suburbs and towns.
Energiewende	Germany	National initiative Demand-side	2010-present	EUR 5.8 billion (2016)	To phase out Germany's nuclear power plants by the end of 2022, transform the energy system to become strongly reliant on

					renewable energy resources, enhance energy efficiency, and reduce GHG emissions by 80-95% by the year 2050.
SD Tech Fund	Canada	National grant schemes Demand-side	2001-present	EUR 37.1 million (average 2001-2017)	To support the development and demonstration of Canadian cleantech projects to facilitate the movement towards scale-up for commercialization.
<u>Plan D'Investissement d'Avenir</u>	France	Grant schemes	2010-2025	EUR 300 m (average 2010-2017)	Provide capital finance and grants for business R&D in the area of sustainability
NEDO	Japan	National R&D management agency Demand-side	1980-present	EUR 1.3 billion (2018)	To address energy and global environmental problems and raise the level of industrial technology through integrated management of technological development. This ranges from the discovery of technology seeds to the promotion of mid- to long-term projects and support for practical application.
<u>Future cities catapult</u>	United Kingdom	Smart cities	2013-present	N.A.	Facilitate collaborative research, provide expertise & testing facilities for innovative urban solutions
ARPA-E	United States	National R&D management agency Supply-side	2009-present	EUR 226 million (average 2009-2017)	To support energy technology innovations that will enhance the US economic and energy security, reduce energy-related emissions, improve energy efficiency across all sectors economy, and ensure the US maintains a technological lead in the development and deployment of advanced energy technologies.

Source: (Machado, 2019^[81]) (Borowiecki, 2019^[82])

The direction of innovation however is not always linear because sustainability challenges are systemic problems. Innovation policies for sustainability are tied to a range of policy domains. For example, policies for clean energy such as hydro-power must take into account environmental regulations on waterways, waste generation and disposal. Therefore, innovation policies for sustainability require taking into account the synergies or trade-offs in different policy domains. Another dimension of innovation policies for sustainability is the need to consider institutional and technology lock-in that prevent new, more sustainable technologies from entering the market. In this case, policies that provide incentives for technology demonstration and commercialisation play a more important role than solely upstream R&D policies such as research grants. Furthermore, sustainability can only be achieved through the co-design and uptake of innovative solutions at both the national, subnational and local levels.

Some key takeaways from the case studies are the following:

- Governments, business and stakeholders should jointly develop a vision of the technologies, regulations, business models and behavioural changes that are likely to play an important role in future transport, energy or agricultural systems;
- Top-down and bottom-up approaches as well as supply- and demand-side innovation policies should be used to create these visions and implement them. For example, efforts to commercialise the supply of low carbon energy technologies must go hand in hand with demand-side policy incentives to change consumer and firm behaviour;
- It is important to support a broad portfolio of pre-commercial technologies that are too early for the private sector. In addition, the participation of SMEs is critical in many of the programmes surveyed;
- Providing grants to consortia and public-private partnerships using strong vetting and selection mechanisms appear to be strong mechanisms to reduce the risk of crowding out private investments;
- Co-funding arrangements and “mission-oriented” innovation policies that gather wide stakeholder involvement can help to break down barriers to implementation that result from institutional lock-in, short-term political choices and socio-cultural attitudes. Stakeholder participation at the local level also ensures top-down strategies are legitimate to those participating in the development of solutions;
- Digital technologies are a crosscutting technology that can support a range of climate and environmental goals from energy efficiency to biodiversity;
- Green R&D and innovation projects should be scalable in order to link short-term project goals with long-term policy objectives.

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