LANCET COVID-19 COMMISSION
TASK FORCE ON GREEN RECOVERY

Final Statement

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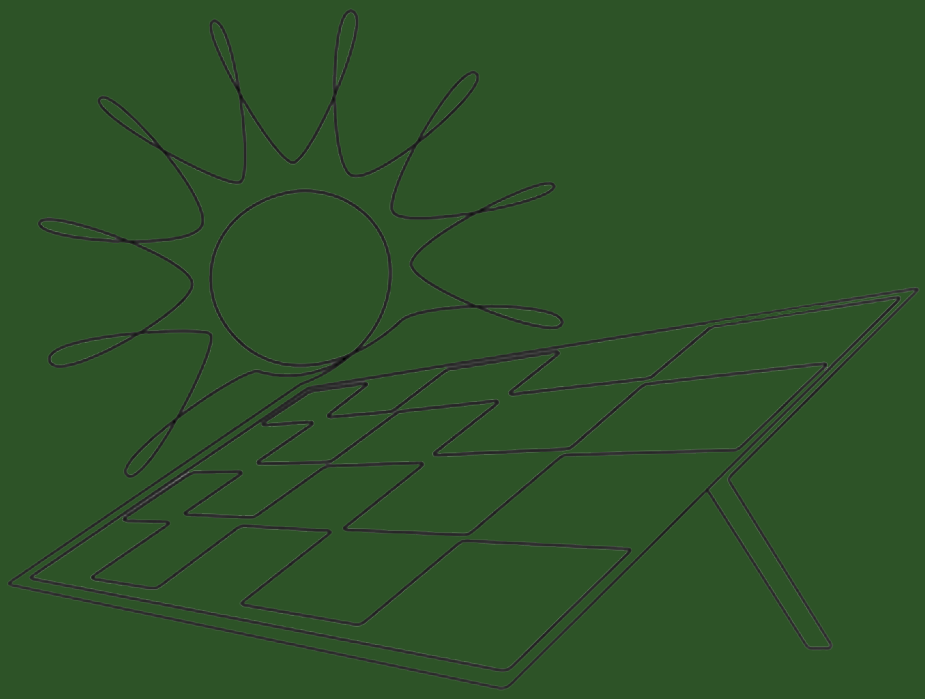

The *Lancet* COVID-19 Commission

Task Force on Green Recovery

THE *LANCET*
COVID-19 COMMISSION

Task Force Members and Staff

TASK FORCE MEMBERS

Phoebe Koundouri (Co-chair), Professor in Economics, Athens University of Economics and Business and Denmark Technical University; President, European Association of Environmental and Resource Economists (Greece)
Josep M. Anto, Senior Research Professor, ISGlobal; Professor of Medicine, Universitat Pompeu Fabra (Spain)
Ian Bateman, Professor of Environmental Economics, University of Exeter Business School (UK)
Kirsten Brosbøl, Founder, Parliamentarians for the Global Goals (Denmark)
Stefan Brunnhuber, Trustee, World Academy of Arts and Science (WAAS); Chair of Sustainability, University Mittweida (Germany)
Richard T. Carson, Distinguished Professor of Economics, University of California, San Diego (USA)
Anthony Cox, Senior Policy Advisor, Ecologic Institute (Germany)
Rabia Ferroukhi, Director, Knowledge, Policy and Finance Centre, IRENA (United Arab Emirates)
Luiz Augusto Galvão, Senior Researcher, Fundação Oswaldo Cruz (Fiocruz) (Brazil)
Ben Groom, Professor, Dragon Capital Chair in Biodiversity Economics, Land, Environmental Economics and Policy (LEEP) Institute, University of Exeter Business School (UK)
Heba Handoussa, Managing Director, Egypt Network for Integrated Development (Egypt)
Cameron Hepburn, Professor of Environmental Economics, University of Oxford (UK)
Lamia Kamal-Chaoui, Director, OECD Center for Entrepreneurship, SMEs, Regions and Cities (France)
Catherine Kilelu, Senior Research Fellow, African Center for Technology Studies (Kenya)
Manfred Lenzen, Professor of Sustainability Research, University of Sydney (Australia)
Christine Lins, Co-Founder and Executive Director, GWNET (Austria)
Gertrude (Trudi) Makhaya, Economic Advisor to His Excellency President Cyril Ramaphosa (South Africa)
Arunima Malik, Senior Lecturer in the Integrated Sustainability Analysis group, School of Physics, University of Sydney (Australia)
Brian O'Callaghan, Lead Researcher and Project Manager, Oxford University Economic Recovery Project (UK)
Ketan Patel, Co-founder and CEO, Greater Pacific Capital; Chairman, Force for Good (UK)
Ismail Serageldin (Co-chair), Co-chair, Nizami Ganjavi International Center (Egypt)
E. Somanathan, Professor, Economics and Planning Unit, Indian Statistical Institute (India)
Dale Squires, Adjunct Professor of Economics, University of California, San Diego (USA)
Thomas Sterner, Professor of Environmental Economics, University of Gothenburg (Sweden)
Theodoros Zachariadis, Professor, the Cyprus Institute (Cyprus)
Min Zhu, Chairman, National Institution of Financial Research, Tsinghua University (China)

ADDITIONAL AUTHORS
Mark C. Freeman, Professor of Finance, School for Business and Society, University of York (UK)
Christian Hansmeyer, Founding Member, Greater Pacific Capital (UK)
Conrad Felix Michel Landis, Senior Researcher, Adjunct Lecturer, Athens University of Economics and Business (Greece)
Tamara Paremoer, Divisional Executive: Mergers and Acquisitions, Competition Commis-sion of South Africa (South Africa)
Angelos Plataniotis, Researcher, ATHENA RC (Greece)

SECRETARIAT STAFF
Lauren Barredo, Chief of Staff, UN Sustainable Development Solutions Network (USA)
Neena Joshi, Consultant, UN Sustainable Development Solutions Network (USA)

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More information about the Green Recovery Task Force of the *Lancet* COVID-19 Commission can be found here: https://covid19commission.org/green-recovery

OVERVIEW

During the first two years of the COVID-19 pandemic, The *Lancet* COVID-19 Commission convened an international group of experts to provide recommendations on how to suppress the epidemic; address the accompanying humanitarian, financial, and economic crises; and rebuild a green, inclusive, fair, and sustainable world. Within the Commission, numerous Task Forces were created, each focusing on a specific issue related to COVID-19, including humanitarian relief, social protection, and vulnerable populations; vaccines and therapeutics; and global governance. This compendium is a product of the Commission's Green Recovery Task Force, a group of world-renowned economists, academics, environmentalists, and private sector experts convened to discuss and provide recommendations on how to build economic resilience and reduce inequality as we recover from the COVID-19 pandemic and work towards a more equitable, sustainable, and inclusive future.

The essays in this volume address a number of critical topics, and make the following key recommendations for ensuring a sustainable and equitable recovery, and build resilience to future shocks to the global system:

- Recovery plans need to be implemented urgently following a crisis, and promote equitable and green recovery; marginalized communities and social groups must be included and empowered by recovery plans and policies.
- To build long-term resilience, the European Green Deal, linked to the Sustainable Development Goals (SDGs), supports the European Union in ensuring a green and sustainable recovery, and can serve as a model to other regions.
- Several sectors emerged as particularly vulnerable to economic shock, highlighting the need for improved resilience. These include energy, agriculture and food, industry, transport, and housing; they are key sectors to focus on for transformations to green and sustainable economies and investment.
- An analysis of various countries' COVID-19 recovery plans finds that in many cases they are poorly aligned with the Sustainable Development Goals and the Paris Agreement, and even where alignment exists implementation has been uneven in achieving international targets.
- Lockdowns had short-term effects on mitigating emissions from building energy use, travel, and transport; these in turn decreased air pollutants and had positive health benefits for populations.[1] Additional research is needed to see what lessons can be learned in the long-term to promote teleworking and other measures to mitigate climate change and reduce energy consumption.
- Finance must significantly increase from all stakeholder groups to meet persistent funding gaps and accelerate progress towards the goals agreed in the Paris Agreement and the SDGs, particularly in vulnerable nations.
- Countries must become more resilient and incorporate resilience into their preparedness plans for future shocks, including climate crises and pandemics.
- Academia must expand the evidence base on the effectiveness of response measures, to understand what worked, what did not, and why, to inform future decision making.

We hope that our readers will use the chapters in this volume as a resource to accelerate action on the SDGs and build resilience to future shocks.

Sincerely,

Phoebe Koundouri
Co-Chair of the Green Recovery Task Force, on behalf of the group

KEY MESSAGES

- Climate change is one of the world's biggest threats; it will remain a pressing challenge long after the COVID-19 crisis has passed and reduces overall resilience to future shocks and global challenges.
- The COVID-19 pandemic has made it more difficult for national, provincial, and local governments to meet their commitments under the Paris Agreement and Agenda 2030.
- Recovery packages offer a once-in-a-generation opportunity to invest in "building back better" and supporting the transition of entire sectors to be less polluting, more inclusive, more effective at delivering services, and resilient to future crises.

INTRODUCTION

CLIMATE POLICY IN THE BROADER SUSTAINABILITY CONTEXT

UN member states unanimously adopted the 17 Sustainable Development Goals (SDGs) in September 2015 at the UN Sustainable Development Summit. The following December, Parties to the UNFCCC met in Paris and reached a historic commitment to fight climate change and strengthen action for a sustainable low carbon future.[2] The SDGs and the Paris Agreement required substantial adjustments involving governments, civil society, scientists, and corporations. By 2020, several countries had already enacted ambitious plans to achieve internationally-agreed targets, such as the European Green Deal (EGD) introduced by the European Union (EU) in December 2019.[3]

In February 2020, the COVID-19 pandemic hit, causing a global health crisis and socioeconomic catastrophe whose full ramifications are yet to be known. Health experts encouraged outbreak response strategies such as "flattening the curve," to decrease the rate of new infections and reduce pressure on health systems, but these strategies unavoidably sped up the macroeconomic recession and threatened supply networks. While some small environmental wins resulted from lockdown policies, such as reduced emissions and improved air quality, these were short-lived and an order of magnitude smaller than the negative consequences of the pandemic for health and the economy. COVID-19 led to increased poverty and hunger, poor educational outcomes, widened inequality, and directly and indirectly impacted global health, with disadvantaged groups disproportionately bearing the burden. These impacts set the world back and make it even more challenging to achieve the SDGs.

In response, many countries have passed legislation to increase spending and recover from the pandemic. Many also dedicated Official Development Assistance (ODA) to help lower-income countries recover, and international financial organizations such as the International Monetary Fund (IMF) and World Bank implemented programs to support the recovery. For example, in mid-2020 EU leaders agreed to spend €1.8 trillion on COVID-19 recovery, which includes the expanded 2021-2027 EU budget and the "Next Generation EU" recovery facility. These programs represent an immense opportunity for the world to "build back better" from COVID-19 and to accelerate the transition to a green, inclusive, and equitable global economy. However, experiences have been uneven. For example, while the European Union adopted legally-binding greenhouse gas (GHG) emissions targets in the summer of 2021 (in the European Climate Law), they simultaneously implemented a recovery package of which US $178 billion will negatively impact the environment, according to OECD analysis.[4]

This report explores COVID-19 and the opportunities it has created to transition towards a green global economy. It seeks to understand what would and would not be considered part of a green recovery and describe how what has been achieved can or cannot facilitate "building back better." It also attempts to pull together some lessons learned from the pandemic and make recommendations so the world can better respond to future crises and even leverage them to create a world of vibrant green economies, equal opportunities, and sustainable development.

TECHNOLOGICAL PATHWAYS FOR SUSTAINABLE INFRASTRUCTURE

Sachs, J., Koundouri, P., et al. 2021 outline a set of technology and policy insights for EU policymakers to consider as they plan the EU's long-term path to climate neutrality by 2050.[5] Public investments, elimination of fossil fuel subsidies, market dynamics, regulatory frameworks for energy and land use, and focused research and development (R&D) are some examples of policy instruments which could be implemented. The World Bank (2019) finds that investing in climate-resilient infrastructure returns, on average, four dollars for every dollar spent.[6] In terms of technological solutions, there are a variety of current and emerging options, from 5G-enabled intelligent power grids with artificial intelligence (AI) capabilities, to synthetic fuels made from sustainable sources of energy. FEEM (2020) identified six central decarbonization pillars for managing the energy system's complexity: zero-carbon electricity, intelligent power grids, electrification of

end uses, materials efficiency and circular economy, green synthetic fuels, and sustainable land use.[7] Except for green fuels, which require a longer time horizon and significant investments to reach the market, these pillars provide policymakers with a set of transformation pathways that can be immediately pursued. For example, smart grids can enable fast penetration of low-cost renewable electricity. Also, specific circular economy options are cost-effective and require business awareness and training and targeted incentives, and sustainable land use can benefit both climate change mitigation and adaptation.

WHY IS GREEN RECOVERY SO IMPORTANT?

COVID-19 IS OVERLAID ON OTHER SYSTEMIC CHANGES

The COVID-19 pandemic revealed complex global economic interdependencies and exposed structural gaps that perpetuate social, economic, environmental, health, and gender inequalities. These inequalities are particularly pronounced in developing and emerging economies, especially in sub-Saharan Africa, where the pandemic was overlaid by pre-existing factors such as the climate crisis and economic and political uncertainties that dispropor-

BOX 1. COMPETITION POLICY AND GREEN GROWTH: EMERGENT POLICY LESSONS FROM THE SOUTH AFRICAN EXPERIENCE

In a globally-pioneering decision in competition regulation (anti-trust), on 18 June 2021, the Competition Tribunal of South Africa imposed a set of carbon emission reduction conditions as part of its approval for an acquisition. Air Liquide, the French multinational, acquired assets (air separation units) owned and operated by Sasol South Africa (one of the country's largest carbon emitters). Such competition enforcement and competition policy may contribute to the green recovery by impacting corporate behavior, market structure, and the game's rules.

In line with the country's competition legislation, the authorities assessed the Sasol/Air Liquide transaction on competition and public interest grounds. The resultant conditions included those familiar in local compe-tition evaluations, such as Black economic empowerment, access to inputs (in this case, the supply of spare liquid oxygen for the healthcare sector), and the novel conditions related to carbon emission reductions. These are crafted as a commitment by the parties of the transaction to invest a particular sum (confidential) in sustaining and upgrading the assets' performance and integrity and procuring 900 MW of renewable energy for a specific site. This should reduce carbon emissions-associated by 30% within ten years from the transaction's implementation date.

In doing so, the Competition Tribunal has expanded the reach of competition regulation as an instrument for supporting green growth. Such environmental considerations may also be seen in an earlier transaction in the ostrich farming industry (KKI/Mosstrich), where an increase in market power was assessed against the backdrop of an industry under pressure due to persistent droughts. Here the authorities seemed to signal tolerance for high concentration levels if it helped firms grapple with climate vulnerability. In particular, the Air Liquide precedent is a more robust use of the competition toolkit concerning how it has been conceptu-alized in competition strategies elsewhere, such as in the EU, where competition regulation for the green economy tends to focus on state aid and exemptions for certain kinds of conduct.

Competition policy and market structure may also affect the prospects of decarbonization. For example, there is a long (and ongoing) journey to regulatory reform in the electricity supply sector, with recent policy changes towards vertical disintegration of the state electricity monopoly Eskom paving the way for more robust renewable energy deployment from the private sector.

tionately threaten the livelihoods of the most vulnerable groups.[8, 9, 10, 11]

Green recovery efforts need to recognize how systemic challenges intersect and avoid deepening inequalities; to do so would derail efforts to achieve the Sustainable Development Goals (SDGs). The argument is that green recovery needs to embrace a "just transition" that recognizes the vulnerability of developing regions. Thus, moving toward a low-carbon economy should prioritize inclusive innovation and growth for secure, decent green jobs that will build resilient and thriving communities.[12, 13]

PLANS SHOULD BE EQUITABLE AND EMPOWER MARGINALIZED COMMUNITIES AND SOCIAL GROUPS

The COVID-19 pandemic deepened already entrenched inequalities in society, exacerbating disparities and making it harder to realize the SDGs' objective to "leave no one behind." Homeless populations suffered disproportionately, and they may continue to grow in number in the post-pandemic period, exposing more individuals to climate and health risks. The unhoused population is continuously exposed to extreme climatic events such as heatwaves, food insecurity due to rising food prices, respiratory diseases linked to air pollution, and gastrointestinal and vector-borne disorders. They also have a higher incidence of mental and physical health problems, suffer systemic discrimination and prejudice, and have limited healthcare access. A better and inclusive society requires new systems with solutions that are accessible to populations that are involuntarily in a vulnerable situation, such as individuals experiencing homelessness, migrants, refugees, and people in institutionalized housing.[14]

URGENCY OF A GREEN RECOVERY

Fiscal response to any crisis is defined by three typologies: rescue, recovery, and reinforcement. Short-term rescue measures are designed to keep people and businesses alive. Mid-term recovery measures act to reinvigorate economic growth by stimulating aggregate demand and/or supply. Longer-term reinforcement measures build upon rescue and recovery measures as a platform for the permanent economic realignment of a sector. Recovery and reinforcement measures provide the greatest opportunity to simultaneously advance economic and climate priorities. Unfortunately, many nations failed to use their recovery packages for this purpose, often instead supporting measures with limited long-term benefit.

The concept of post-COVID-19 green recovery is based on a variety of arguments. One is that, to a large extent, COVID-19 and climate change are convergent crises that share some critical upstream contributing factors, including the biodiversity crisis and the increasing risk of spillover of zoonotic diseases.[15] Addressing the shared determinants of both problems is an opportunity to obtain co-benefits and increase the cost-effectiveness of the investments. As suggested by Hepburn et al., there is evidence that investments in clean physical infrastructure, building efficiency retrofits, education and training, natural capital, and clean R&D have high potential concerning the economic multiplier and climate impact metrics.[16] O'Callaghan et al. (2022) review existing economic literature, finding that there seem to be climate mitigation investments that can have faster impact, while creating more jobs and delivering a higher fiscal multiplier, although the authors highlight that empirical evidence is lacking.[17] Alongside traditional multiplier impacts, the health co-benefits of investment in some climate mitigation measures can also deliver economic value, perhaps exceeding the costs of the measures.[18]

PLACE-BASED, INCLUSIVE GREEN RECOVERY

The climate challenge is global, but the response needs to build on regional and local actors. Cities and regions will play a vital role in the transition to net-zero GHG emissions. Although cities are at the forefront of implementing ambitious measures to mitigate and adapt to climate change, they are also responsible for 55% of public spending and 64% of public investment for climate mitigation and adaptation.[19] Globally, cities account for more than 50% of the global population, 80% of global GDP, two-thirds of energy demand, and more than 70% of energy-related CO_2 emissions. Moreover, these shares are expected to increase significantly over the coming decades unless significant action is taken.[20]

On the other hand, rural regions cover around 80% of the territory in OECD countries and contain the biodiversity and ecosystem services we need to sustain our lives. Unfortunately, these are increasingly under threat.[21] Greening the policies and budgets of subnational governments is required on both the expenditure and revenue side. An added benefit of doing so is that well-being co-benefits often arise locally and can exceed the costs of climate action. For instance, cities can reduce congestion, noise, and air pollution by encouraging active mobility, such as through investing in bike lanes and public transit, this can both reduce emissions and improve public health.

Climate challenges and opportunities vary greatly across geography, and supporting the most affected areas and

the most vulnerable communities early is key to ensuring a just transition. GHG emissions per capita vary more strongly across regions within countries than across countries.[22] In some industries where activities are geographically concentrated, such as steel, cement, or chemicals, moving to net-zero emissions will be challenging as affected communities are particularly vulnerable to employment issues. Although the estimated employment impacts of decarbonization are modest overall, they can be disproportionately higher in some regions than others. For example, across the OECD an average of 2.3% of employment is in sectors at potential risk from climate policies consistent with the Paris Agreement, while in some large subnational regions it exceeds 6%. In the Polish part of Silesia, more than 50% of employment is in at-risk sectors like coal mining. Some of these regions may also already experience higher poverty rates, long-term unemployment, and lower GDP per capita than national averages. The green transition will bring employment opportunities; however, they may not arise where losses occur, and require the acquisition of new skills.

Climate change poses unique challenges for adaptation, which requires locally-tailored approaches as physical impacts and costs will differ significantly across regions. In Mexico, for example, road infrastructure is at risk from increasing temperatures, while precipitation is likely to vary from 1% in the least vulnerable state to 100% in the most vulnerable.[23] Rural economies are also closely linked to their natural resource endowments, which are highly climate-sensitive and heavily affected by the increasing frequency and intensity of extreme weather events. Again, attention needs to be paid to ensuring support to the most vulnerable. For example, women and children are 14 times more likely than men to die during natural disasters, and correspond to over 80% of people displaced by climate change, often due to food and water shortages in rural areas.[24]

Another significant issue is water governance. By the 2030s, in the absence of adaptation, coastal flood risk is projected to increase by four, while fluvial flood risk could more than double.[25] Informal settlements in cities, where approximately 29% of the global urban population lives, are at higher risk of suffering the effects of floods, landslides, and other natural disasters. Strong and inclusive stakeholder engagement can mitigate these risks. Local authorities play an essential role in promoting and facilitating stakeholder engagement in setting and implementing policies for enhanced water resilience, and they must include critical stakeholders such as women (as the primary users of water in many parts of the world for domestic consumption, subsistence agriculture, and health), youth (as the future generation that will need to solve issues related to water), the rural and urban poor (as the primary consumers in informal urban and rural settlements), and Indigenous and Aboriginal communities to ensure traditionally unheard voices influence the process.

In the context of the COVID-19 crisis, recovery packages offered a clear opportunity to green economies, and many national and supranational recovery plans had sustainability at their core.[26] But we could do more: only 17% of total recovery spending was been allocated to environmentally-positive measures.[27] Climate policy needs to be integrated into regional, urban, and rural development agendas to add the necessary momentum to climate action. Many cities and regions have adopted climate neutrality targets that are more ambitious than national targets. However, acting alone, their full potential remains untapped. Local governments are estimated to oversee and be able to cut up to one-third of GHG emissions, with the remaining two-thirds dependent on national and state governments or coordination across different levels of government.[19]

Public action and investment alone are not enough to achieve the Paris Agreement's targets; involvement of the private sector is crucial. This is especially true of small- and medium-sized enterprises (SMEs), which are the predominant form of enterprise globally, a significant source of economic growth and added value, and essential contributors to job creation. This places SMEs at the center of the transition to a greener economy. In OECD countries, SMEs account for 99% of all businesses, 60% of total employment, and 50-60% of national business sector value added.[28] Many SMEs are already leading on green technologies. For example, while small firms account for about 8% of all United States patents, they account for 14% of green technology patents.[28] The private sector can also play a key role in closing the necessary funding gap to implement the transition to a circular economy. A recent OECD survey, looking at over 50 cities and regions worldwide, shows that nearly three-quarters of them (73%) do not have enough funding to do so.[29] These pressures are likely to worsen, as the pandemic strained local government finances. Sustainable and green finance can also play a key role in helping SMEs reduce their environmental footprint. Social economy organizations are leading the way towards circular economies in regions and cities by pioneering and mainstreaming inclusive and innovative business models, and have demonstrated the potential of business engagement in achieving net-zero emissions.

National and local governments, the private sector (including SMEs), and the social economy all have crucial roles in enabling and supporting place-based climate

action. Along with a granular approach, multilevel governance, and finance mechanisms to coordinate policies; a clear evidence-base and recommendations to identify, prioritize, and implement climate action measures and policy priorities and monitor progress and scale-up ambition is required. One example of a successful initiative to achieve place-based climate action is the OECD Centre for Entrepreneurship, SMEs, Regions and Cities. Through its unique perspective, recommendations, and data at the subnational and firm level, it supports evidence-based decision making for policymakers, local governments, SMEs, and the social economy, to drive the net-zero transition and build systemic resilience.

TABLE 1. A brief presentation of the 17 Sustainable Development Goals

SUSTAINABLE DEVELOPMENT GOAL	AMBITION OF THE GOAL
Goal 1 - No Poverty	End poverty in all its forms everywhere
Goal 2 - Zero Hunger	End hunger, achieve food security and improved nutrition and promote sustainable agriculture
Goal 3 - Good Health & Well Being	Ensure healthy lives and promote well-being for all at all ages
Goal 4 - Quality Education	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
Goal 5 - Gender Equality	Achieve gender equality and empower all women and girls
Goal 6 - Clean Water & Sanitation	Ensure availability and sustainable management of water and sanitation for all
Goal 7 - Affordable & Clean Energy	Ensure access to affordable, reliable, sustainable, and modern energy for all
Goal 8 - Decent Work & Economic Growth	Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all
Goal 9 - Industry, Innovation & Infrastructure	Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation
Goal 10 - Reduced Inequalities	Reduce inequality within and among countries
Goal 11 - Sustainable Cities & Communities	Make cities and human settlements inclusive, safe, resilient, and sustainable
Goal 12 - Response Consumption & Production	Ensure sustainable consumption and production patterns
Goal 13 - Climate Action	Take urgent action to combat climate change and its impacts
Goal 14 - Life Below Water	Conserve and sustainably use the oceans, seas, and marine resources for sustainable development
Goal 15 - Life On Land	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
Goal 16 - Peace Justice & Strong Institutions	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all, and build effective, accountable, and inclusive institutions at all levels
Goal 17 - Partnerships for the Goals	Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development

PATHWAYS TO ACHIEVE THE EUROPEAN GREEN DEAL

SUSTAINABLE DEVELOPMENT GOALS

The European Green Deal (EGD) is a collection of policy measures introduced by the European Commission to achieve climate neutrality in the European Union (EU) by 2050. The plan's creation was prompted by environmental concerns such as climate change, biodiversity loss, ozone depletion, water pollution, urban stress, waste production, etc. It has goals extending to many different sectors, including construction, biodiversity, energy, transport and food. Moreover, it covers a broad range of policy areas such as clean energy, sustainable industry, buildings and renovation, farm to fork, eliminating pollution, sustainable mobility, biodiversity, and sustainable finance.[3]

The 2030 Agenda for Sustainable Development contains 17 Sustainable Development Goals (SDGs) and 169 objectives (Table 1). The Agenda is a pledge to eradicate poverty and achieve sustainable development on a global scale by 2030, considering three pillars of sustainable development – economic, social, and environmental. The SDGs are international in scope and universal in application, considering the different national specificities, capacities, stages of development, and specific difficulties. Thus, all countries share responsibility for achieving the SDGs, and each has a critical role to play locally, nationally, and globally, under the principle of "leaving no one behind."[2]

The EGD and the SDGs share common objectives, meaning that the implementation of EGD policies would simultaneously support actions that will contribute to achieving various SDGs. In Sachs, J., Koundouri, P., et al. 2021, a methodology is presented to link the objectives of the EGD Policy Areas with those of the 17 SDGs, which is based on a text-mining exercise to match specific parts of the EGD document to all relevant SDGs.[5] Figure 1 demonstrates the relation between SDGs and EGD policy areas, and the relationship between the two frameworks is vibrant. Dark green represents a direct connection between the EGD and the SDGs, according to the number of EGD text extracts that are conceptually similar to the SDGs. Light green illustrates associations between EGD and SDGs indirectly, and white shows a weak or no evident linkage.

The SDGs, like the Paris Climate Agreement, call for profound changes in every country, requiring coordinated efforts by governments, civil society, research, and business. However, stakeholders lack a broad consensus on how to operationalize the 17 SDGs. Therefore, Sachs et al. (2019) suggested six "transformations" that integrate the SDGs in public policy interventions, namely: (1) education, gender and inequality; (2) health, well-being and demography; (3) energy decarbonization and sustainable industry; (4) sustainable food, land, water and oceans; (5) sustainable cities and communities; and (6) digital revolution for sustainable development.[30] In addition, recommended critical investments and regulatory concerns accompany each transformation, which government structures can use to operationalize transformations while still respecting the 17 SDGs' interdependencies (Figure 2).

These Transformations must be systems-based to address the most critical synergies and trade-offs between essential interventions. For example, when promoting system-wide decarbonization, Transformation 3 encompasses all primary energy usage and Transformation 4 integrates agriculture, food, and biodiversity, as the first two are primary causes of biodiversity loss.

The EGD should be implemented based on a similar systems approach to address several objectives simultaneously and promote policy instruments and technical solutions that can be applied across industries. Decarbonization and environmental sustainability are among the EGD's goals, as are economic development (including alleviating poverty) and social inclusion that leaves no one behind. Public investments, phased-out fossil-fuel subsidies, market processes, regulatory frameworks, and land-use restrictions are policy instruments, while technology solutions cover many present and emerging technologies, from smart power grids to synthetic fuels.

A systems approach, or efforts toward any one or more objectives, connects one or more of the policies mentioned above with the necessary instruments or technical solutions. While a single action can have negative consequences for another, a series of coordinated efforts can have a multiplier effect and accomplish more than one goal at once. The electricity grid, for instance, is a complex system that must continue to be functional and efficient even while undertaking the most significant shift in its history. No policy or technology can achieve decarbonization by itself or be adopted without fully considering its spillover consequences or the comprehensive system.[5]

The Global Goals for Sustainable Development - Agenda 2030	The European Green Deal								
	P1	P2	P3	P4	P5	P6	P7	P8	P9
	Biodiversity	From Farm to Fork	Sustainable agriculture	Clean energy	Sustainable industry	Building and renovating	Sustainable mobility	Eliminating pollution	Climate action
Goal 1 - No Poverty									
Goal 2 - Zero Hunger									
Goal 3 - Good Health & Well Being									
Goal 4 - Quality Education									
Goal 5 - Gender Equality									
Goal 6 - Clean Water & Sanitation									
Goal 7 - Affordable & Clean Energy									
Goal 8 - Decent Work & Economic Growth									
Goal 9 - Industry, Innovation & Infrastructure									
Goal 10 - Reduced Inequalities									
Goal 11 - Sustainable Cities & Communities									
Goal 12 - Responsible Consumption & Production									
Goal 13 - Climate Action									
Goal 14 - Life Below Water									
Goal 15 - Life On Land									
Goal 16 - Peace Justice & Strong Institutions									
Goal 17 - Partnerships for the Goals									

FIGURE 1. Mapping of the European Green Deal Policies to the 17 SDGs.
Source: Sachs, J., Koundouri, P., et al. 2021.

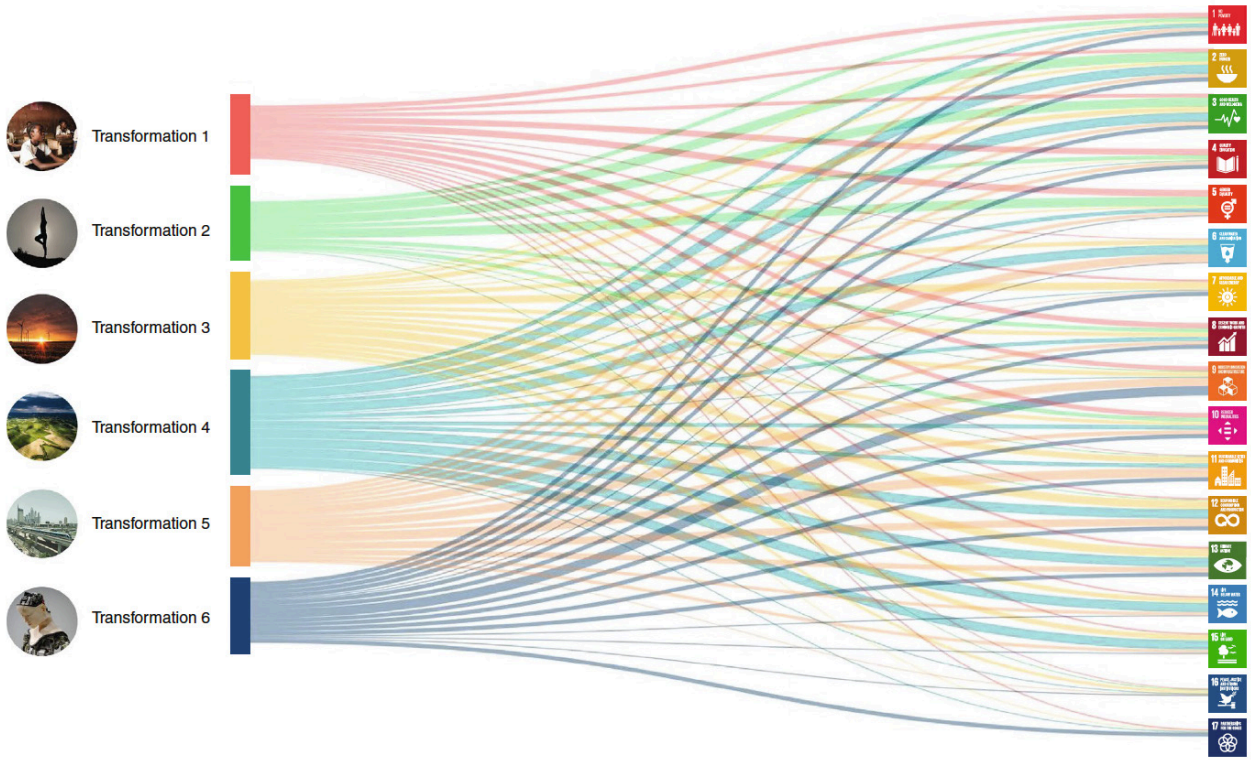

FIGURE 2. A Sankey diagram of how each SDG Transformation contributes toward the 17 SDGs.
Source: Sachs, J. D., Schmidt-Traub, G., Mazzucato, M., Messner, D., Nakicenovic, N., & Rockström, J. (2019). Six transformations to achieve the sustainable development goals. Nature sustainability, 2(9), 805-814.

TABLE 2. Connection of the European Green Deal to the 17 SDGs

	SDG 1	SDG 2	SDG 3	SDG 4	SDG 5	SDG 6	SDG 7	SDG 8	SDG 9	SDG 10	SDG 11	SDG 12	SDG 13	SDG 14	SDG 15	SDG 16	SDG 17	Total Score
A New Industrial Strategy for Europe	1	2	1	2	0	0	3	2	3	0	1	2	2	1	2	2	2	26
Circular Economy Action Plan	0	2	1	0	0	2	2	2	3	2	0	3	2	2	2	0	0	23
EU Biodiversity Strategy for 2030	0	2	2	1	1	0	2	2	1	1	0	2	2	3	3	0	2	24
Farm to Fork Strategy	2	3	2	0	0	0	2	2	1	2	0	3	2	2	2	0	1	24
EU Hydrogen Strategy	1	0	0	2	0	0	3	2	3	1	2	2	3	0	0	2	1	22
7 technology flagship Areas, ASGS for 2021	0	0	2	1	1	0	2	3	3	3	3	2	2	0	1	2	1	26
Stepping up Europe's 2030 climate Ambition	0	0	2	1	0	0	3	2	3	3	2	3	3	1	2	0	0	25
Chemicals strategy for Sustainability	0	1	3	0	0	0	1	0	3	0	1	2	3	3	3	1	0	21
EU Strategy to reduce methane emissions	1	3	1	1	0	0	2	1	2	0	1	2	1	1	1	1	1	19
A Renovation Wave for Europe	1	0	0	1	0	0	3	1	2	0	3	2	3	1	1	1	1	20
EU Commission Recommendation on Energy Poverty	3	0	0	0	0	0	2	2	0	3	1	1	2	0	0	0	0	14
EU Strategy to harness the potential of offshore renewable energy for a climate neutral future	0	0	0	1	0	0	3	2	3	0	2	1	3	2	0	2	2	21
European Climate Pact	0	2	1	2	1	0	0	1	2	1	2	2	3	2	2	0	0	21
Smart Mobility Strategy	0	1	2	0	0	0	3	0	3	2	2	2	3	2	0	0	1	21
The European economic and financial system: fostering openness, strength and resilience	0	0	1	0	0	0	2	2	2	1	0	1	1	0	1	3	3	17
EU Strategy on Adaptation to Climate Change	2	2	2	1	1	3	2	3	3	2	3	1	3	2	2	2	2	36
Directing finance towards the European Green Deal	0	0	0	0	0	0	0	2	0	2	0	2	3	1	1	0	0	11
Updating the 2020 New Industrial Strategy: Building a stronger Single Market for Europe's recovery	1	2	1	2	0	0	3	2	3	0	1	2	2	1	2	2	2	26
The EU's Blue Economy for a Sustainable Future	0	2	0	1	1	2	2	1	1	0	2	2	2	3	0	0	1	20
European Climate Law	0	2	2	0	0	2	2	2	2	2	0	2	3	2	2	0	2	25
Strategy for Financing the Transition to a Sustainable Economy	0	0	0	0	0	1	1	3	3	3	1	1	2	1	2	3	2	23
Fit for 55	0	0	1	1	0	1	3	2	3	3	3	3	3	0	2	0	2	27
Total Score	**12**	**24**	**24**	**17**	**5**	**11**	**46**	**39**	**49**	**31**	**30**	**43**	**53**	**30**	**31**	**21**	**26**	

Source: Koundouri, P. et al (2022).

MATCHING EU POLICY AND STRATEGY DOCUMENTS TO THE 17 SDGS

SUSTAINABILITY IN THE EUROPEAN GREEN DEAL POLICY FRAMEWORK

Following the launch of the EGD in 2019, the European Commission introduced a significant number of policies and strategies to support its implementation and the achievement of its ambitious goals. These documents cover a wide range of sectors of the economy, articulating the substantial impacts that achieving these goals will have on the way financial markets operate, on society, and on the everyday life of European citizens.

In the 2nd Annual Report of the SDSN's Senior Working Group on the European Green Deal, entitled Financing the Joint Implementation of Agenda 2030 and the European Green Deal, a cross-mapping of 22 European Green Deal Policies to the 17 SDGs was performed, with human textual mining and machine learning approaches.[31]

The human approach is similar to the process followed in the 1st Annual Report (Transformations for the Joint Implementation of Agenda 2030 for Sustainable Development and the European Green Deal: A Green and Digital, Job-Based and Inclusive Recovery from COVID-19 Pandemic).[5] Specifically, the linkage between each policy or strategy document and the SDGs was made by identifying phrases or sentences in each text conceptually close to each of the 17 Goals. Then, assuming that the greater the number of relevant references, the greater the influence of the policy on the SDGs; a score from 0 to 3 was assigned to show the level of impact:

3: the Policy document directly affects the SDG outcomes
2: the Policy document reinforces the SDG outcomes
1: the Policy document enables the SDG outcomes
0: the Policy document does not interact with the SDG

The main conclusion from the "human" approach (Table 2) is that, overall, the policies resulting from the European Green Deal affect all SDGs, some to a greater extent and others to a lesser extent. The most significant impact is found on SDG 13 (climate action), SDG 9 (industry, innovation and infrastructure), SDG 7 (affordable and clean energy), SDG 12 (responsible consumption and production), and SDG 8 (decent work and economic growth).

A MACHINE LEARNING METHOD FOR POLICIES CLASSIFICATION UNDER THE SDGS

DEEP LEARNING

In addition to the "human" approach, the Senior Working Group on the European Green Deal developed a machine learning method based on deep learning. Deep learning refers to extensive neural networks with many layers (deep) that "allow computational models that are composed of multiple processing layers to learn representations of data with multiple levels of abstraction."[32]

The usefulness of this method is threefold. First, it can validate the linkages between EGD policies and the SDGs found by the "human" approach. Second, it is an automated tool that is a fast and accurate classifier for policy and strategy documents to be published in the future. Third, it can discover any new possible connections between the SDGs and the scanned policy documents that were not identified during the classical approach.

Machines learn from experience by representations expressed in terms of other, more straightforward phrases.[33] In 2017, Google Research introduced The Transformer, a deep learning model based on attention mechanisms, dispensing with recurrence and convolutions entirely.[34] This innovation led to the development of a wide range of models based on transformers, allowing the processing of entire sequences without the need for labelled data in pre-training.

The Senior Working Group on the European Green Deal built on this and fine-tuned a pre-trained transformer-based model to find the similarity score of each policy document with each SDG by taking the ambiguity of the natural language (lexically, syntactically, semantically, anaphorically, pragmatically). To overcome the disadvantages of standard language models, which are unidirectional, and thus limit the architectures that can be used for pre-training, the Group used Bidirectional Encoder Representations from Transformer (BERT), a bidirectional transformer pre-trained by using masked language modelling objective and next sentence prediction.[35]

Results

The model returns the probability that a specific policy or strategy document under consideration is associated with

TABLE 3. Adjusted similarity scores (probabilities)

Policy Document	SDG1	SDG2	SDG3	SDG4	SDG5	SDG6	SDG7	SDG8	SDG9	SDG10	SDG11	SDG12	SDG13	SDG14	SDG15	SDG16	SDG17
A New Industrial Strategy for Europe	0.54%	4.04%	2.31%	4.86%	3.61%	2.50%	12.25%	23.41%		2.13%	3.89%	21.38%	4.21%	3.15%	3.83%	2.08%	5.80%
Circular Economy Action Plan	1.28%	7.45%	1.82%	0.95%	0.95%	1.76%	13.47%	12.54%	39.57%	1.62%	5.81%		2.73%	2.45%	1.78%	0.93%	4.89%
EU Biodiversity Strategy for 2030	3.02%	5.11%	16.44%	4.43%	7.14%	2.28%	1.80%	4.38%	5.69%	4.87%	2.99%	10.85%	5.22%	9.12%		7.71%	8.95%
Farm to Fork Strategy	1.45%		3.51%	1.82%	0.40%	1.04%	12.03%	2.18%	5.40%	0.70%	12.60%	41.74%	5.27%	3.02%	0.82%	3.49%	4.54%
EU Hydrogen Strategy	0.76%	1.27%	1.19%	0.39%	0.34%	1.58%		0.97%	2.02%	0.66%	1.71%	16.52%	32.81%	1.58%	0.59%	8.65%	28.97%
7 Technology Flagship Areas, ASGS for 2021	0.70%	6.04%	20.37%	1.85%	0.97%	4.44%	21.13%	2.50%		2.19%	2.74%	2.09%	12.15%	3.02%	1.29%	3.38%	15.15%
Stepping up Europe's 2030 Climate Ambition	0.27%	0.80%	0.34%	0.33%	0.26%	0.88%	2.37%	0.17%	1.65%	0.60%	0.68%	0.44%		0.87%	0.62%	32.36%	57.36%
Chemicals Strategy for Sustainability	0.58%	2.04%	23.87%	1.08%	1.60%	21.09%	12.72%	0.79%	2.75%	1.08%	3.60%		3.24%	10.65%	4.13%	5.65%	5.13%
EU Strategy to Reduce Methane Emissions	0.87%	0.48%	1.07%	0.19%	0.34%	2.72%		0.85%	0.53%	0.86%	2.52%	29.09%	27.81%	0.81%	0.58%	9.08%	22.20%
A Renovation Wave for Europe	1.11%	1.04%	2.24%	2.95%	2.03%	4.31%	7.97%	3.24%	6.55%	2.52%		25.18%	22.84%	2.95%	3.32%	8.46%	3.29%
EU Commission Recommendation on Energy Poverty	1.55%	2.01%	1.66%	0.90%	0.75%	8.99%		3.00%	2.05%	1.02%	4.15%	24.03%	13.17%	3.38%	0.81%	11.79%	20.74%
EU Strategy to Harness the Potential of Offshore Renewable Energy for a Climate Neutral Future	1.33%	0.92%	1.64%	1.16%	1.06%	2.95%		6.15%	3.98%	1.63%	4.39%	32.83%	16.39%	4.17%	0.91%	7.12%	13.35%
European Climate Pact	0.38%	1.34%	0.61%	0.24%	0.20%	1.06%	3.00%	0.19%	0.94%	0.57%	0.73%	1.25%	46.36%	1.02%	0.90%	41.21%	
Smart Mobility Strategy	1.56%	1.67%	8.49%	5.26%	3.96%	6.58%	10.11%	2.96%	20.42%	3.22%		10.09%	6.09%	5.42%	3.52%	8.37%	2.28%
The European Economic and Financial System: Fostering Openness, Strength and Resilience	0.21%	0.46%	0.28%	0.89%	0.32%	0.57%	0.31%	1.31%	3.58%	1.79%	0.55%	0.23%	1.35%	1.47%	0.55%		86.12%
EU Strategy on Adaptation to Climate Change	0.32%	1.04%	0.49%	0.55%	0.45%	1.08%	3.31%	0.29%	2.07%	0.80%	0.94%	0.56%		1.10%	0.81%	36.75%	49.43%
Directing Finance Towards the European Green Deal	0.84%	6.36%	1.39%	0.22%	0.54%	6.87%	18.49%	1.22%	1.06%	0.42%	2.98%		7.69%	2.41%	1.69%	13.75%	34.07%
Updating the 2020 New Industrial Strategy: Building a Stronger Single Market for Europe's Recovery	0.25%	0.82%	0.74%	1.10%	0.97%	0.87%	9.62%	30.67%		0.95%	1.03%	46.54%	1.30%	0.99%	0.99%	0.86%	2.30%
The EU's Blue Economy for a Sustainable Future	1.02%	0.90%	0.24%	0.26%	0.27%	0.80%	7.41%		4.52%	1.39%	1.43%	69.17%	0.89%	0.96%	0.23%	2.24%	8.27%
European Climate Law	0.30%	1.05%	0.47%	0.44%	0.35%	0.77%	1.76%	0.18%	1.05%	0.49%	0.73%	0.33%		0.88%	0.60%	40.97%	49.64%
Strategy for Financing the Transition to a Sustainable Economy	0.35%	1.03%	0.35%	0.32%	0.19%	0.67%	2.36%	0.23%	1.06%	0.59%	0.53%	0.51%	54.77%	1.04%	0.48%	35.52%	
Fit for 55	0.22%	0.58%	0.31%	0.33%	0.24%	0.76%	1.56%	0.14%	1.00%	0.57%	0.63%	0.35%		0.75%	0.54%	37.84%	54.17%

Source: Koundouri, P. et al (2022).

the 17 SDGs. However, the model assigns an extremely high score, exceeding 99% in some cases, to the SDG with the highest relevance; the rest, up to 100%, is distributed to all other SDGs, thus making the results difficult to interpret. To make the results more straightforward and easier to translate, the Senior Working Group on the European Green Deal excluded the highest score of each policy document, and the scores (probabilities) were distributed proportionally to the rest of the SDGs.

Table 3 shows the similarity scores calculated by the model, where a higher score (percentage) implies a greater probability of a scanned policy being linked to a certain SDG. However, one should view the results intuitively and not only from a strictly quantitative perspective to get a better insight.

Discussion

The highest-relevance scores in the majority of the documents are obtained with SDG 17 (partnership for the goals), SDG 12 (responsible consumption and production), and SDG 16 (peace, justice and strong institutions. Following, a strong connection is observed with SDG 13 (climate action), SDG 7 (affordable and clean energy), and SDG 9 (industry, innovation and infrastructure).

The research yielded an interesting result in regards to the New Industrial Strategy and Updating the 2020 Industrial Strategy. One would expect a higher connection of these documents to SDG 7 (affordable and clean energy). However, the deep learning model reveals a stronger relationship with SDG 8 (decent work & economic growth) and SDG 12 (responsible consumption and production).

Furthermore, the EU's Blue Economy for Sustainable Future policy seems more relevant to SDG 8, SDG 12, SDG 17, and SDG 7, rather than SDG 14 (life below water), as intuitively expected.

Finally, all policy documents seem to be closely related to SDGs 16 & 17, even though text excerpts used during the training were very few compared to the rest of the SDGs.

In conclusion, the developed deep learning model gives interesting results in calculating the similarity between the SDGs and the policy documents. The results do not contradict those of the human approach but seem to agree with the human method and in some cases reveal connections not observable by the human eye. This indicates that in some areas, such as text analysis and pattern recognition, machines have reached a satisfactory level approaching human intelligence, and have the advantage of being able to process vast volumes of data quickly, efficiently, and accurately.

SUSTAINABLE RECOVERY AND RESILIENCE

Recovery plans, for COVID-19 as well as future crises, must consider the climate and biodiversity crises, as it is increasingly clear that the world has passed the limits of our planet. Governments need to learn lessons from the pandemic and lay the foundations for more resilient and inclusive societies. They must align with what the United Nations General Assembly has called "The Future We Want", which embraces Agenda 2030 and the 17 Sustainable Development Goals (SDGs), as well as the Paris Agreement. The European Green Deal has laid forth a detailed vision for the "Future Europe Wants", namely a green and digital, job-based, inclusive recovery from the pandemic.[36]

A "return-to-normal" is considered environmentally unsustainable and economically mediocre relative to a green recovery approach that prioritizes energy efficiency retrofits and sustainable urban transportation. Nevertheless, toward the end of this decade, investments in capital-intensive industry and infrastructure projects can act as catalysts for the green transition.[37]

In Europe, growth- and employment-enhancing strategies include green energy and the circular economy, organic agriculture, and nature-based solutions. Nonetheless, policymakers must consider trade-offs; for example, recovery programs that focus on short-term employment may have a minor influence on long-run growth, as the green transition demands longer-term commitments to public expenditure and price changes. Additionally, because green recovery initiatives appear to be most effective in locations where employees already possess the requisite green skills, Member States should exploit the European Just Transition Fund and offer adequate training for other vulnerable workforce segments.

The European Green Deal is a comprehensive strategy to make the European continent resource-efficient and carbon-neutral by 2050, cutting-edge in terms of technology, and socially just. These goals will be a part of EU economic policy, which will "place people and planet at the centre of EU economic policy," as they have also chosen to incorporate the SDGs into the European Semester.[38] Additionally, EU leaders responded to the enormous health, environmental, and economic challenges faced by the pandemic with a powerful "Next Generation EU" package of policies and funds to aid economic recovery while pursuing Europe's green and digital transformation.[39]

The EU has a great chance to transform and become a model for the rest of the world if it has the funds and the will to make Europe a digital, sustainable, and more resilient continent. The NextGeneration (NGEU) Recovery Package is a recovery plan of €750 billion agreed upon among EU member states, on top of the EU's long-term budget of €1.074 trillion for the 2021-2027 multiannual financial framework. This sums to €1.8 trillion, an unprecedented amount to support member states to recover from the negative consequences of the COVID-19 crisis and the EU's long-term priorities across various policy areas. The NGEU is an effort to help and speed up the transition to a new reality that will make the European Union more robust than before. It encourages activity reorientation toward innovation for resilience and imposes conditions on available financing, and it demands member states to prioritize investments in the environment, technology, and healthcare.

The Recovery and Resilience Facility[i] (RRF), the cornerstone of the NGEU, accounting for €672.5 billion or 90% of the NGEU budget, is facilitating loans and grants to assist reforms and investments, and requires member states to submit Recovery and Resilience Plans (RRPs), consistent with EU priorities, namely: (1) Enhancing economic and social resilience through increasing growth potential, job creation, and economic and social stability; (2) Addressing the issues derived from the European Semester's country-specific recommendations; (3) Promoting a green transition by allocating at least 37% of resources to climate action and environmental sustainability; and (4) Promoting the digital revolution by devoting at least 20% of resources to the EU's digital transformation.[39]

The long-term path of EU recovery is still uncertain. Europe's economy was unstable before the COVID-19 crisis, having not fully recovered from the 2008 economic crisis. Furthermore, within the eurozone, nations continue to have wildly divergent levels of competitiveness, mainly due to variations in investment in crucial economic drivers such as education, R&D, and labor force skills. Unless Europe implements a new action plan that considers both the rate and direction of growth, the continent faces a decade of stagnation. This was true before the COVID-19 pandemic, and continues to be during it.[40]

Rather than simply reacting to crises and adapting to new situations, science has the potential to play a significant role in building economies and communities that address the potential hazards posed by climate change, biodiversity loss, and pandemics. Governments must engage citizens and use their power to deliver the vision of a prosperous, inclusive, climate- and pandemic-resilient society with a circular, net-zero-emissions economy. The Intergovernmental Panel on Climate Change (IPCC) report expressly states that "rapid, far-reaching, and unprecedented transformations in all parts of civilization" are required, and gradual adjustments will not suffice. A radical reform of economic, social, and financial systems that will exponentially increase social, economic, health, and environmental resilience is necessary. Bold ideas and huge adjustments are required. System innovation and transitional thinking can benefit, but they need extensive public input.

Following the 2008 financial crisis, governments mainstreamed large amounts of money, often to highly polluting businesses and the wealthy. Learning from this mistake, following the COVID-19 pandemic there were attempts to target investments to areas that strengthen society and the economy in the face of crises. We must lay the groundwork for a green, circular economy that includes nature-based solutions focused on public well-being. The 17 SDGs and the European Commission's European Green Deal should be used as a framework for European economies. Financial institutions and governments should adopt EU taxonomy for sustainable investments now, which calls for them to phase out fossil fuels by using existing renewable energy technologies, eliminate fossil fuel subsidies that amounted to nearly $6.0 trillion in 2020,[41] and redirect them to green and intelligent climate mitigation and adaptation infrastructure projects.

KEY SECTORS FOR TRANSFORMATION

THE ENERGY SECTOR

The market is already moving in the direction of green recovery.

The COVID-19 pandemic highlighted key economic fragilities and widespread impacts of a decline in the consumer base over multiple sectors. However, world industries and economies proved highly resilient, based on their ability to bounce back after the global financial crisis, as countries heavily invested in infrastructure and utilities to kick-start growth and economic development. COVID-19 recovery efforts presented a massive opportunity for the renewable energy sector.

i. As the central instrument at the core of NextGenerationEU, the Recovery and Resilience Facility is responsible for assisting the EU in emerging stronger and more robust from the current crisis.

Renewable energy, electric vehicles, and other sectors were more "COVID-proof."

The global electricity and transport sectors rely heavily on fossil fuels, such as coal and crude oil, respectively. Increasing demand for fossil fuels has resulted in a significant rise in global emissions during the past two decades. With this increase in emissions and concerns about resource depletion, research into renewable energy is growing worldwide.[42] Renewable energy was prioritized as a critical component of COVID-19 economic recovery. For both developed and developing countries, and especially small-island developing states (SIDS), "Seizing green energy opportunities through increased investments in renewables can contribute to post COVID-19 economic recovery and create more jobs."[43] Renewable energy can act as a catalyst for economic recovery by creating "green" jobs and strengthening resilience. Directing investments towards a green and healthy recovery also accelerates the transition to a low-carbon energy future and reduce GHG emissions – an urgent task for meeting the goals of the Paris Agreement.[44,45]

Growth of jobs in the green sector, getting people back to work.

Research suggests renewable energy technologies can generate employment and economic stimulus.[46,47,48] Specifically, Malik *et al.* 2015 and Malik *et al*. 2016 outline the potential of bioenergy to (a) create employment and economic stimulus in regional areas; (b) reduce GHG emissions and urban air pollution; and (c) provide a sustainable, energy-secure future.[47,49] According to IRENA, under the Planned Energy Scenario (PES), the workforce occupied in the energy sector could escalate to almost 140m workers globally, from 106 million.[45] Many research articles have acknowledged the potential of algae as a novel feedstock for biofuel production due to its ability to grow on marginal land at much faster rates than any other feedstock.[50,51,52,53,54,55,56,57,58] Malik et al. highlight the carbon sequestration potential of algae. In addition to offering job opportunities and enhancing productivity and economic growth in the region, bio-crude produced from algae provides a reliable, low-emissions alternative to crude oil.[49] Governments can respond to crises by implementing plans to support individuals and businesses in transitioning to low-carbon vehicle fleets; for example, the EU's stimulus package mentioned installing one million electric vehicle charging stations.[59]

Modelling trade impacts (co-benefits) of a green recovery.

International trade has contributed to adverse environmental and social impacts,[60] such as carbon dioxide emissions, water use, land use, modern slavery, income inequality, and much more. These impacts, known as spillovers, are driven mainly by consumer demand in the developed world. For emissions, green recovery plans must ensure that any strategy implemented for transitioning economies out of COVID-19 does not inadvertently lead to outsourcing emissions. This has been shown to occur widely worldwide.[61,62]

From fuel-based to minerals-based.

Before the COVID-19 pandemic, the global energy system was already transitioning to clean energy that reduces GHG emissions through the extensive deployment of a wide range of clean energy technologies.[63,64] This transition requires evolving from a fuels-based to minerals-based energy production, storage, and distribution system. Central to this emerging minerals-based energy system are critical minerals such as copper, nickel, cobalt, lithium, and rare earth minerals.

Overall minerals demand is expected to grow 400% by 2040 to meet the 2016 Paris Agreement and from 500% up to 600% to meet net-zero globally by 2050, with exceptionally high growth for minerals related to electric vehicles, wind turbines, and solar panels.[63,64] For example, since 2010, the average amount of minerals needed for a new unit of power generation capacity has increased by 50% as the share of renewables has risen.[64] By 2040, the demand for lithium is forecast to grow up to 42 times 2020 levels; followed by graphite, cobalt, and nickel (around 20-25 times); and rare earths (7 times).[64] The expansion of electricity networks is expected to double copper demand by 2040.

As the energy transition gathers pace, secure and resilient mineral supply gains prominence in the energy security debate, a realm formerly occupied by oil.[64] Many minerals come from a small number of producers, and the production of many energy transition minerals is more geographically concentrated than for oil or natural gas.[64] For example, the world's top three producers of lithium, cobalt, and rare earth elements control well over three-quarters of global production. This high level of concentration, compounded by complex supply chains, increases risks from physical disruption, trade restrictions, or other developments in major producing countries.

Growing minerals demand can be satisfied by the circular economy, newly available primary supply from terrestrial mining (TM), and possibly by deep seabed mining (DSM).[65] The circular economy cannot meet all new mineral demands.[63,64,66] Current supply and investment plans for many critical minerals fall short of what's required for the energy transition, are below the historic pace, and are largely from regions with low governance scores and high emissions intensity.[64,67] New supply requires long lead-in times for discovery and production (10-15 years), often requiring expansion to lower-grade ore sites, which in turn raises costs, GHG emissions, and waste.[64,67,68] Capital spending lies 50% below its 2012 peak and sustains current production; but it does not create new capacity.[67] TM costs rise in response to growing demand and due to mining increasingly lower quality deposits with lower grades. Some energy-transition metals markets are too small for big miners.[67]

Satisfying rising demand depends upon the responsiveness of primary supply given current capacity (i.e. the price elasticity of supply), and over the longer-term shifts due to investment and technological progress. Growing demand in the face of relatively unresponsive (inelastic) supply can lead to a long-term trend of rising minerals prices, which invariably follows a super-cycle, raising energy costs and a slower green energy transition. Over a more extended period, increasing fees and expenses could induce quicker green technological change, dampening price increases and facilitating the green energy transition. However, supply faces further impediments, and costs may rise due to global supply chains diversifying to become more resilient to global shocks, reducing concentrated minerals suppliers, and addressing genuine security concerns.[64,67,69] In sum, without more significant investment and supply, and more price-responsive supply, minerals shortages and avoidable costs may slow the green energy transition.

Minerals production faces growing environmental, social, and environmental justice concerns, impacting the nature and timing of the green energy transition. Mining increasingly lower grades and less accessible deposits directly expands land clearing through the construction of more extensive and open cast mines; the amount of water, energy, and chemical inputs grows, solid or toxic wastes rise, and GHG emissions increase.[64, 70,71] Abandoned mines pose additional environmental costs, with, for example, over 60,000 abandoned mines in Australia alone.[64] Energy transition minerals from TM have high water requirements. TM may also have a higher carbon footprint than DSM.[72]

Deep-sea minerals occur on the seabed at depths below 200 meters.[73] These deposits include cobalt-rich crusts, massive seabed sulphides, and polymetallic nodules that yield copper, cobalt, manganese, nickel, zinc, lithium, and rare earth elements.[74] Deep-sea mineral deposits are higher grade compared to equivalent land deposits.[75] Although commercial exploitation has yet to commence, relevant technologies have been tried.[76] The International Seabed Authority (ISA) has approved 31 exploration contracts for the Area Beyond National Jurisdiction, but no exploitation contracts have been awarded and no DSM has occurred on extended continental shelves. The ISA has drafted mineral exploitation regulations for the area.

DSM generates adverse environmental impacts in environments rich in species diversity, low in biomass, and with slow regeneration rates of exhaustible resources. DSM comes at the ("external") cost of seafloor disturbance, sediment plumes, pollution, foregone marine biodiversity and ecosystem services, degraded marine food chains and genetic resources, and increased carbon footprint.[77,78,79] It may even contribute to the extinction of undiscovered species.[73] The impact of deep-seabed mining upon high-seas fisheries is unknown. The vast majority of the impacted fisheries is expected to be pelagic, and the impact is then expected to be less than if the fisheries were demersal and benthic. Halting DSM's adverse environmental costs by not mining comes with the price of foregone benefits from current and future consumption of private and public goods financed by DSM royalties, while delaying or halting DSM leads to spillovers onto TM to satisfy growing minerals demand.[80]

Environmental justice issues and human costs primarily concentrate on TM. TM can adversely impact local populations living adjacent to mining sites through extreme ecological and health hazards, as well as armed conflicts, human rights violations, and disparity in the distribution of economic benefits that accrue from mining.[70,81,82.] TM can also lead to community displacement, mine closures, large water requirements, contamination, waste disposal, and corruption.[64] Local populations, especially low-income, Indigenous, and/or racial and ethnic minorities,[83] often disproportionately bear these costs, while broader populations enjoy the benefits.[71,84]

Artisanal and small-scale TM employs about ten times the workforce of large-scale TM, employing 20 to 30 million people worldwide. It extracts more than 30 minerals from primary and secondary ores, and contributes 15-20% of the global production of minerals and metal.[81] Artisanal mining increasingly forms a livelihood for many poor households.[70] However, artisanal miners are typically paid only for what they produce and lack access to health care or compensation following an accident.[85,86] It often

employs child labor/forced labor and is characterized by high rates of financial crime.[87,88,89] Over a million children work in artisanal mining and quarrying.[90] The effects on the educational attainment and health of young children raise additional inter-generational equity questions.[91,92] Governments may not capture TM revenue through royalties, and TM costs can also be cultural and spiritual, such as Australian aboriginal sacred sites. Local TM costs may also include colonial legacies due to the significance of TM in colonization's historical process.[93,94]

Resource-rich and resource-dependent nations have struggled to leverage natural resource development towards broader economic diversification and sustained growth,[95] and countries with high environmental and social risks also tend to have high governance risks.[96] Therefore, the global mining industry has responded to these ESG issues by establishing mining principles and working with the International Union for the Conservation of Nature.[73,97]

Cobalt and lithium mining illustrate many TM environmental, environmental justice, and human cost issues. Nearly 50% of world cobalt reserves are found in the Democratic Republic of the Congo, accounting for over two-thirds of global cobalt production.[98] About 20% of this cobalt comes from artisanal mines, where some 40,000 children from low-income households and below-average education work in hazardous conditions.[98,99] The 150,000-200,000 artisanal miners produce about one-fifth of the cobalt production in the Democratic Republic of Congo.[100] Many artisanal miners work as subterranean workers in the tunnels where minerals are excavated, arguably one of the riskiest occupations due to the exposure to toxicity in the air and the risks of collapsing tunnels.[87]

Lithium brine deposits represent about 66% of global lithium resources. Over 50% of global lithium lies beneath the Andean regions of Argentina, Bolivia, and Chile.[98] Lithium mining requires enormous amounts of groundwater to pump brine from drilled wells (about 500,000 gallons/metric tonne) to the surface, where it is arrayed in evaporation ponds. This is leading to water competition between miners, Indigenous quinoa farmers, and llama herders in one of the world's driest regions.

Sustainable minerals sourcing from DSM and TM interact with the 2030 Agenda and the Paris Agreement in complex and interlinked ways, with trade-offs among goals and targets. The exploitation of exhaustible resources makes sustainable development difficult. Given that one of DSM's environmental impacts is the mining of an exhaustible resource with extremely slow regeneration makes satisfying the no net loss in biodiversity virtually unattainable. DSM thus unavoidably affects SDG 14 (sustainable use of marine resources for sustainable development). Similarly, TM unavoidably impacts SDG 15 (sustainable use of terrestrial ecosystems, biodiversity), as some terrestrial ecosystems are close to an exhaustible resource with little or no possibility of no net loss in biodiversity, while others are capable of relatively quick regeneration. Both TM and DSM contribute to SDG 7 (affordable, reliable, sustainable, modern energy), SDG 12 (consumption, production), and SDG 13 (climate change, impacts) by underpinning the clean energy transition. However, TM more strongly impacts SDG 10 (inequality within, among countries) and SDG 16 (sustainable development, justice) than DSM due to the concentration in a limited number of countries, some with governance issues. DSM also more inherently satisfies procedural and distributive justice due to the requirements of sharing DSM royalties and other benefits to meet intra- and inter-generational equity requirements established by the United Nations Convention on the Law of the Sea (UNCLOS) and the inherent fair division of ISA as a voluntary international organization whose State Parties have equal exogeneous rights and parity as legal personalities that make decisions through consensus.[101,102,103] DSM could also adversely impact TM prices and social welfare, thereby requiring compensation to TM countries to satisfy UNLOS.[103] Meeting SDGs requires considering DSM-TM spillovers, trade-offs, and impacts upon equity, including local populations, least developed, small island developing and landlocked developing states.

THE AGRICULTURE AND FOOD SECTOR

Current debates about ways to tackle the myriad threats to sustainable development posed by a changing climate have increased urgency following the dire scenario in the IPCC's AR6.[104] The scientific findings are unequivocal – a warming of 1.5°C and 2°C will be exceeded during the 21st century unless deep reductions in carbon dioxide (CO_2) and other GHG emissions occur in the coming decades.

While most of the focus on mitigation efforts centers on energy policies and programs, and the move away from fossil fuels to renewable energy sources, it remains true that the agricultural sector has the most significant direct interface with our environment and the ecosystems on which all life depends. Agriculture transforms land use, drives deforestation and biodiversity loss, uses almost two-thirds of all water withdrawals, pollutes surface and groundwater with pesticides and fertilizers, contributes significantly to methane emissions, and contributes to overfishing. Agriculture in its broad sense (i.e., including livestock, forestry, fishing, and growing and harvesting of

crops for food, feed, and fiber) is a significant force in our interactions with climate change. Furthermore, our poor stewardship of soils is contributing to desertification, reduced yields, and missed opportunities in the capture and sequestration of ever-increasing GHG emissions.

Food systems perform poorly in delivering the requisite quantity and quality of food and nutrition to humankind, due to a number of locally-specific challenges that include low yields, high amounts of loss and waste, and negative environmental impacts. At the same time, many farming families live below the poverty line. According to the FAO, over 811 million people are undernourished, of which more than half (418 million) live in Asia, more than a third (282 million) in Africa, and over 60 million in Latin America and the Caribbean. Almost 2 billion people are deficient in critical vitamins and minerals necessary for growth, development, and disease prevention; furthermore, one in 10 people are impacted by contaminated food. In addition, energy and micronutrient deficiency affect approximately 150 million children under the age of five who are stunted and cannot grow to achieve their full potential, both physically and mentally. Hunger worsened during the COVID-19 pandemic, as a result of disrupted supply chains, and was the worst in Africa, where 21% of the population is undernourished, more than double that of any other region.[105] At the same time, more than 2 billion adults are overweight and obese, increasing the risk of non-communicable diseases such as Type 2 diabetes, hypertension, heart attacks, and certain cancers.

While efficient at producing calories, production systems in rich countries have substantial hidden costs. A report from The Rockefeller Foundation calculates the actual price of food in the US.[106] They note that the US spends $1.1 trillion a year on food; however, when one accounts for the cost of producing this food and factors in health care costs, climate change, and biodiversity loss, the bill grows to at least $3.2 trillion per year.

To meet the needs of the current global population and expected increases, the world needs to produce significantly more food by 2050 and address loss and waste, assuming delivery systems function effectively. However, over the next 50 years, climate change could reduce food crop yields by 16% worldwide, and 28% in Africa. Agriculture is also a significant part of the climate problem; it generates up to 25% of total GHG emissions, including emissions through land-use change; without action this could rise to 70%.

The world urgently needs climate-smart agriculture (CSA) to deliver a triple-win: increased productivity, enhanced resilience, and reduced emissions. Reducing the environmental footprint of agriculture is key to achieving the needed transformation of the sector and achieving the SDGs. The good news is that the agriculture and food sectors have the biophysical potential to offset and sequester about 20 per cent of total annual emissions through improved soil management techniques. Reforestation can add to that figure, subject to avoiding negative impacts from changing the earth's albedo.

Precision agriculture can improve the quantity and quality of agricultural outputs while reducing inputs of water, energy, fertilizers, and pesticides, thereby generating climate benefits. In some cases, it can also increase time efficiency, such as performing farming practices remotely or limiting fertilizer inputs to the areas where they are needed based on soil testing. This could improve the well-being of farmers. In the United States, precision agriculture technologies are already being deployed on 30-50% of corn and soybean acreage.[107] This solution is not only available in wealthy countries; there is a great deal of innovation in this space for lower-income and small-scale settings, and it can improve the attractiveness and profitability of farming in many contexts and farming systems. For example, in India, the Nano Ganesh system uses digital applications to control irrigation pumps remotely by mobile phone, which saves farmers water, energy, and time. Hello Tractor matches tractor owners to smallholder farmers who need services via simple text messages in Ghana, Kenya, and Nigeria. Farmers and others without access to banking services are also being supported through rapidly emerging financial technology, or "FinTech," solutions. For example, M-PESA, a mobile phone-based payment system introduced in 2007 in Kenya, reached 65% of Kenyan households in just two years.

Any discussion about improving the productivity and sustainability of the agriculture and food sectors must also address the pressing problem of food waste. This problem is acute in industrialized and emerging economies alike. According to a 2019 FAO report, 14% of food produced globally is lost between the harvest and retail stages of the food system, with losses around 14% in Sub-Saharan Africa, over 15% in North America and Europe, and over 20% in Central and South Asia.[108] Reducing food loss and waste can deliver significant societal benefits, but requires careful analysis of the exact linkages between food loss and destruction, food security, nutrition, and environmental sustainability.

Biotechnology can help farmers grow more nutritious plants (for example, Golden Rice, currently in the testing stage, which hopes to reduce vitamin A deficiency);

plants more resistant to droughts, flooding, and salinity; and plants with higher yields. Biotechnology can also be a valuable tool for diagnosing animal diseases (critical given the COVID-19 pandemic and future emergence of zoonotic diseases), vaccine development, and production of fermented food, among others. However, the FAO has warned that biotechnology has not benefited smallholder farmers, producers, and consumers sufficiently. Therefore, more research and development of agricultural biotechnologies should focus on smallholders' needs.

To recover from the disastrous COVID-19 recession, a significant effort should be deployed to transform the agriculture and food sector. This should go from boosting research funding to more considerable support for smallholder farmers in developing countries. Inputs for farmers, including agricultural extension and small farmer credit, should be made available. Reduction of post-harvest losses and movements towards local procurement, including nature-based solutions in urban agriculture, must be considered. In the industrialized countries, incentives should assist in the deployment of precision agriculture and climate-smart agriculture, and major campaigns to reduce food wastage are all parts of what a "green recovery" should entail.

HOUSING AND URBANIZATION

Urbanization is the gradual shift in residence of the human population from rural to urban areas, combined with the expected growth of the world's population. In 2018, 55% of the world's population lived in urban areas, and this is expected to increase to 68% by 2050.[109] In other words, an additional 2.5 billion people will move into urban areas by 2050, with close to 90% of this increase taking place in Asia and Africa.

From 1950 to 2018, the world's urban population has grown from 751 million to 4.2 billion people. Despite its relatively lower level of urbanization, Asia is home to 54% of the world's urban population, followed by Europe and Africa (13%).

By 2030 it is expected that there will be 43 megacities, mostly in developed regions, with more than 10 million inhabitants. Currently, one in eight people live in 33 megacities worldwide, whereas close to half of the world's urban dwellers reside in smaller settlements with fewer than 500,000 inhabitants.

As urbanization grows, sustainable development depends increasingly on the successful management of this growth, especially in low and middle-income countries where the pace of urbanization is projected to be the fastest. Many countries will face challenges meeting the infrastructure, housing, transportation, energy systems, employment, and essential service needs (such as education and health care) for their growing urban populations. There is a need for integrated policies that build on existing economic, social, and environmental ties and improve the lives of both urban and rural dwellers. To ensure that the benefits of urbanization are fully shared, policies to manage urban growth need to provide equitable access to infrastructure and social services, focusing on the urban poor and other vulnerable groups for housing, education, health care, and decent work.[110]

Statistics show that 95% of all cases of COVID-19 occurred in cities, and according to UN-Habitat,[111] compact, well-planned programs to improve access to public spaces and affordable housing improved public health, the economy, and the pandemic experience. Therefore, UN Habitat calls for investment in areas that are overcrowded, cut off from other parts of the city, and at-risk due to environmental and health hazards. In fact, as with previous public health crises, the key determinants of risk for urban residents are inequality, inadequate housing, and lack of access to clean water, sanitation, and waste management.[111] Leveraging recovery packages to invest in these areas and improve these indicators will support fast recovery from COVID-19, improve health outcomes in the long term, and build resilience to future crises.

THE HEALTH SECTOR

The health-related industrial sector includes pharmaceutical production, medical equipment manufacturing, and the production of chemicals for public health campaigns; it also consumes energy, requires transportation, and involves other activities responsible for GHG emissions. In 2018, global spending on health was US $8.3 trillion, or 10% of global GDP,[112] and in some countries much more. For example, in the US in 2019 it represented 17.7% of GDP.[113] Promoting a more sustainable health sector is vital to lower emissions and mitigate the climate crisis.

One crucial area that can influence the practices of the health sector is procurement. For example, health products are one of the UN's largest procurement categories, which increased by 25.5% to US $5.5 billion from 2019 to 2020.[114] Several initiatives, including Sustainable UN System (SUN), Greening Procurement in the Health Sector, and Greening the Blue, have achieved significant progress. Indicatively, in 2019, the United Nations System retained its declining trend in emissions generation. It emitted 2 million tonnes of CO_2 equivalent emissions, with per capita emissions of

6.5 tonnes CO_2 equivalent. In comparison, per capita emissions in 2010 were 6.5 tonnes CO_2 equivalent, according to the Greening the Blue Report.[115]

> "Health sector facilities are the operational heart of service delivery, protecting health, treating patients, and saving lives. Yet, health sector facilities are also a source of carbon emissions, contributing to climate change. The world's health sector facilities churn out CO_2 by using significant resources and energy-hungry equipment. This is perhaps ironic; as medical professionals, our commitment is to not harm first. Places of healing should be leading the way, not contributing to the burden of disease." - Tedros Adhanom Ghebreyesus, Director-General, World Health Organization.[116]

The health sector's annual climate footprint report shows it is equivalent to 514 coal power plants and corresponds to 1-5% of global net emissions,[117] or roughly equivalent to the fourth largest emitting country, Russia, which is responsible for 5% of global emissions. Not all countries have an equal contribution; the United States' health sector produces 57 times and China's six times that of India.[116,117]

The health sector is explicitly named in the UNFCCC's Race To Zero campaign to promote a "zero-carbon recovery that prevents future threats, creates decent jobs and unlocks inclusive, sustainable growth."[118] Another initiative, Health Care Without Harm, counts 1,350 members in 72 countries, representing the interests of over 43,000 hospitals and health centers that are working on estimating and reducing their emissions from energy, transport, waste, and gases, benchmarking their footprints and promoting suitable solutions.[119] COVID-19 recovery packages represent an unprecedented opportunity to invest in health systems strengthening, but should not do so at a cost to the global climate. By learning from the experiences of so many hospitals and health facilities in reducing the greenhouse gas footprint, we can leverage recovery packages to green the health sector.

The COVID-19 pandemic has demonstrated the inability of today's society to cope with a major global shock effectively. The pandemic has produced an enormous cost of human lives and has profoundly altered social and economic functioning, with significant impacts on the health, environment, and governance systems in most countries. In this context, resilience, understood as the set of capacities of natural and social approaches to prevent, react, and recover from global shocks, is gaining renewed interest.[120]

A key sector in response to COVID-19 has undoubtedly been health systems, and therefore understanding what resilience means and how to strengthen it is of the utmost importance. Thomas et al. defines health system resilience as the ability to prepare, manage (absorb, adapt and transform), and learn from crises, and they have identified which strategies can improve the resilience of health systems.[120] Such methods include governance, funding, human and material resources, and the ability to adopt flexible and innovative approaches to service provision. A relevant aspect is evaluating and monitoring resilience so the knowledge gathered can inform recovery policies.[120]

Modern epidemics have shown the importance of considering structural political-economic conditions together with contextual and ill-defined processes that result from complexity and uncertainty. To address this complexity, it is necessary to consider some key strategies.[121] The first is how scientific evidence is managed and incorporated into political decisions, within a larger context of pre-established power relations and great uncertainty. Second, economies' behavior and the restrictions imposed by conventional models of economic growth should be understood. Third, we must understand new political relations that modify citizen-state's traditional ties and that, as in the case of COVID-19, range from solidarity and response to political authority, and the questioning of democracy.

The Oxford COVID-19 Government Response Tracker (OxCGRT) collects systematic information on policy measures that governments have taken to tackle COVID-19. The different policy responses tracked since 1 January 2020 cover more than 180 countries and are coded into 23 indicators, such as school closures, travel restrictions, and vaccination policy. Trinidad and Tobago, a small island developing state, has been ranked among the best on four of the six WHO criteria for rolling back COVID-19 "lockdown" measures. The country's critical mitigation and containment strategies were evidence-informed and demonstrated an "all-of-government" approach. The COVID-19 health system response of this country indicates that, although developing countries face many health system challenges; political will, evidence-informed decision-making, respect for science, and timely, coordinated, collaborative actions can strengthen the resilience and response of the health system during a health emergency.[122]

Kimhi et al. studied fluctuations in national resilience in Israel during COVID-19, considering both the direction and extent of changes in the national resilience score during the crisis and its predictors. The average score declined significantly across three repeated measures, as did three of the four score factors: belief in the government, the prime minister, civil society, and patriotism. Interestingly,

predictors of the score mainly reflected one's political attitudes and sense of political and economic threats, rather than health threats.[123]

The evidence provided above, along with other sources of information, shows the importance of including resilience as part of health systems strengthening. At the same time, there is increasing knowledge about the environmental impacts of health systems on various planetary boundaries and how they contribute to the climate and biodiversity crises.[117] Once again, COVID-19 and the climate crisis appear as converging situations requiring policies to integrate recovery with sustainability.

R&D FOR GEO-ENGINEERING

The pandemic hit every country, and the associated lockdowns and other actions to mitigate the spread of the disease led to massive economic setbacks. Since governments must relaunch their economies, they should do so with recovery strategies that include substantial investments. These efforts should make economies "greener," more digital, more resilient, and more capable of achieving the Sustainable Development Goals (SDGs) to which all countries have committed. Further, these investments must address the overarching challenge of climate change.

Regretfully, despite the commitments that various governments undertook, it seems unlikely that humanity will be able to limit global warming to 1.5°C or control the increase to below 2°C by the end of the century. It also looks like attempts to reach the interim goal of zero net emissions by 2050 are farfetched. Over the thirty years in which the successive reports of the International Panel on Climate Change (IPCC) gave fair warnings to humanity, the situation has massively deteriorated. CO_2 global emissions were about 22.7 Gt in 1992, whereas in 2019 they reached nearly 38 Gt CO_2, roughly a 66% gain in three decades.[124]

Additionally, and contrary to what some had hoped, namely that economic recessions induced by the public health measures would result in significant reductions in global emissions, the effect of such reductions was minimal, amounting to a slowing down of global warming by no more than 0.01 degrees in 2030.[125]

Global temperatures, on average, have already increased 1.1°C; yet, we can already witness the significant and dire

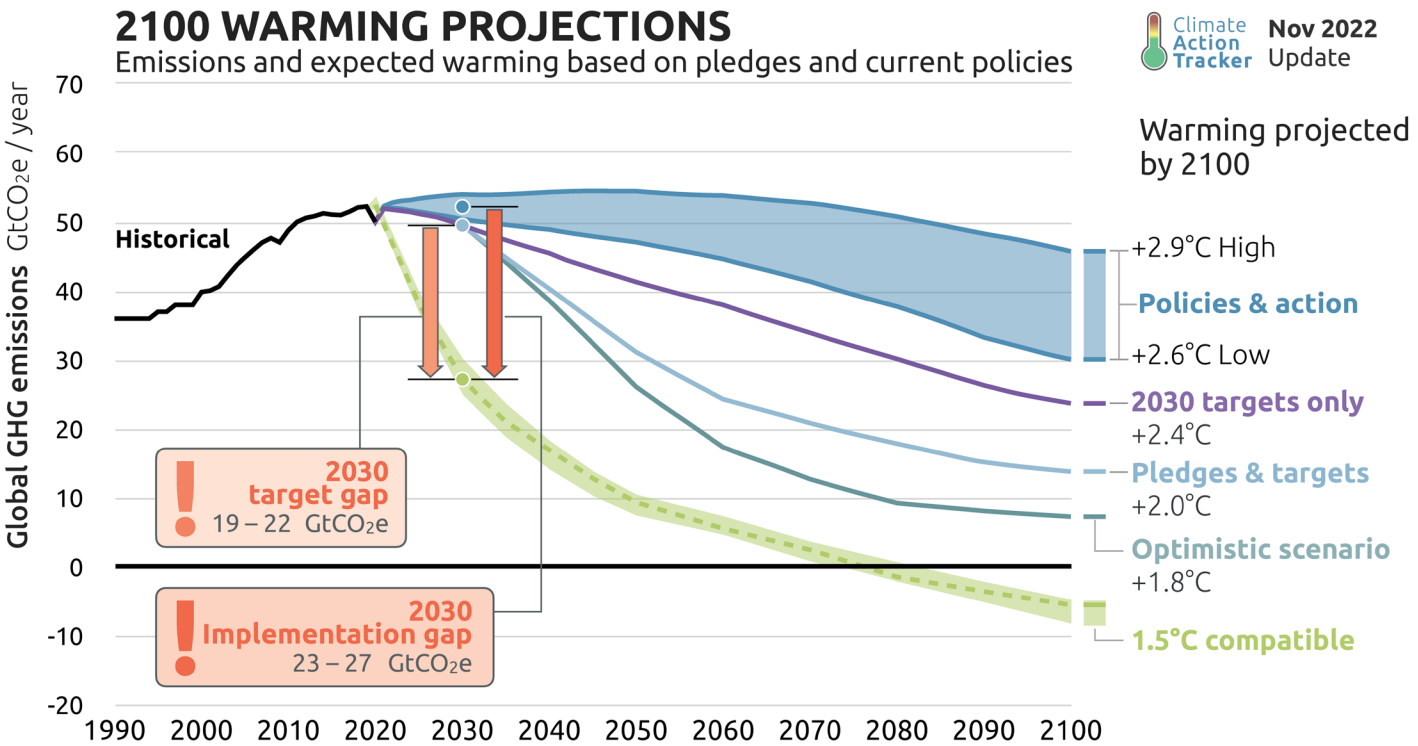

FIGURE 3. Current policies presently in place around the world are projected to result in about +2.7°C warming above pre-industrial levels. Source: https://climateactiontracker.org/global/temperatures.

impacts of climate change on extreme weather events, from heatwaves to hurricanes, forest fires to floods and droughts, and melting ice in the arctic and permafrost.

The most recent IPCC report confirms the previous fears of the scientific community that we are on a path towards an increase of 3-5°C rather than the targeted 1.5-2°C, with concomitant increases in disaster magnitude and frequency risks.[104]

These fears were discussed in 2019, as shown in Figure 3, which reveals that current policies, and even current promises (pledges and targets), lead to increases in emissions and are not compatible with holding global warming to the agreed 1.5-2°C range.

Severe reductions are required to be consistent with 1.5-2°C. However, Vaclav Smil has warned repeatedly that despite pious declarations and promises, we are doubtful to reach the emission reduction targets, noting "Despite this record, we are to believe that the world's reliance on fossil carbon, which now supplies 85% (when excluding traditional biomass energies) or 80% (when including such fuels) of the world's primary energy, will start plunging immediately, recording unprecedented annual declines leading to no emissions in 2050. The experience or realistic forecasts do not indicate such rapid retreat."[126]

Revisiting geo-engineering

Many discussions of geo-engineering solutions to climate change have been set them aside over worries about dangerous side effects that could not be appropriately predicted or are irreversible. Such concerns remain legitimate. However, there might be a role for some forms of geoengineering to remove carbon dioxide from the air, as well as more drastic forms as an option of absolute last resort in the event of tail-end runaway warming and likely mass extinction. No effort should be spared to reduce emissions today to avoid that catastrophe. However, in the event that all efforts today fail to be sufficient, we should be ready to act with alternative solutions, too risky to use in any ordinary climate scenarios. Green recovery pathways might include research investment to study various forms of geoengineering solutions and determine their risk. It is probable that such studies would reveal both opportunities as well as initiatives too risky to advance, even in the worst-case scenario. Some of the ideas proposed to date are described below.

Removing CO_2 from the atmosphere

There are several ideas, including the following:

- Direct Air Capture (DAC) pulls CO_2 out of ambient air and has been implemented on a relatively small scale. Further research is needed to determine whether it can be scaled up significantly.
- Oceans are already one of the planet's major carbon sinks. Research is needed to understand how much more they could absorb, under what circumstances, and with what side effects.
- Green walls, or continent-scale forest barriers, are meant to rejuvenate the land, making large areas of the planet more livable. Such massively deployed reforestation programs could help limit desertification, capture soil moisture, fight drought, and capture excess carbon dioxide in the atmosphere. However, this also impacts the Earth's albedo (or ability to reflect solar energy).

Blocking the Sun

- Inducing rainfall through cloud seeding: Increasing cloud cover and inducing rain have long been discussed, but research is needed to understand if it could be done at scale and what the cost and potential side effects are. Improving the regularity of rainfall in specific locations may be beneficial, but it is unknown if a sufficient level of precision is possible.
- Blocking the sun with aerosols: Aerosols, containing compounds like sulfate, when sent into the Earth's stratosphere, could reflect incoming sunlight and reduce global temperatures. This could be deployed, monitored, and evaluated in stages, with intermittent assessments to understand if this process might have a cooling effect similar to the ash plume from a volcanic eruption. However, like an ash plume, we realize that once aerosols get into the lower stratosphere, they can have adverse side effects, as well as spread out and impact a much larger area, could contribute to acid rain, and have significant impacts on agriculture.
- Blocking the sun with giant parasols: Some researchers suggest deploying a vast, thin, wide sheet of carbon fiber in Earth's orbit to act as a sun shield. While this would block only a small part of solar radiation, it may help limit the sun's overall effect and keep the planet within reach of the 1.5-2°C target.

An emerging consensus

A consensus is emerging around the utility of funding research and undertaking such studies. A Nature Editorial titled "Give research into solar geoengineering a chance" argued there is no substitute for aggressive cuts in GHG emissions.[127] However, the risks of surpassing the 1.5-2°C

target are so significant that all technologies that could mitigate global warming need to be evaluated. In March 2021, the US National Academies of Sciences, Engineering, and Medicine recommended that the US government establish a coordinated federal research program to investigate solar geoengineering. The proposal is based on a major study undertaken by the National Academies and presented in a report entitled "Reflecting Sunlight" which recommends establishing a research program costing the US $100-200 million over the first five years, to assess the potential benefits and risks of solar geoengineering, as well as the ethics and public perception of such technologies.[128] The Royal Society began looking at geoengineering, flagging governance and risks.[129] More recently, in 2019, they published a report that considered the need for careful administration of solar geoengineering research.[130]

Nobody knows if geoengineering would work, how well, or the potential risks. However, given the well-established dangers of the alternative, we would be remiss if we did not fund a comprehensive, scientific evaluation of the risks and benefits of such technologies, including the governance and public involvement required to undertake such a research program responsibly. This is one item that could be included within green recovery packages.

RECOVERY PLANS: ARE THEY SUPPORTING THE SDGS AND PARIS AGREEMENT?

Despite evidence of the opportunities offered by green recovery strategies, evidence of actual progress towards their implementation is still limited. An assessment by O'Callaghan and Murdock determined that, as of December 2020, most countries were not building back better.[10] The authors found that, in 2020, only 13% (US $1.9 trillion) of the total US $14.6 trillion in fiscal spending announced by the fifty largest economies in response to the COVID-19 was for long-term economic recovery. Regarding the European Commission, only 18% of recovery spending and 2.5% of total spending were expected to enhance sustainability. As expected, most green spending occurs in a few high-income countries. According to the Green Stimulus Index 2021 (GSI), the world's leading economies have announced a total of US $13 trillion spending on economic stimulus packages, of which US $4 trillion will go into sectors that have a significant and lasting impact on carbon emissions and nature, namely agriculture, industry, waste, energy, and transport.[132]

Spending patterns in 2020 show that some of the areas offering enormous opportunities to evolve towards intense green recovery include green energy, green transport, green buildings & energy efficiency, natural capital, and green research and development.[10] The latter is consistent with a survey of 231 central bank officials, finance ministry officials, and other economic experts from G20 countries on 25 major fiscal recovery archetypes. They identified five high potential policy areas on economic multiplier and climate impact metrics: clean physical infrastructure, building efficiency retrofits, investment in education and training, natural capital investment, and clean R&D.[16]

Unfortunately, the GSI 2021 showed that most governments failed to implement sufficiently ambitious green recovery plans.[132] According to 2020 data, the announced recovery stimulus to date will have a net negative environmental impact on 15 of the G20 countries and economies, including the US, Australia, Italy, and Japan. Among emerging economies, China, India, and Mexico have announced stimulus measures that will damage the environment, and stimulus funding announced by South Africa and Russia will primarily reinforce the existing, damaging impacts of their environmentally-intensive sectors. Other countries, such as Indonesia and Brazil, still support the carbon-intensive industry, energy, and unsustainable agriculture that destroys biodiverse habitats.

Regarding investment areas, most of the green stimulus measures focus on reducing carbon emissions, with only occasional attention to preserving and enhancing nature and natural capital. For example, only seven of the 25 economies analyzed by the GSI have invested in nature-based solutions (NBS), such as tree planting, forest protection, and regenerative agriculture. Interestingly, NBS investment also created more than 580,000 jobs, which represents a small share of what would be possible with a greater stimulus focus on NBS.

Although the above data strongly suggests that economic responses to the COVID-19 crisis were insufficient to avoid amplifying negative environmental trends, there is an opportunity to learn from countries that have taken the lead. Contrasting with the overall negative pattern, the GSI also reveals some encouraging developments.[132] Switzerland has shown good underlying environmental performance and significant green stimulus measures, resulting in a positive GSI score. Western Europe, South Korea, and Canada devoted a portion of stimulus spending in a way likely to be nature-friendly, coupled with green infrastructure investments in energy and transport. Germany's 'Package for the Future' was the first to include widespread green measures. Over five years, South Korea has announced sig-

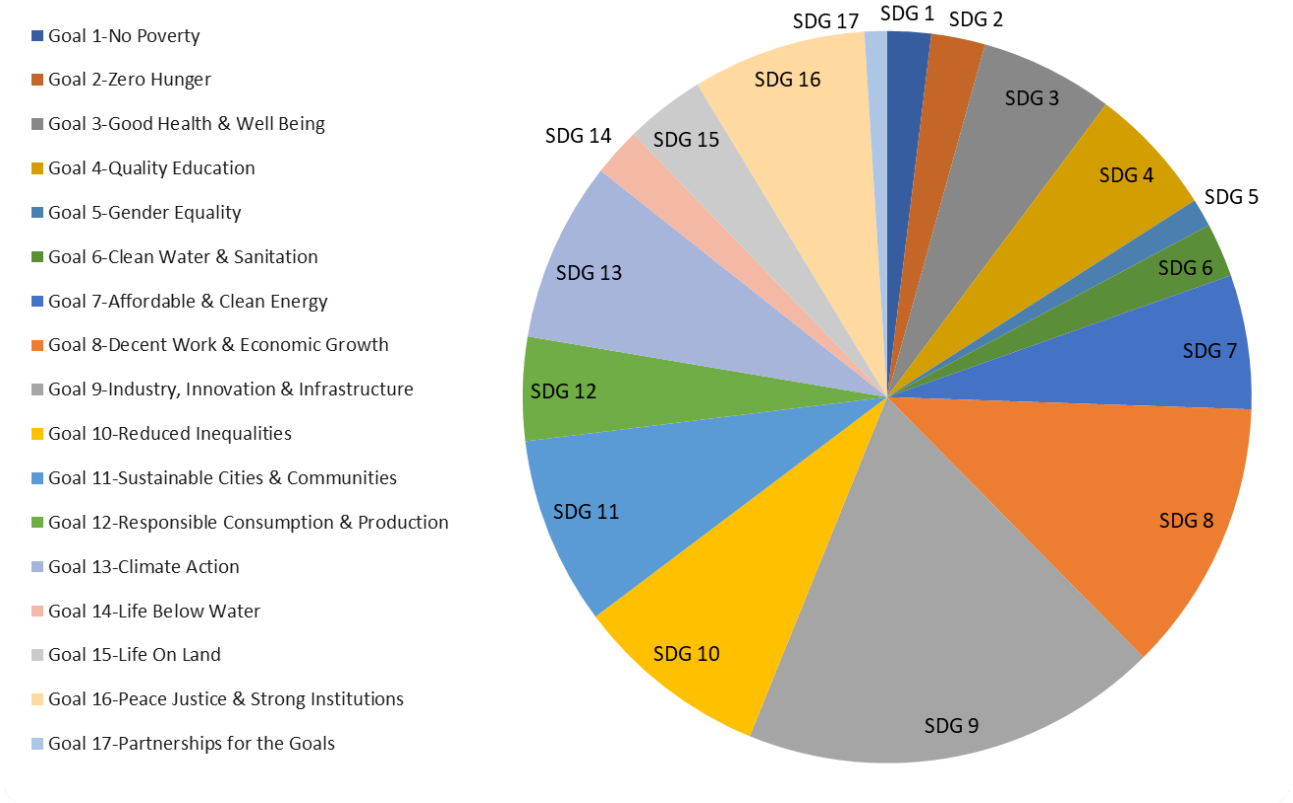

FIGURE 4. Share of total reforms & investments of RRPs of seven South European counrties addressing each SDG.

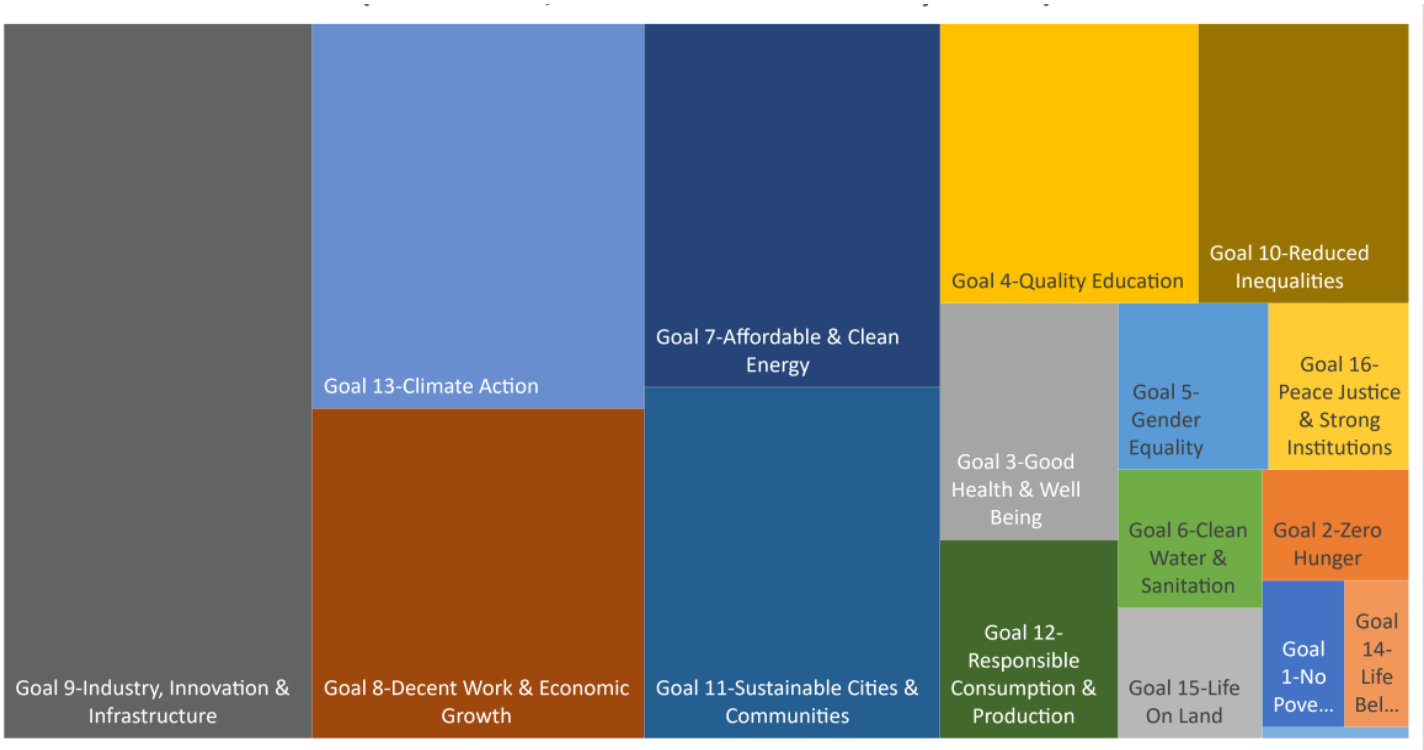

FIGURE 5. Allocation of the recovery budgets of the seven EU member states analyzed to different SDGs

nificant support for its 'Green New Deal'. France's recovery plan, France 'Relance', sets an excellent example of integrating green policy into the economic recovery, as does Spain's 'Recovery, Transformation and Resilience Plan'. The UK benefits from a less environmentally-intensive economy to start, and has decided to retain green rules and policies. Additionally, the UK outlined a 'Ten Point Plan for a Green Industrial Revolution' and has committed significant capital to green endeavors, boosting the UK's GSI score even further. Canada also announced and budgeted funding for effective green stimulus measures over the next ten years, significantly driving its GSI score. A study in Belgium suggests that well-designed public policies can reverse the COVID-19 pandemic's economic damage, while also achieving economic growth and a disproportionally significant decrease in emissions.[133]

There are reasons for hope that green recovery investments will gain momentum.[133] 37% of the €750 billion (US $830 bn) 'Next Generation EU' package will be directed towards green initiatives, half as grants and half as loans. It includes targeted measures to reduce dependence on fossil fuels, enhance energy efficiency, and invest in preserving and restoring natural capital. On the other hand, the Biden administration in the US will be critical in shaping the future direction of the massive US stimulus in the world's biggest economy.

The 'Next Generation EU' program has unique features, as few countries or regions have announced medium-term programs (as opposed to annual budgets) covering the entire economy (and not just packages for specific economic sectors) and addressing recovery spending (and not just financial relief spending). Therefore, the EU's approach can serve as a valuable case study on the consistency of short- and medium-term policy priorities with the officially declared long-term goals towards the sustainability transition.

The central part of the 'Next Generation EU' package is currently funding most EU member states according to specific Recovery and Resilience Plans (RRPs). These plans contain investments and reforms that national governments submitted to the European Commission, the EU's executive body, in spring 2021, the first of which were adopted by EU leaders in summer 2021.[39] Among other legal obligations, countries had to contain a minimum amount of funds devoted to climate policies and digitalization (at least 37% and 20% of the RRP budget, respectively). However, EU countries were not obliged to align their RRPs with the SDGs. This lack of an explicit linkage makes it challenging to assess whether the recovery packages indeed address all significant environmental, social, and economic sustainability challenges in each country beyond the minimum requirements for climate- and digitalization-related spending. To overcome this challenge, in its annual report on the progress of European nations towards the achievement of the SDGs,[134] SDSN Europe included an analysis of the RRPs of Spain and Italy against all SDGs. As a result, these two countries will receive the most significant portion of the €750 billion packages. Furthermore, the recent report of the SDSN's Senior Working Group linking the SDGs with the European Green Deal (EGD) contains a similar analysis of seven in total EU member states benefiting from this recovery package.[31] Figure 4 and Figure 5 demonstrate the main results from the study of all seven countries (Bulgaria, Croatia, Cyprus, Greece, Italy, Slovenia and Spain), which will receive half of the EU recovery grants and an equally substantial portion of the corresponding EU recovery loans.

Overall, SDSN Europe's analysis has found that all 17 SDGs are addressed in the recovery plans of most EU countries, albeit to different degrees. However, the SDGs mostly covered, in terms of the number of stimulus measures and budget allocated, are not always those on which countries face the biggest sustainability challenges. In particular, although several European nations demonstrate relatively poor performance on transforming food systems and diets and achieving biodiversity goals, these challenges have received less attention in RRPs than green energy, electrification of transport, and energy efficiency measures. Although this misalignment is partly understandable because the 'Next Generation EU' package must be executed before 2026, and should include 'shovel-ready' projects, the minor focus on systemic issues such as the agri-food sector and biodiversity calls for increased attention of EU nations to these topics through other post-pandemic public and private investments.

HEALTH CO-BENEFITS OF GREEN RECOVERY

The co-benefits of climate change mitigation for health started to be systematically considered in the late 1990s. Early studies showed significant health co-benefits of mitigation interventions. For example, a study examining strategies to mitigate emissions from household energy showed that the UK housing sector generally benefited from health interventions.[135] A strategy of combined fabric, ventilation, fuel switching, and behavioral change, was associated with 850 fewer disability-adjusted life-years (DALYs), while saving 0.6 megatonnes of carbon dioxide (CO_2) per million people in 1 year. A mitigation strategy

in India was associated with 12,500 fewer DALYs and saving 0.1-0.2 megatonnes CO_2-eq per million population in 1 year, mostly in short-lived greenhouse pollutants. Regarding land transportation,[136] it has been found that in two cities (London, UK, and Delhi, India) reduction in GHG emissions through increased active travel and less use of motor vehicles would provide the most considerable benefits (reductions of 7,439 DALYs in London, 12,995 in Delhi), notably from a reduction in the number of years of life lost from ischemic heart disease.

Using more sophisticated comparative assessment methods to inform the COP16 climate summit, Hamilton et al. modelled scenarios to analyze the health co-benefits of Nationally Determined Contributions (NDCs) for the year 2040 for Brazil, China, Germany, India, Indonesia, Nigeria, South Africa, the UK, and the USA. The assessment included the energy, food and agriculture, and transport sectors, and mortality related to risk factors of air pollution, diet, and physical activity. The study compared the health co-benefits in two alternative scenarios, one consistent with the goals of the Paris Agreement and the SDGs, and another that included health in all climate policies. Compared with the baseline, the Paris Agreement-SDGs scenario resulted in an annual reduction of 1.18 million air pollution-related deaths, 5.86 million diet-related deaths, and 1.15 million deaths due to physical inactivity across the nine countries 2040. Adopting the more ambitious health in all climate policies scenario further increased the number of prevented deaths.[137]

An area of increasing interest is sustainable food systems. Recent evidence suggests that significant health and environmental benefits could be achieved by adopting appropriate dietary guidelines. To assess how much current food-based dietary guidelines (FBDGs) at a national level comply with the environmental targets of the Paris Agreement and several other planetary boundaries, Springmann et al. conducted a modelling study in 85 countries.[138] When universally adopted, the majority of FBDGs (67-87%) were incompatible with the Paris Climate Agreement and other environmental targets; by contrast, adoption of recommendations from the EAT-Lancet Commission on Food, Planet, and Health was associated with 34% greater reductions in premature mortality, more than three times greater reductions in GHG emissions, and general attainment of global health and environmental targets.[138]

The multisectoral approach as used by Hamilton et al. is consistent with a recent systematic review based on thirty-six studies and, using narrative reviews, the authors assessed GHG mitigation strategies in energy generation, transportation, food and agriculture, households, and industry and economy measures that include more than one sector, reinforcing the concept that GHG mitigation strategies can bring about substantial, cost-effective public health co-benefits.[137]

The magnitude and distribution of economic gains from health co-benefits were recently compared to the financial cost of mitigation. Markandya et al. (2018) assessed the ratio of air pollution abatement health co-benefits to the cost of achieving the targets of the Paris climate agreement (both 2°C and 1.5°C) under different scenarios.[18] The ratio of the value of health co-benefits to the cost of mitigation ranged from 1.4-to 2.45, depending on the plan. At the regional level, the costs of reducing GHG emissions could be compensated by health co-benefits alone for China and India, whereas the proportion varied but could be substantial in the EU (7-84%) and the USA (10-41%), respectively. This and other similar economic studies strongly support the role of large-scale financial investments in climate change mitigation worldwide.

A relevant gap in the current evidence is related to the social distribution of co-benefits and to what extent these co-benefits, if materialized, will reduce existing inequalities. For example, a recent study modelling the co-benefits of climate action in the UK has suggested that, despite overall improvements in exposure to air pollution, current health inequalities will remain.[139] Another relevant gap relates to gender equity in climate recovery policies.[140,141,142] Both social and gender equity in green recovery are crucial as the COVID-19 pandemic has increased the already significant inequalities in place before the pandemic.

Although modelling comparative assessments based on mitigation scenarios is subject to many different sources of uncertainty, it should be emphasized that the health co-benefits considered in the studies reviewed above are those for which causal evidence is well established and that the actual health co-benefits are likely to be greater than those considered so far.

Many studies question the possibility of green growth (or implicitly green recovery).[143,144] Their main thrust is the lack of evidence for decoupling – meaning that economic growth can proceed whilst environmental impact stagnates (relative decoupling) or even declines (absolute decoupling).[145] In addition, it is argued that technological progress alone will be unable to keep humanity within planetary boundaries and substantial reductions in consumption – termed degrowth – are required, mostly from high-income countries.[146,147,148] What is essential in this context is that such degrowth must not mean reducing happiness and health.[149] Research shows that behavioral

change towards downscaling is often accompanied by an increase in well-being.[150] These insights have significant implications for strategies promoting green recovery, in that messaging needs to address consumers, and assist them in overcoming denial and accepting grief, ultimately creating and reinforcing a sense of contentment over status and affluence.[151,152,153,154,155]

PUBLIC INVESTMENTS IN ENVIRONMENT AND HEALTH

In public project appraisal the public authority must determine today how future costs and benefits are weighed in the appraisal of investments. In cost-benefit analysis, and economic welfare analysis more generally, this weight is determined by the Social Discount Rate (SDR), which measures the rate at which values that accrue in the future are lessened by their futurity. In the context of health and the environment, specific considerations are required to ensure the welfare implications of investment in these areas are coherently valued. Some of these considerations are already present in the government and guidelines and a reminder of this fact is required. Other considerations are not always present, and ought to become more central to public investment appraisal.

With health investments in general it is important to take into account how the relative prices of health change over time. As incomes increase in society, health outcomes become more highly valued, and willingness to pay for these services increases relative to other goods and services. Values that increase relatively with the time horizon of project appraisal should be accounted for carefully in project appraisal, and most government guidance is careful to state that relative price changes should be considered. For example, the UK's so-called Green Book makes clear the need to account for relative prices, as does the Netherlands' Central Policy Bureau working group recommendation on the SDR, and France's Quinet Report. Increasing relative prices is another way to say that the weight on health and health care is increasing in the future, and for marketed services the prices used for appraisal should reflect this. However, many health services are non-marketed. An equivalent way in which to take into account relative price effects for non-marketed aspects is through the SDR in a so called dual discounting approach.[156,157] Rising relative prices for non-marketed aspects of health manifest in a lower discount rate for health services. In particular, the UK government takes the position that the value of health services in general increases at the same rate that incomes grow (the per capita growth rate). This has the effect of removing the 'wealth effect' component of the SDR and reduces the SDR for health services from 3.5% to 1.5%, applied to Quality Adjusted Life Years (QALYs). A normative interpretation of this practice is that health should not be discounted just because we are richer in the future, as health is equally valuable to rich and poor societies. Similar adjustments to discounting for health are recommended elsewhere, including the US, Belgium and the Netherlands. Freeman et al. (2018) make clear that the cost of health care provision may also decline in the future, which has an opposite effect. Yet, the lower discounting of benefits is still recommended for similar reasons.[158] The 2015 discounting working group for the government of the Netherlands also addresses this point for health.

Dual discounting/relative price effect is important for the evaluation of the environmental costs and benefits of public investment in green growth. Increasing scarcity of non-marketed environmental quality and ecosystem services means increasing relative value to society, or equivalently a lower discount rate applied to environmental change.[159,160] If environmental degradation approaches a tipping point or minimum threshold for sustainability, an SDR that declines with the time horizon under consideration should be applied to environmental change.[161] Nowhere have the potential impacts of rising social value for the environment been demonstrated more clearly than in relation to the economic evaluation of climate change, where relative scarcity has the same effect on mitigation as a reduction of 1% in the discount rate, increasing the optimal carbon tax commensurately. Wagner and Kelleher (2017) make the same argument for the SDR in the context of climate change as the UK government does with regards to health; the benefits of reducing climate damage increase with income, and so the wealth effect of the SDR should be removed.[162] Comprehensive evaluations of public projects for green growth should follow existing guidelines on relative prices carefully, and ensure that the appropriate weight is placed on future environmental and health impacts.

The future is uncertain however, and future well-being, health, and environmental quality (e.g., climate change and biodiversity) depend on stochastic processes. These factors should also be taken into account in welfare analyses and the public appraisal of projects. For projects which provide certain benefits in the future, the fact that growth is uncertain provides an argument for a lower discount rate, to protect against future outcomes in which we are worse off than today. For longer term projects and policies, if uncertainty in growth increases with the time horizon considered, then a declining discount rate should be used.[163,164,165] This policy is also present in current guide-

lines in many countries, including the UK.[166]

Further adjustments are needed to the SDR when the project's net benefits are also uncertain. If net benefits are positively correlated with how rich society is in the future, projects have a high payoff precisely when it is valued less, due to diminishing marginal utility. Transport infrastructure would be a good example, as it exhibits higher usage when the economy is booming. When the correlation is negative, i.e., higher net benefits in economic recessions, then the project adds more to social well-being precisely when it is needed. This insurance type property is often found in health-related projects. For transport projects the project risk should be reflected in a higher discount rate. For health-related projects, a lower discount rate. These asset-pricing principles are well known and appear in government guidelines. (This argument is the standard Consumption CAPM argument, where the project "beta" reflects the correlation, and a systematic risk premium adjusts the discount rate up or down depending on positive or negative correlation with secular growth. The most recent discounting guidelines for the French government discuss this issue and provide evidence on transport and health betas, inter alia).[167] The correlation of environmental benefits with growth (the environmental "beta") is an active area of research.[168,169,170] The size of the correction depends on how risk averse society is.

Many environmental problems are not just risky, but have potentially catastrophic downsides. Catastrophic risk, even when occurring with a very low probability, can have important effects on the appraisal of public investment. The implication of catastrophic risk for asset-prices can be found in Barro,[171,172] who shows that for sure projects, the appropriate discount rate is dramatically reduced when the prospect of deep recession (such as the Great Depression of the 1930s, or the financial crisis of 2008 onwards) is included. For risky projects, adjustments to the SDR should reflect the project beta.

In relation to the environment, Weitzman (2009) showed that, in the presence of catastrophic risk with "fat tails" (not vanishingly small probabilities of catastrophes), an infinite weight should be placed on future damage reductions.[173] While this extreme result has been attenuated by subsequent scholars,[174,175] the point remains: investments in climate change mitigation are extremely valuable for future generation because they reduce the risk of catastrophe. These principles have powerful implications for the appraisal of green growth strategies at the macro level, and green growth project appraisal.

In the context of pandemics and green growth, the principles of how to treat future costs and benefits in the presence of risk have clear relevance. In terms of health investments in general, these are likely to have higher pay offs in the event of recessions and deep depressions (catastrophic risk a la Barro). Indeed, looking back over the past 10 years or so, it seems clear that greater investment in health in the past would have had an enormous payoff now, during the pandemic and its associated economic downturn. This ex-post reflection is an intuitive way to think about the ex ante implications for project appraisal and public investment in health and the environment. Indeed, these principles have been discussed by the work funded by the Bill and Melinda Gates Foundation in their analyses of the value of health interventions.[176,177]

Public investments in health or green growth, and the evaluation of Green Growth in general, need to carefully weigh the well-being of future generations and the future costs and benefits that will affect their well-being.[160,162,176,177] Investments in health and environment have unique characteristics that affect the Social Discount Rate with which their net benefits over time should be appraised to ensure that they provide social value.[158,159,160,175] First there are long-run, intergenerational implications which can justify declining SDR if the net benefits are certain.[162,163,168] Second, relative prices of health and environmental quality are likely to increase due to scarcity or income growth.[156,159,160,178,179,180,181] Increasing relative prices can justify a lower SDR for health and environment. Third, investments in health, pandemic prevention, and environment is likely to have insurance type properties in that they, particularly health investments, pay off more in times of recession.[167,176,182] Finally, in relation to global problems such as pandemics or climate change, the avoidance of catastrophes cannot be ignored in the evaluation of green growth.[172,173,174,183] Be it the prospect of an ensuing depression associated with a pandemic,[172] or a climate shock,[173] the catastrophe insurance properties of investments in health, climate change mitigation, ecosystem conservation, and biodiversity conservation should be clearly and systematically embodied in green growth strategy and public investment appraisal.[176,184]

COVID-19 AND BIODIVERSITY

Green growth should be sustainable growth. Globalization has ensured that our economic fortunes are entwined via trade and the complex supply chains that it entails. Any green growth strategy should take an international perspective and consider greenness in relation to both consumption and production, rather than focus solely on domestic production impacts. The origins and implications

TABLE 4. The Financial Cost of Pandemics[184,185]

PANDEMIC	ECONOMIC COST (USD 2020, BILLIONS)
COVID-19 (2019-2020, to date (20/11/20)[a]	8000-16000
Ebola (2014) [a]	53
Zika (2017) [a]	7-29
SARS (2003) [b]	40-80
Spanish flu (1918) [b]	3000
World Bank Prediction of pandemic cost in 2007 (Influenza, avian flu)	800

of the COVID-19 pandemic illustrate why this is important. The cost of the COVID-19 epidemic has been enormous, and fits with Barro's definition of a catastrophic downturn.[171,172] Previous pandemics had similar proportional effects on the regional or global economy (Table 4). Other studies have shown long-lasting effects of pandemics as a result of fetal exposure.[185] The economic effects of the current pandemic may be far from over, even when vaccination rates are high.

The IPBES pandemic report notes that all pandemics have been caused by zoonoses and the interaction of humans with the natural environment,[184] particularly the degradation thereof. There is a well-defined wildlife-livestock-human transmission pathway that arises through these interactions. Land-use change such as deforestation and intensive agriculture, both related to international commodity trade, as well as contact via the wildlife trade are central to this transmission. IPBES (2020) explains that there are over 600,000 viruses that could infect humans through increased human contact with livestock and wildlife.[184] The link between pandemics, land use change, and biodiversity loss are complex and sometimes contested.[184] It is estimated, however, that 30% of emerging disease events are due to land-use change from deforestation and human settlement. An average of five new diseases emerge per year, and it is believed that this risk is increased due to continued land-use change and degradation of ecosystems. Biodiversity, it is argued, can be an attenuating factor in emergence and transmission, and so biodiversity loss is also an important contributor to this risk.

There are many reasons for halting the degradation of terrestrial ecosystems in tropical areas, ranging from global ecosystem services (e.g. climate regulation and genetic-diversity for medicine and crops), to local ecosystem services (regulatory, provisioning, and supporting). Emerging infectious diseases are yet another important reason. The cost of pandemic prevention via biome and ecosystem protection is estimated to be a fraction of the expected costs of pandemics.[184] Any strategy for green growth should introduce policies to reduce ecosystem degradation in tropical areas for all of these reasons. To the extent that trade and international capital facilitate environmental degradation, green growth policies should address such dimensions of consumption and trade. Zero-deforestation consumption goods, nature based financial disclosure, and improved ESG metrics should accompany area-based policies in situ in tropical areas. Commitment to internationally-agreed goals such as the UN Sustainable Development Goals, the Convention on Biodiversity, the CITES treaty on trade in endangered species, and the next set of commitments adopted at the CBD COP 15 are also essential for a post-COVID green growth strategy.

Pandemics such as COVID-19 are examples of the catastrophic outcomes of environmental degradation, agricultural intensification, and trade in wild species. The potential for catastrophic outcomes of climate change has sharpened climate change policy.[173] Similar arguments apply to the environment and biodiversity and should be part of any broad definition of Green Growth.

FINANCING GREEN RECOVERY

SUSTAINABLE, LONG TERM FINANCE AND FISCAL POLICY IN THE RECOVERY FROM COVID-19

The COVID-19 pandemic completely altered the landscape of international economies and rolled back or even halted progress on the 2030 Agenda. The short-term response, mainly through economic injections, has failed to account for mid- and long-term effects and objectives. There is a critical need for a more integrated and forward-looking vision that places sustainable recovery at the center.

The United Nation's 2021 Financing for Sustainable Development Report puts forward proposals to change this trajectory by mobilizing investments in people and infrastructure that is aligned with the 2030 Agenda.[187] Crisis response packages that focus on prevention, risk reduction, and protection of the most vulnerable can stimulate economic growth while strengthening resilience to future shocks and helping achieve the SDGs.

Solutions rely on developing strategies with very long-term lending and investment horizons. Providing access to relatively short-term market finance alone is not the answer; as seen in some countries, this will exacerbate the risk of debt distress. Relying on private finance to fill all the gaps is also an incomplete solution, as it is suitable in some but not all SDG contexts. Moreover, capital markets should be re-oriented towards investing in sustainable development-aligned priorities by encouraging the removal of short-term incentives along the investment chain. The current business model, which prioritizes short term financial returns for shareholders, is not conducive to supporting businesses' contributions to the SDGs.[188] Regulation and innovation will only converge when investment is stable.[189]

The EU must decide how to govern resilience and recovery strategies to promote sustainable development and public value, starting with existing policies so that Europe's response to the crisis does not rely on "leftover ideas." However, austerity-driven nation-state bailout conditions weakened resilience to future shocks and fragmented inter-European partnerships. Pre-pandemic EU policies, including the Industrial Strategy; the European Green Deal (EGD), with its pledge to "leave no one behind," and the Just Transition Mechanism; ongoing work on the Circular Economy, Biodiversity, and the "Farm to Fork" sustainable food strategy; and the mission-oriented approach underpinning Horizon Europe, have also been embraced by member states and sub-national governments.

There is no shortage of money; the challenge is to direct it efficiently towards narrowing the innovation gap. The Next Generation EU Recovery Package can and should help redirect growth towards innovation, long-termism, and resilience; it should require member states to prioritize challenge-oriented areas, including green, digital, and healthcare investment. The SDGs should be used to guide conditions placed on available funds. Financial markets were flooded with liquidity in 2008 due to unconditional bailouts. It is possible to link COVID-19 relief conditionalities to sustainable outcomes, and there are differences between 'emergency' liquidity lending (which can be challenging to attach restrictions too) and longer-term lending directed towards recovery.[190] Conditions can be applied to the latter to ensure that bailouts are organized in ways that save sectors while also investing in employees and preparing them for new technology. Conditionalities should not be perceived as creating hurdles to doing business. Companies that pivot quickly will be the most competitive, innovative, and long-lasting.

THE URGENT NEED TO FUND THE SDGS

The global coronavirus pandemic spotlights our global interdependencies and interconnectedness, reinforcing the urgency of meeting the United Nations Sustainable Development Goals (SDGs), and representing a potential red line between a carbon past and a cleaner, more empowered future. The coming transition period between these two eras calls for unprecedented responses by states, organizations, and individuals.

The 17 SDGs represent a baseline level of progress that needs to be achieved in the next decade to establish a sound foundation of sustainable development for future generations. However, with less than a decade to go until 2030, the achievement of the SDGs is at serious risk. Further, the interconnectedness of the goals means that failure to address any one goal hinders progress on others. This creates systemic risk for the world should the plans be missed, creating a potentially vicious circle of environmental degradation, political upheavals, economic disruption, conflict, and human security risk, making the need of meeting the SDGs an urgent one for the world.

Funding requirements and gaps.

Continued underspending, the increasing costs of meeting the goals, and the setbacks suffered from the COVID-19 pandemic are widening the SDG funding gap, previously estimated at US $4.2 trillion per annum.[191] However, a more recent bottom-up estimate that includes the costs of meeting increasing commitments under the Paris

Agreement and the cost of creating financial inclusion and prosperity for large parts of the world found that the actual funding gap is likely twice as high or more.

Additional estimates of the actual SDG funding gap range from US $8.4 trillion to US $10.1 trillion, equal to 9-11% of the estimated 2021 global GDP.[192] This compares to an estimated current annual spending of US $3.2-4.1 trillion on the SDGs,[193] bringing the total yearly cost of achieving the SDGs to US $11.6-14.2 trillion every year through 2030 (Figure 6).

An analysis of current spending against the SDGs highlights that the overall volume of financing is insufficient and that its allocation is imperfect. In 2020, 40 of the world's leading financial institutions which explicitly supported the SDGs deployed a record total of US $2.1 trillion of capital in furtherance of the 17 goals. Despite these record amounts, their stated priorities in terms of individual SDGs, fiduciary and commercial mandates, and the distribution of their funding points to gaps for consideration, particularly on specific goals.

While climate-related goals account for about 22% of the SDG funding requirement, they receive about 44% of the current funding. This is expected, given that a strong business case has been established for renewables and green investing. However, the total financing need still exceeds current commitments, and climate targets are unlikely to be met (even with sufficient funding) if other SDGs relating to uplifting the developing world economically and socially are not sufficiently addressed.

While most institutions do not specifically indicate the location of their sustainability investments, it is apparent from analysis of disclosed information that most of the current spending appears to be allocated to advanced economies. This is natural for many reasons, ranging from the location of the financial institutions and where carbon polluting industries sit (given the concentration of SDG funding on climate goals), but it leaves developing countries with more outstanding shortfalls in investment to address other SDGs.

There is a significant shortfall in funding for the human, economic, and social SDGs. These goals account for about 40% of the total funding need, but only 32% of current funding. As the shortfall is unlikely to be made up elsewhere – from local government transfers, charities, government aid, international organizations, and other stakeholders – these goals stand to be unmet.

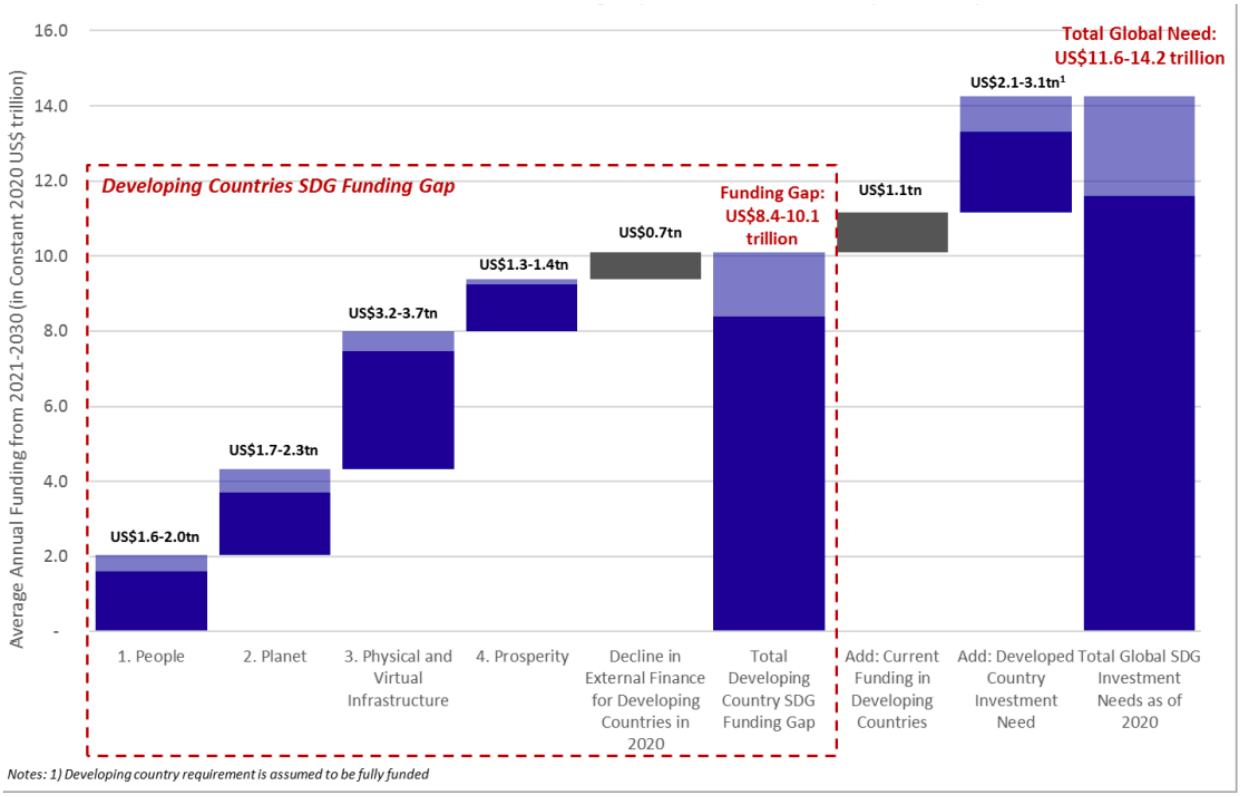

FIGURE 6. The Annual Sustainable Development Goal Funding Gap.
Source: Force for Good, 2021, Capital as a Force for Good: Capitalism for a Sustainable Future, page 42. Available at https://www.forcegood.org.

A multi-stakeholder funding effort, with an over-weight role for the finance industry.

Funding the US $84-101 trillion shortfall through 2030 is a challenge beyond governments' capacity and ability, and requires private sector capital deployed at scale. On the positive side, the largest global financial institutions are rapidly scaling their commitments in this regard through multi-pronged engagement strategies, making investments using increasingly comprehensive ESG tools promoting businesses and activities related to the goals, increasing their sustainability financing, and engaging with stakeholders more broadly, particularly in the form of community financing to drive inclusion and prosperity. In addition, a small number of the largest institutions are breaking new ground in this respect, engaging in a 'race to the top' in both the depth and breadth of their engagement by developing the business cases that allow them to deploy their capital for both profit and impact (Box 2).

However, while the finance industry, as the steward of over 85% of the world's gross liquid assets, clearly has a critical role to play in funding sustainable development, it cannot solve the challenge alone, given the multi-stakeholder nature of both the SDGs and the financial system itself. For example, asset managers have a requirement to deploy capital according to the mandates that clients sign up for, and these have parameters such as themes, sectors, geographies, returns, risks, and duration as part of their scope and limitations. Clients must be on board to change these factors. Once the broad spectrum of specific issues is examined, it quickly becomes apparent that solving the deployment of capital requires cooperation and is, therefore, a collective issue and needs a range of specific multi-stakeholder solutions.

Funding sustainable development and a transition to the future will require the coordination of governments, individuals, and private corporations beyond traditional financial services companies. Individuals own $255 trillion of liquid assets and represent 80% of the world's consumption. Acting collectively, the individual can mobilize systemic change and redirect the global flow of funds. Unlocking this collective action will likely require technology platforms, mainly social media platforms, which have built deep relationships with over half the world's population, implying an essential role for 'Big Tech' too. Further, despite their limited direct spending capacity, both developed and developing country governments have vital roles in unlocking development investment from the private sector, acting as arbiters of policy and bridges, and as enablers for private capital. Development finance institutions, for example, have long invested in projects and countries where the risk-return requirements of financial institutions and their clients have excluded the private sector and so have a depth of experience. They also have a clear mandate to drive capital towards sustainability and development and can partner with the private sector finance industry, for example by filling gaps where it is not viable for private financial institutions to provide funding alone.

Efficient collaboration between these parties will require a shared blueprint of goals, deliverables, roles, and actions

BOX 2. RACE TO THE TOP – GROUND-BREAKING COMMITMENTS BY FINANCE INDUSTRY LEADERS

- Trillion Dollar Financial Commitments to Drive the SDGs – $7 trillion of capital committed to the SDGs (by five institutions)
- Redefining Scale in Climate Change Commitments – $690 billion mobilized for environmental finance (by ten institutions)
- Driving Inclusion for Under-Served Communities – $407 billion of community finance for sustainable and inclusive deployed (by ten institutions)
- Championing Underfunded SDGs – $104 billion of commitments targeting neglected SDGs focusing on ending hunger, delivering clean water, and cleaning the oceans
- Prioritizing Critical Social Issues – $33 billion committed to advance racial equality over the next ten years (by five institutions)

Source: Force for Good, 2021

for the world to own. This would need to include new rules of engagement, new principles of competition and collaboration, new resource management regulations, and new fiscal and monetary policy directions, while encompassing a diverse range of national strategies, power blocs, and international coalitions. Such global blueprints have traditionally been the remit of the UN, which has convened its member states to build consensus on the most significant issues facing the world and promote united action. Given the projected future flows of global capital, the UN will need to include the four major power blocs (initially the US, EU, and China, and given its scale and rise, India) at an early point and will quickly need to expand beyond national governments to become a true global compact. However, existing political and economic structures are not on track to develop this blueprint for financing, despite its urgent priority.

Funding the future – key themes for execution and investment

Capital to fund the SDGs, the future, and the transition between the two cannot be mobilized as a charitable endeavor, nor funded by governments through taxes, or deployed at a loss by private sector investors. Hence, the vast majority of the world's capital requires investment themes where profits are made at sufficient levels to reward bold action and risk-taking, allowing for re-investment in the future while providing for employment, taxes, social security, and pensions today.

Taking a lesson from the business case for climate change, simplicity is essential, and these themes need to make the SDGs more accessible. The SDGs can be grouped into four critical financial investment platform categories: people, planet, prosperity, physical and virtual infrastructure, and an enabling one that cuts across them all, peace and partnerships.

The macro investment themes, from the work of the 2021 Capital as a Force for Good: Capitalism for a Sustainable

Category	Estimated Annual Funding Gap for SDGs	% of Total	Total Funding by Industry Leaders in 2020	% of Total
People	US$1.6-2.0tn	21%	US$0.2tn	10%
Planet	US$1.7-2.3tn	23%	US$0.8tn	40%
Physical & Virtual Infra.	US$3.2-3.7tn	40%	US$0.6tn	29%
Prosperity	US$1.3-1.4tn	16%	US$0.4tn	21%
Total	**US$7.7-9.4tn**	100%	**US$2.1tn**	100%
Decline in External Finance For Developing Countries in 2020	US$0.7tn			
Total Developing Country SDG Funding Gap	**US$8.4-10.1tn**		**US$2.1tn**	

Notes:
- *The funding gap represents incremental funding required while the funding by industry leaders is a total number*
- *The 2020 sustainability funding by the 100 industry leader in the dataset has been split into the categories based on the types of products financed, and is indicative given that most institutions do not report a detailed breakup by SDGs*
- *Additionally, the geographic allocation of the 2020 sustainability funding by the 100 industry leaders is not available, so it is not possible to ascertain how much of this financing was going towards addressing the funding gap in developing countries*

FIGURE 7. Mapping Current Sustainability Financing to the Total Funding Gap for the SDGs.
Source: Force for Good, 2021, Capital as a Force for Good: Capitalism for a Sustainable Future, page 97. Available at https://www.forcegood.org

Future report,[192] which conducted an extensive analysis of and engagement with 100 leading financial institutions, DFIs, tech companies, and fintech businesses, indicating the scale of challenge and ambition required, whose funding will determine the shape of this global transition provide examples:

I. Platform. A better and more sustainable future platform for the world, including laying the foundations for the future. Key focus areas include:
- Closing the SDG Funding Gap, by investing US $116-142 trillion, an additional US $84-101 trillion, over the next decade, with major financial institutions partnering with other stakeholders to adopt the SDGs, particularly the most neglected.
- Mobilizing the Individual, shaping the flows of $49 trillion of annual household spending globally[ii] as the individual becomes a responsible consumer and investor (reflecting the growing awareness of the power of the individual as a collective and potential force for good).
- Stakeholder Aligned and Resilient Companies, influencing the priorities of the 99% of global companies not yet fully aligned to the SDGs,[194] reflecting the resilience that comes with businesses that are relevant to the values of sustainability in the world and ready to tap the US $12 trillion in business opportunities associated with the SDGs.[195]
- Radical Energy Breakthroughs, enabling a step-change in human civilization with energy sources that are a breakthrough in functionality while being clean, affordable, reliable, and abundant (funding the future energy for a new society).

II. People. Addressing basic human needs. Key focus areas include:
- Food and Water Security, increasing global food production by 70% to meet rising demand by 2050; providing safe, nutritious, and varied food for 9.7 billion people (turning low productivity arable land into industrial-scale yield while maintaining farmer ownership).
- Resilient Healthcare and Social Security Systems, caring for the 3.9 billion people who lack access to critical healthcare services, recognizing universal health care and social security as a fundamental human right.
- Mass Education and Skill Development, including better awareness and mental resilience, using digital platforms to break the boundaries of location and local restrictions (moving beyond education to a more inclusive, aware, and resilient population).

III. Prosperity. Creating shared prosperity. Key focus areas include:
- Mass Financial Inclusion, providing financial access and services to the 67% of the world's population that remains un- or underbanked,[196] including moving beyond basic bank accounts to meaningful inclusion in the financial system, such as access to credit.

IV. Planet. Saving the planet. Key focus areas include:
- Mass Scaling of Existing Green Energy Solutions, replacing 83% of global energy still generated by fossil fuels;[197] going beyond net-zero, representing a replacement of the current infrastructure to net negative.
- Regeneration of the Environment and Ecosystems, renewing 20-40% of global land area estimated to be degraded or degrading to varying extents and degrees,[198] and cleaning cities and industries (enhancing the SDGs by also restoring urban and industrial environments for what has been destroyed, at scale).

V. Physical and Digital Infrastructure. Enabling human activity.
- Reimagined Urban Life, creating sustainable living for the 2.5 billion new urban inhabitants expected by 2050,[199] in the face of migration within and across boundaries (beyond 2030, reflecting the rise in urbanization).
- Global Digital Participation and Inclusion for the over three billion people without internet access;[200] this is a universal project which goes beyond the agreed SDG access goals to move forward together.

Realizing these themes holds the promise of a stable transition to a very different world from today's sustainable information age. This world would be one of universals – universal connectivity, universal inclusion, universal education, and universal healthcare access – eliminating hunger, illiteracy, diseases, and countless unnecessary deaths. Such a world would also be abundant in food, water, energy, and life's essentials, eliminating absolute poverty and creating economic opportunities for all. And such a world would be one of balance, with regenerated ecosystems and manufactured and natural environments operating in harmony, promoting biodiversity and thriving communities.

ii According to IMF data, individual consumptions is the consumption by households and non-profit institutions serving households (NPISH).

ECONOMIC VALUATION OF ECOSYSTEM SERVICES

Natural capital refers to the world's stocks of natural assets such as forests, fisheries, rivers, biodiversity, land, and minerals. Biodiversity can be defined as the variability among living organisms from all ecosystems of which they are part, covering richness, rarity, and uniqueness. This definition captures both the living and non-living aspects of ecosystems and implies that the elements of nature have value to society.[158]

A resource's use value might be a market value, such as for minerals, wood, water and other goods, or a non-market value, such as outdoor recreation, landscape amenity, and many others. Non-use values, such as the importance people attach to specific habitats or species, are also included. It is important to note that the utility of putting a price on ecosystem services is oft debated; while there is practical value in doing so, estimates are bound to undervalue nature, both because our understanding of the manifold benefits provided by nature is limited, and because there is a somewhat inherent futility in putting a price on something that is essentially priceless.

Ecosystem services.

Ecosystem services are final products or results that directly and indirectly affect human well-being, and these factors can work well with an economic strategy. The main reason for valuing ecosystem services is that it will help people make informed decisions. It will make sure that policy decisions consider the costs and benefits of the natural environment and the implications for human well-being, while giving policymakers new ideas. Indeed, the term "ecosystem services" indicates the link between natural capital and the economy, which corresponds to the utility people derive from exploiting ecosystems.

The Millennium Ecosystem Assessment (2005) recognized four categories of ecosystem services:[201]

- Provisioning services: products obtained from ecosystems, e.g. water, food, fiber
- Regulating services: benefits guaranteed by the regulation of ecosystem processes, e.g. climate regulation, water regulation, pollination
- Cultural services: non-material benefits derived from ecosystems, e.g. recreation, aesthetic, spiritual and religious, cultural heritage
- Supporting services: services needed to produce all the other ecosystem services, e.g. nutrient cycling, soil formation, primary production

So far, only a tiny fraction of products offered by nature are considered in current metrics that measure economic progress (GDP) and human well-being.[202] Moreover, other benefits, such as pollination, regulation, and nature's ability to mitigate disasters, have failed to be captured. This

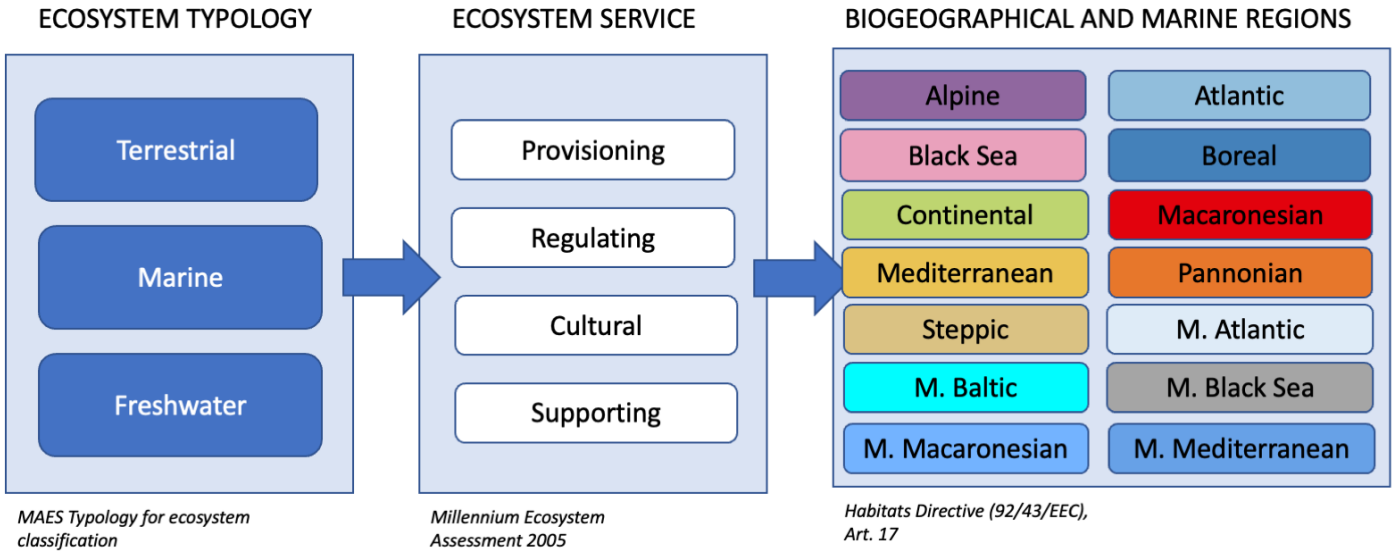

FIGURE 8 Mapping of Ecosystems Typology to Services across Biogeographical regions.
Source: Koundouri, P et al., 2022

incapability to account for the total economic values of ecosystems and biodiversity, jointly with the intense pace of economic activity, has significantly influenced their degradation.

In this section, we provide a valuation of European ecosystem services, by estimating the "willingness to pay" (WTP) for several classifications of ecosystem services and various biogeographical and marine regions across Europe. WTP estimates could be directly used to support decision making and/or facilitate the calculation of hybrid financial metrics which integrate non-market values for ecosystems and ecosystem services into standard metrics related to financial performance.

Valuation methodology – benefit transfer method.

A meta regression and benefit transfer method was used to estimate WTP for ecosystem services, accounting for heterogeneity in the typology of ecosystems and bio-geographical regions. Primary literature related to ecosystem services valuation from 2012 to 2022 has been selected using the publicly accessible database EVRI (Environmental Valuation Reference Inventory). Two hundred and twelve studies have been identified according to the ecosystem typology, the ecosystem services valued, and the geographical area in which the study was conducted.

The Mapping and Assessment of Ecosystems and their Services (MAES) Typology for ecosystem classification has been followed to identify the typology of ecosystems. This includes three main groups: 1) terrestrial ecosystems, including urban, cropland, grassland, forest, heathland and shrub, sparse vegetated land, and inland wetlands; 2) marine ecosystems, including marine inlets and transitional water, coastal, shelf, and open oceans; and 3) freshwater ecosystems, including rivers and lakes.[203]

On the other hand, ecosystem services have been distinguished between provisioning, regulating, cultural and supporting services in compliance with the aforementioned MA classification, as discussed above. Finally, since ecosystem typologies vary across regions, the geographical area of the study has been defined according to Habitats Directive (92/43/EEC) and for the EMERALD Network set up under the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention).

This last distinguishes 9 EU biogeographical regions, i.e. Alpine, Atlantic, Black Sea, Boreal, Continental, Macaronesian, Mediterranean, Pannonian, and Steppic; and 5 EU marine regions, i.e. Marine Atlantic, Marine Baltic, Marine Black Sea, Marine Macaronesian, and Marine Mediterranean. Figure 8 presents the mapping of Ecosystems (Typologies), Ecosystem Services, and bio-geographical regions.

To summarize and synthesize the empirical findings of various studies, in our research we rely on the meta-regression benefit function transfer. Our purpose is to statistically explain the variation found in the studies under consideration due to identifiable characteristics among the considered studies, such as the valuation method, geographic location, study-specific factors, survey mode, and other relevant determinants and demographic elements. The meta-analysis model is presented in Equation 1,

$$WTP_i = \beta_0 + \sum_{j=1}^{z} \gamma_j Z_{i,j} + \sum_{k=1}^{m} \beta_k X_{i,k} + \varepsilon_i$$

where *i* corresponds observations from each study under consideration, the dependent variable is Willingness To Pay (WTP), *Z* is a matrix of policy, site and other qualitative dummy explanatory variables, and *X* a matrix of socioeconomic explanatory variables; ε is the error term with the usual properties.

Specifically:

- **Willingness to pay (WTP)**: This continuous variable expresses the annual mean willingness to pay for ecosystem services (in euros). In cases in which the value of the willingness to pay was expressed in a currency other than the euro, the exchange rate from the year in which the study was developed was applied. In some studies in which the willingness to accept was calculated, values have been translated into a willingness to pay by assuming that willingness to pay equalizes willingness to accept. Similarly, in other studies, consumers' surplus values have been considered equal to the willingness to pay.

Various policy, site and other qualitative explanatory variables (Z) were considered to explain the variation mentioned above. Namely:

- **Ecosystem** is a categorical variable reporting the ecosystems' typology valued, which follows the categorization provided by MAES, i.e. forest (42 studies), cropland (18), heathland and shrub (1), sparsed vegetated land (1), inland wetlands (3), rivers and lakes (14), urban (15), grassland (6), and marine (65). The ecosystem variable has been subsequently divided into three different

dummy variables: Terrestrial (assuming a value of 1 if the ecosystem was equal to forest, cropland, heathland and shrub, sparsed vegetated land, urban, grassland, and inland and wetlands, and equal to 0 otherwise), freshwater (assuming a value of 1 if the ecosystem was similar to rivers and lakes and 0 otherwise), and marine (taking a value of 1 if ecosystem was similar to marine and coastal, and 0 otherwise).

- **Cultural, Provisioning, Regulating and Supporting** are dummy variables indicating ecosystems' services, per the MA Reporting categories. They assume a value of 1 if the study provides a monetary value for the specific service and a value of 0 otherwise.
- **Survey design** is a categorical variable describing the different data collection methods used by the surveys in each study, i.e. a) computer-aided individual home interviews, b) computer-assisted personal interview, c) dataset, d) focus group discussions, e) online interviews, f) personal interviews, g) mail survey, h) map layers, i) phone questionnaire, j) online questionnaire, k) in-person questionnaire, l) on-site questionnaire, and m) workshop. This variable has been subsequently divided into three dummy variables: interview (assuming a value of one when survey design was equal to a, b, d, f, k, l, m, and 0 otherwise), online questionnaire (assuming a value of 1 when survey design is equal to e, g, h, i, j, and 0 otherwise) and secondary data (taking a value of 1 if survey design was similar to c, and 0 otherwise).
- **Data year i**ndicates the year of data collection.
- **Valuation method** is a categorical variable indicating the method used to develop the analysis, i.e. contingent valuation, choice experiment, actual expenditure/ market price, count data model, hedonic price method, hedonic property, meta-analysis, replacement costs, travel cost method. In our final dataset, we have 76 choice experiment (CE) studies, 67 CVM studies, and 22 studies using revealed preferences. We have created three dummy variables, for CE (1 for CE and 0 otherwise), CVM (1 for CVM and 0 otherwise), and revealed studies (1 for Revealed and 0 otherwise).
- **Location** is a categorical variable reporting the geographical area in which the analysis has been developed.
- **Country** is a categorical variable reporting the European country in which the analysis has been developed.
- **Biogeographical and marine region**s of the European Union. Specifically, we have the cases of Alpine, Atlantic, Black Sea, Boreal Continental, Macaronesian, Mediterranean Pannonian, Steppic, Marine Atlantic, Marine Black Sea, Marine Baltic, Marine Macaronesian, and Marine Mediterranean as dummy variables indicating the specific biogeographical and marine regions of the European Union in which the study has been developed, according to the categorization used in the Habitats Directive (92/43/EEC) and for the EMERALD Network set

TABLE 5. Descriptive Statistics of the proposed variables.

Variable	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3	Maximum
WTP	76.8	12.9	165.7	0.0	93000.0	23.4	64.4	1404.6
ES Terrestrial	0.521	0.039	0.501	0.000	0.000	1.000	1.000	1.000
ES Marine	0.394	0.038	0.490	0.000	0.000	0.000	1.000	1.000
ES Fresh Water	0.085	0.022	0.280	0.000	0.000	0.000	0.000	1.000
Cultural	0.588	0.038	0.494	0.000	0.000	1.000	1.000	1.000
Provisioning	0.267	0.035	0.444	0.000	0.000	0.000	1.000	1.000
Supporting	0.436	0.039	0.497	0.000	0.000	0.000	1.000	1.000
Regulating	0.327	0.037	0.471	0.000	0.000	0.000	1.000	1.000
SD Interview	0.665	0.037	0.474	0.000	0.000	1.000	1.000	1.000
SD Questionnaire online	0.329	0.037	0.471	0.000	0.000	0.000	1.000	1.000
SD Secondary data	0.050	0.017	0.218	0.000	0.000	0.000	0.000	1.000
CE	0.461	0.039	0.500	0.000	0.000	0.000	1.000	1.000
CVM	0.400	0.038	0.491	0.000	0.000	0.000	1.000	1.000
REVEALED	0.139	0.027	0.347	0.000	0.000	0.000	0.000	1.000
Alpine	0.133	0.027	0.341	0.000	0.000	0.000	0.000	1.000
Atlantic	0.236	0.033	0.426	0.000	0.000	0.000	0.000	1.000
Boreal	0.139	0.027	0.347	0.000	0.000	0.000	0.000	1.000
Continental	0.212	0.032	0.410	0.000	0.000	0.000	0.000	1.000
Macaronesian	0.006	0.006	0.078	0.000	0.000	0.000	0.000	1.000
Mediterranean	0.279	0.035	0.450	0.000	0.000	0.000	1.000	1.000
Steppic	0.006	0.006	0.078	0.000	0.000	0.000	0.000	1.000
Marine Atlantic	0.176	0.030	0.382	0.000	0.000	0.000	0.000	1.000
Marine Black Sea	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Marine Baltic	0.042	0.016	0.202	0.000	0.000	0.000	0.000	1.000
AGE	44.221	0.624	6.301	28.620	40.088	43.000	49.350	58.000
INCOME	27969	1210	15160	2398	18267	24512	35371	104030
GENDER	0.489	0.009	0.087	0.170	0.463	0.510	0.540	0.640
EDUC	0.554	0.178	2113.000	0.104	0.265	0.360	0.460	25.400

Source: Koundouri, P et al., 2022.

up under the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention).
- **Value elicitation methodology** is a categorical variable indicating the typology of elicitation used in the study.

As socioeconomic variables (X), we have considered the following:

- **Age** is a continuous variable indicating the mean age of the sample population and is expressed in years. In the studies in which grouped data were provided, the open classes were assumed to have the same width (in red). Accordingly, the midpoint for each class was calculated and subsequently multiplied per class frequency. The sum of the results was then divided by the total frequencies. As there were many missing values, we considered proxy the mean age for each country and the specific year provided by EUROSTAT.
- **Income** is a continuous variable indicating the mean annual income of the sample population in euros. In the studies in which grouped data were provided, the open classes have been assumed to have the same width (in red). Accordingly, the midpoint for each class has been calculated and subsequently multiplied per class frequency. The sum of the results has been divided by the total frequencies. In the studies in which monthly annual income was provided, the monthly amount was multiplied by twelve months. In cases in which the value of annual income was expressed in a currency other than the euro, the exchange rate from the year in which the study was developed was applied. For studies in which income data were not available, we used EUROSTAT data deriving from EU-SILC and ECHP surveys. Eurostat database provides mean equivalized[iii] net income by year.
- **Gender** indicates the percentage of males and females in the sample population. It is assumed female = 1. This is a variable with 68 missing values, and it was eventually omitted from our regression analysis. However, for the 97 existing values, descriptive statistics are provided.
- **Education** indicates the percentage of the sample population with a high level of education. It is assumed university degree = 1. In the case in which educational level data were not available, we resorted to EUROSTAT data on population by educational attainment level, sex, and age (%); especially we considered tertiary education (level 5-8) according to the International Standard Classification of Education (ISCED 2011).

TABLE 6. Meta Regression Estimates.

	All Ecosystems	Terrestrial	Marine & Fresh Water
ALPINE	**148.94**	**105.93**	43.01
	[0.020]	[0.041]	[0.279]
ATLANTIC	**-86.23**	-21.91	**-64.32**
	[0.084]	[0.487]	[0.091]
BOREAL	-82.96	19.39	**-102.34**
	[0.286]	[0.748]	[0.040]
CONTINENTAL	-48.36	-7.07	-41.29
	[0.162]	[0.817]	[0.269]
MEDITERRANEAN,	**-91.73**	**-54.37**	-37.36
	[0.057]	[0.069]	[0.344]
MARINE_ATLANTIC	**-74.40**	**-62.46**	-11.95
	[0.106]	[0.059]	[0.779]
PROVISIONING	**59.32**	25.77	33.55
	[0.075]	[0.292]	[0.259]
REGULATING	**53.19**	12.98	**40.21**
	[0.224]	[0.541]	[0.214]
SUPPORTING	**42.70**	13.46	29.24
	[0.117]	[0.599]	[0.312]
SD_QUESTIONNAIRE	-42.09	**-50.20**	8.11
	[0.351]	[0.118]	[0.803]
AGE	**3.77**	**1.14**	**2.64**
	[0.007]	[0.127]	[0.023]
EDUCATION	**-5.20**	-0.60	-4.60
	[0.187]	[0.853]	[0.387]
CHOICE_EXPERIMENT	**-79.15**	-0.52	**-78.63**
	[0.157]	[0.983]	[0.126]
CONTINGENT_VALUATION	60.07	10.78	**-70.84**
	[0.297]	[0.704]	[0.161]
R-squared	0.32	0.27	0.18
Adjusted R-squared	0.20	0.15	0.04
F-statistic	**87.90**	**75.71**	**1.96**
	[0.000]	[0.000]	[0.0229]
MWTP	**80.53**	**38.42**	**42.10**

Source: Koundouri, P et al., 2022.

Concerning our final dataset created using the information of studies collected from the Environmental Valuation Reference Inventory (EVRI), the database has 212, of which 165 were used for estimation.[iv]

Empirical results.

Relying on the above information, Table 5 provides the descriptive statistics of the variables used in the analysis.

Next, we performed various stepwise specifications of the variables considered slightly elastic in the individual statistical significance of the explanatory variables (using Newey-West heteroskedasticity and autocorrelation Robust standard errors). Apart from the standard levels (of α=0.01, α=0.05, and α=0.1), we have considered (in such analysis) P-values less than 0.25. BIC criterion was used for

iii To take into account the impact of differences in household size and composition, the total disposable household income is "equivalized". The equivalized income attributed to each member of the household is calculated by dividing the total disposable income of the household by the equivalization factor. Equivalization factors can be determined in various ways. Eurostat applies an equivalization factor calculated according to the OECD-modified scale first proposed in 1994 - which gives a weight of 1.0 to the first person aged 14 or more, a weight of 0.5 to other persons aged 14 or more and a weight of 0.3 to persons aged 0-13. https://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do.

iv In total 47 studies have been omitted. In general, these studies present net present values, total economic values, and monetary values that are hardly compatible with the type of values expressed in the studies under review. In addition, a small number of cases were omitted because the values were too high and thus represented outliers in the database.

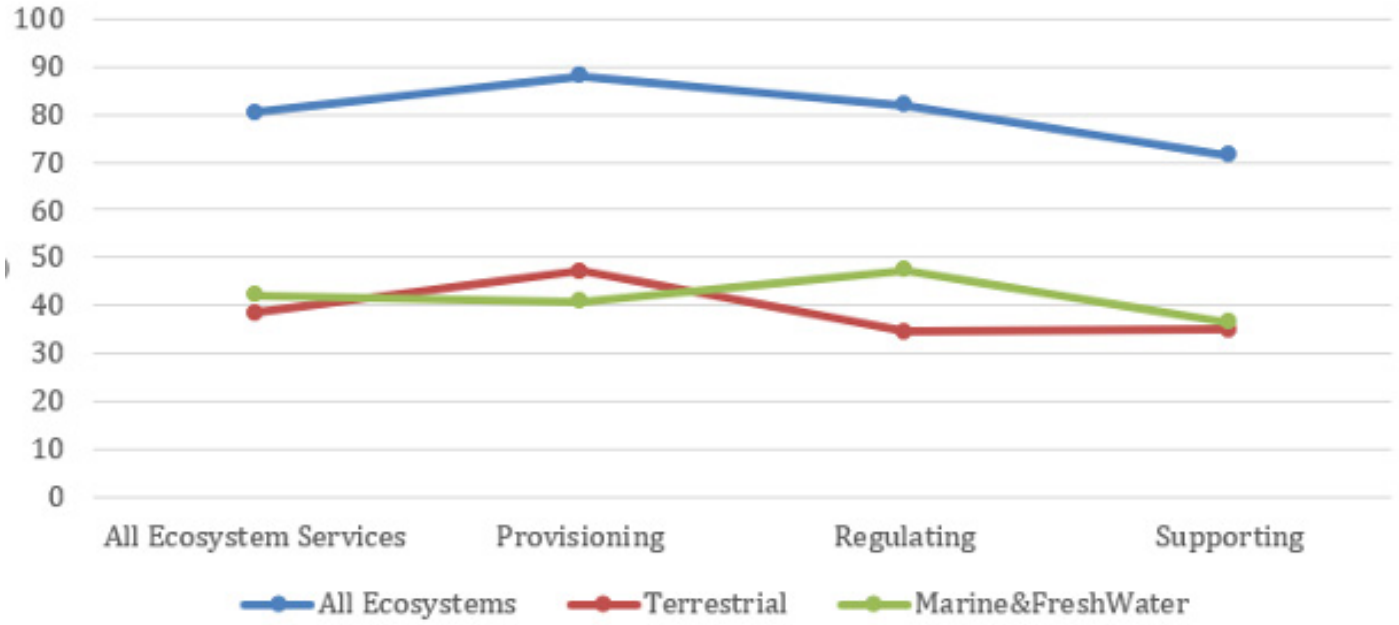

FIGURE 9 Annual Marginal WTP by Ecosystem Service.
Source: Koundouri, P et al., 2022.

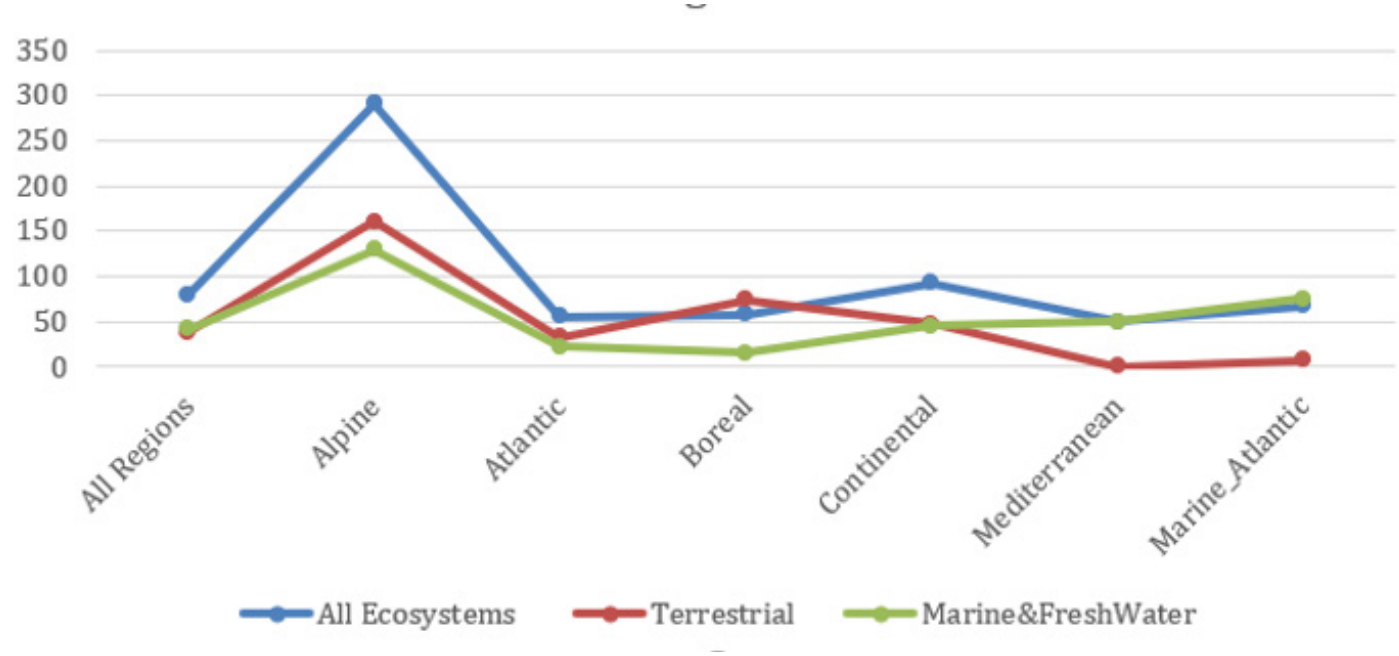

FIGURE 10. Annual Marginal WTP by Biogeographical Region.
Source: Koundouri, P et al., 2022.

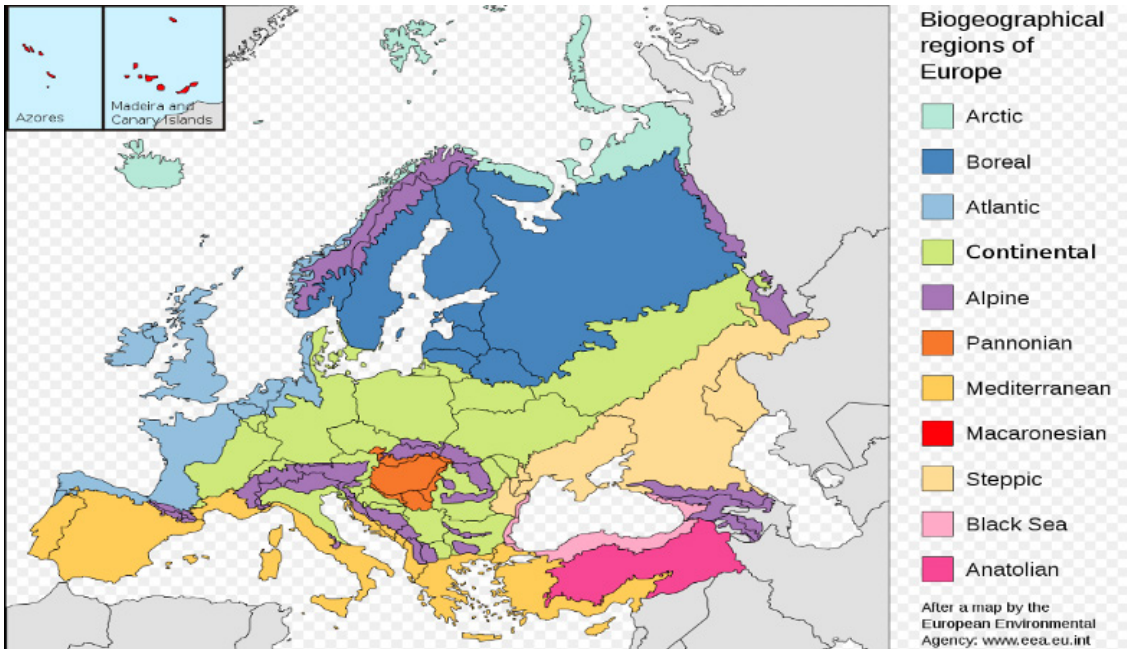

FIGURE 11. European Biogeographical Regions. Source: European Environmental Agency.
Source: Koundouri, P et al., 2022.

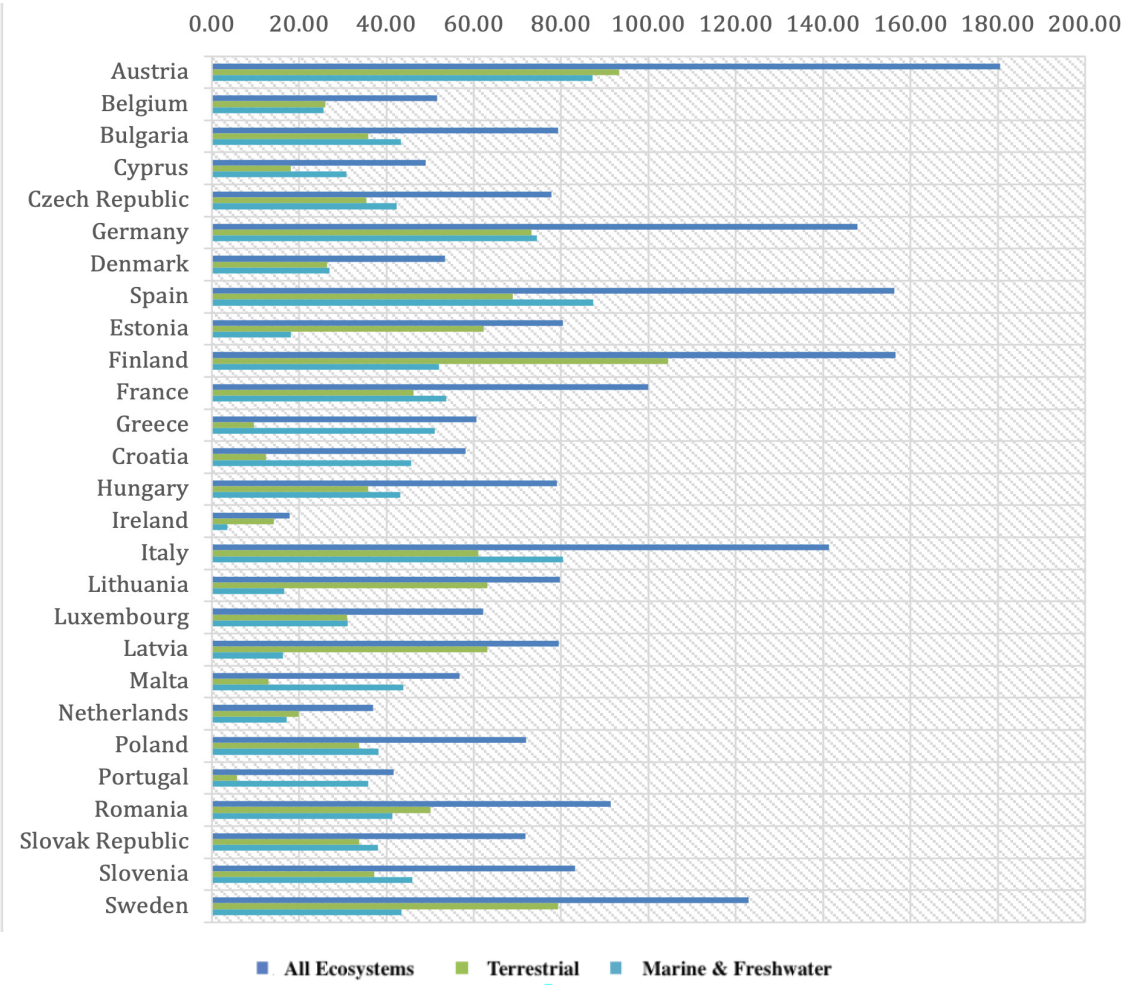

FIGURE 12 Marginal WTP by Ecosystem and Country.
Source: Koundouri, P et al., 2022

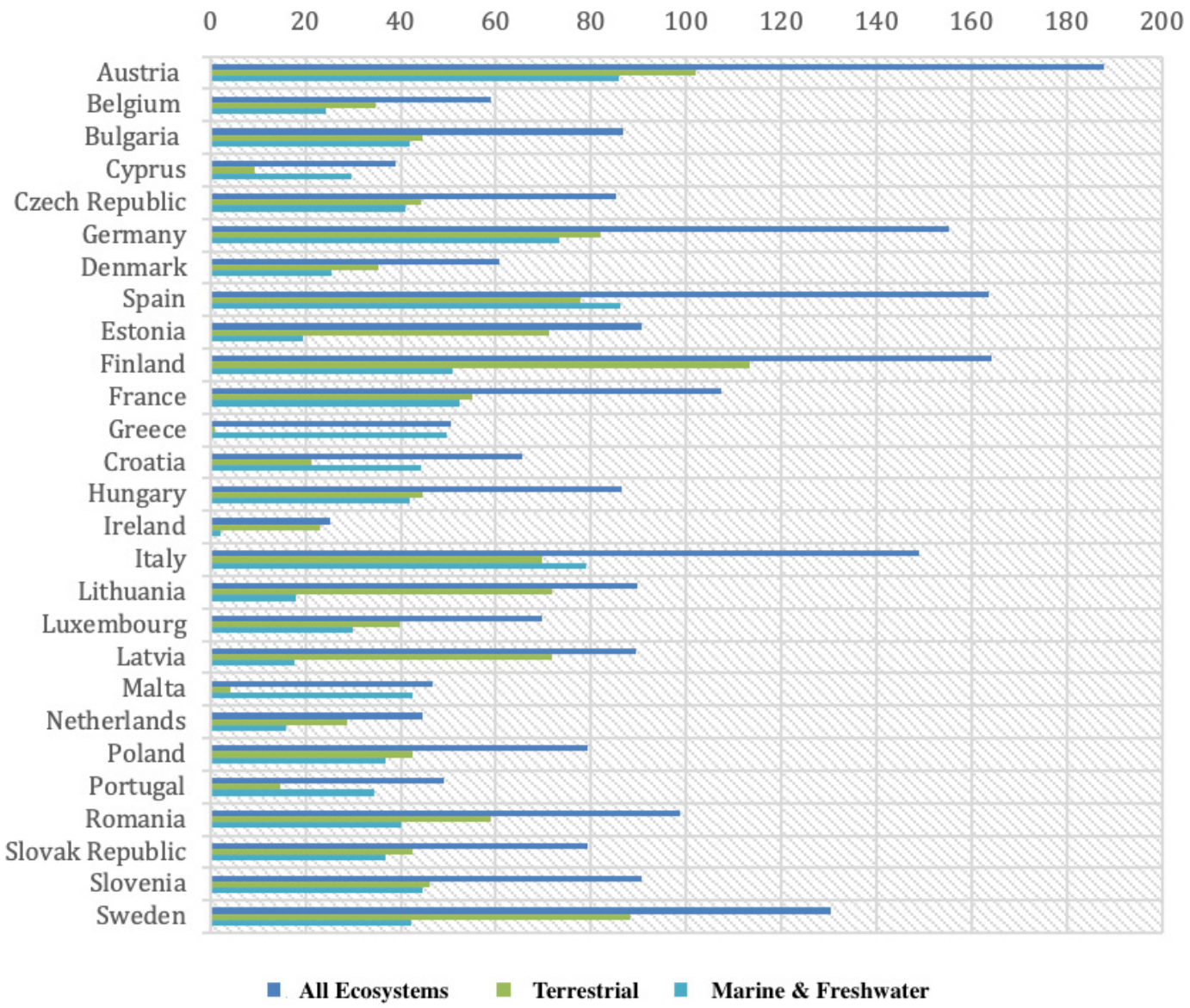

FIGURE 13A. Country Marginal WTP - Provisioning Ecosystem Service. .
Source: Koundouri, P et al., 2022.

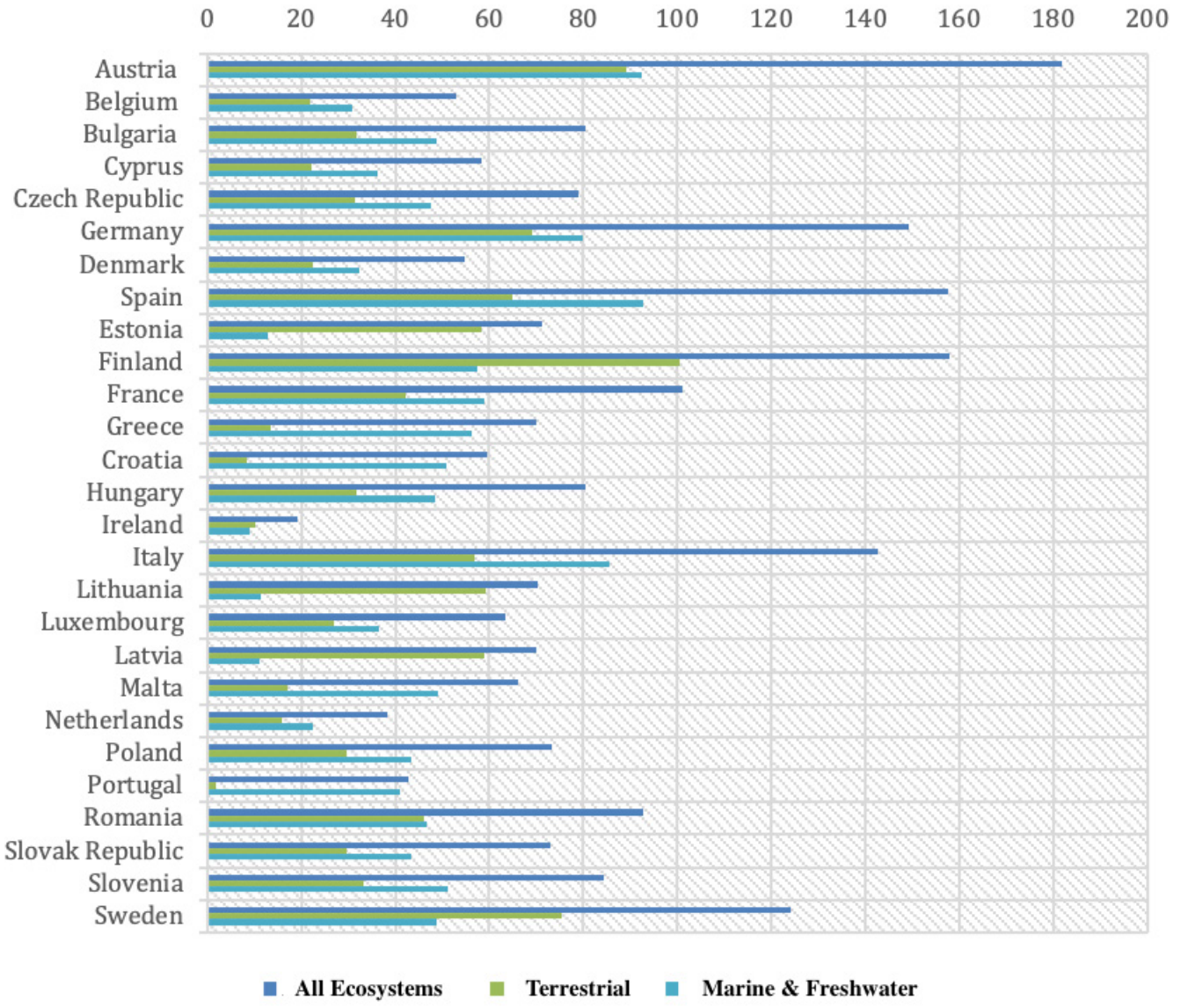

FIGURE 13B. Country Marginal WTP - Regulating Ecosystem Service. .
Source: Kondouri, P et al., 2022.

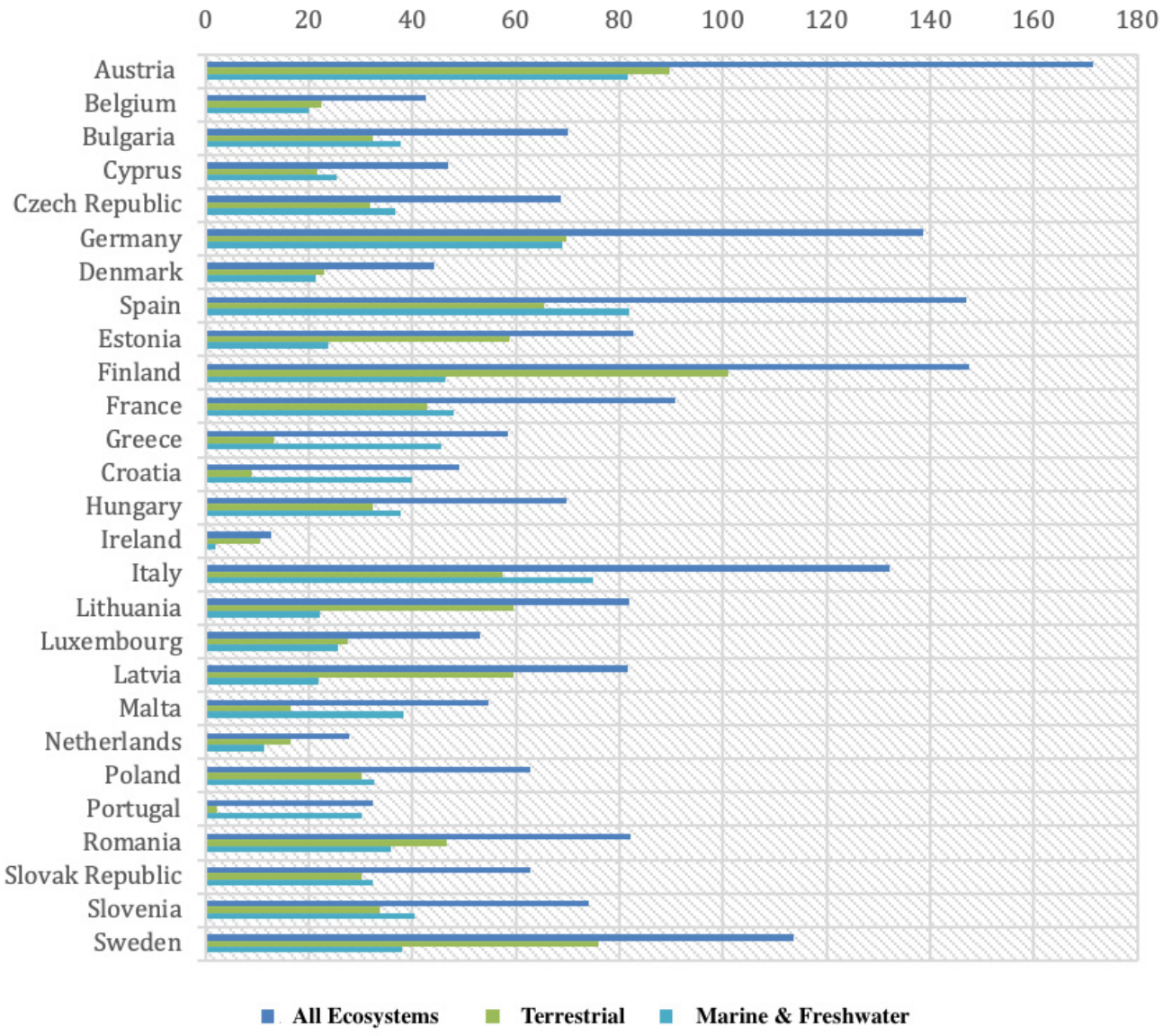

FIGURE 13C. Country Marginal WTP - Supporting Ecosystem Service. .
Source: Kondouri, P et al., 2022.

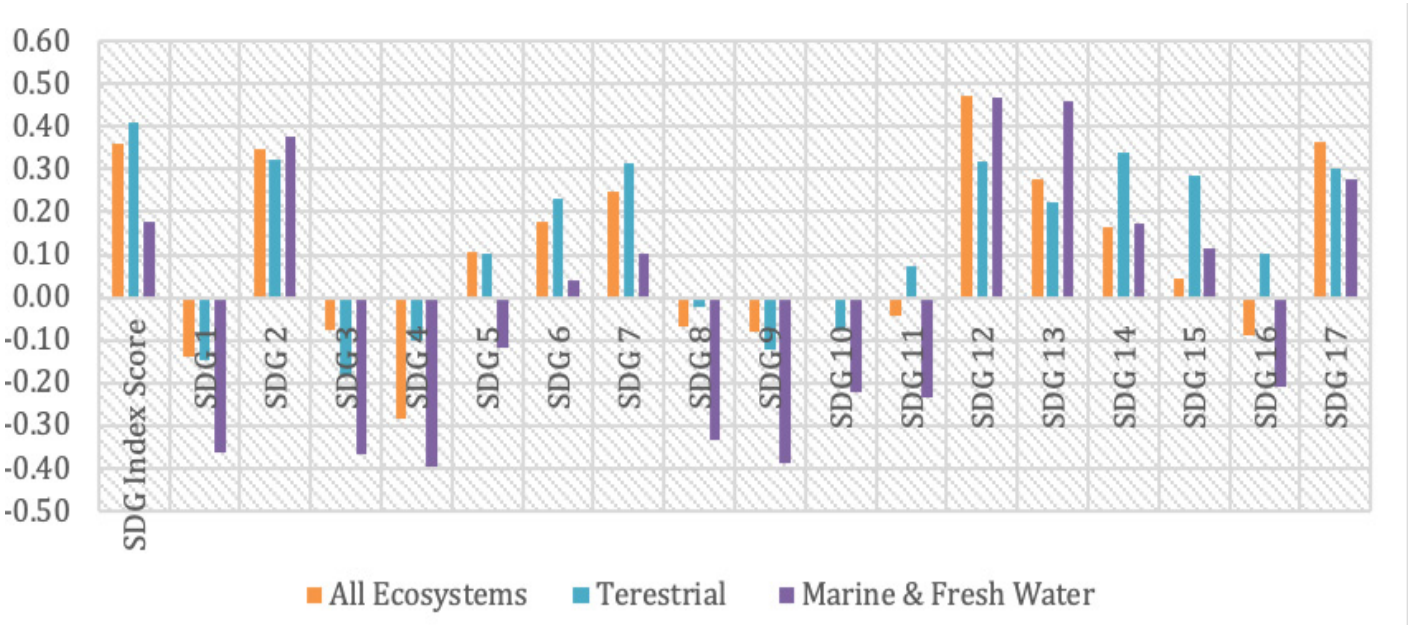

FIGURE 14. Cross Sectional Correlation of SDSN Index Scores and Ecosystem MWTP, by SDG.
Source: Koundouri, P et al., 2022.

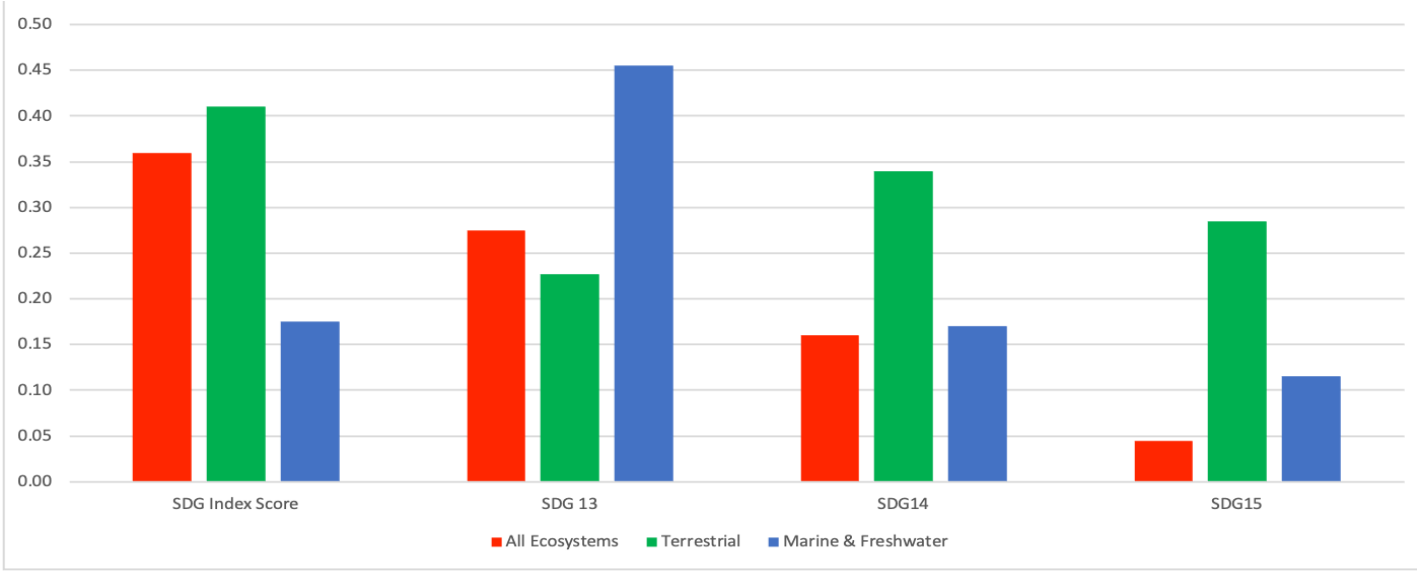

FIGURE 15 Cross Sectional Correlation of SDSN Index Scores and Ecosystem MWTP, by SDGs 13, 14 and 15

the model selection. The 1% extreme WTP observations were excluded from the analysis. Table 6 provides the meta-regression estimates and the parameters of the benefit transfer functions for all the models we considered; that is a model including all ecosystems and its breakdown into terrestrial and aquatic (marine & freshwater[v]). P values for the Newey West HAC standard errors are reported in brackets.

Annual marginal willingness to pay (MWTP) estimates are derived by applying the benefit transfer function:

$$\widehat{WTP} = \hat{\beta}_0 + \sum_{j=1}^{z} \hat{\gamma}_j \overline{Z}_j + \sum_{k=1}^{m} \hat{\beta}_k \overline{X_k}$$

Where $\overline{Z_j}$, $\overline{X_k}$ denote mean values of the underlying explanatory variables.

Figure 9 and Figure 10 present the Annual Marginal WTP per household, disaggregated by Ecosystem Service and Bio-Geographical Region for all three ecosystem specifications (total, terrestrial, and marine & fresh water, respectively). Figure 11 provides a map of the European Biogeographical Regions.

Figure 12 presents the Marginal Willingness to pay at the national level disaggregated by ecosystems (terrestrial, marine and fresh water). To apply the benefit transfer function for individual countries, socioeconomic data (age and education) for the year 2020 were collected from Statista (median age of the world population 2020) and OECD (share of people with tertiary education in OECD countries 2020). The classification of countries into biogeographical regions follows the definitions by the European Environmental Agency. For all countries that mainly refer to a region not included in our model,[vi] we normalize all the relevant dummy variables to add to 1.

A quick conclusion that can be drawn from observing Figure 12 is that in almost 63% of European countries (17 out of 27), the willingness to pay for the improvement of the marine & freshwater ecosystem exceeds that of terrestrial ecosystems. One possible explanation may be that the citizens of these countries recognize that marine and aquatic ecosystems are at a greater risk of collapse than terrestrial ecosystems, so they are willing to spend part of their income on the restoration of aquatic ecosystems. Another possible explanation is that the citizens of these countries are dependent on the marine or aquatic ecosystem, e.g. due to fishery production, tourism, etc., to a greater extent than the terrestrial, and are willing to bear the cost of maintaining these ecosystems in good condition.

Figure 13 presents the national WTP estimates disaggregated into three ecosystem services (provisioning, regulating, and supporting).

Valuing ecosystem services and sustainable development

Finding a balance between socioeconomic development and ecosystem services is a crucial challenge for sustainable development.[205] In this subsection we examine the correlation between willingness to pay and the level of achievement of the 17 SDGs overall, for the 27 countries of the European Union. To calculate the correlation, we used the scores per SDG of each country from the Sustainable Development Report Europe 2021,[206] and the MWTP per country calculated above. In each of the following figures, the first entry with the label "SDG Index Score" refers to the aggregated score for all 17 goals, while the following entries refer to the cross-sectional (27 countries) correlation between WTP estimates and 17 SDG score(s).

A positive correlation means that a high level of MWTP is associated with a high level of achievement of a specific SDG. The closer the correlation is to value 1, the stronger the association. Conversely, a negative correlation means that a high (or low) level of MWTP is associated with a low (or high) level of achievement of a specific SDG. Again, the closer the correlation is to the value -1, the stronger the (negative) association.

Figure 14 presents the cross-sectional correlation coefficients between national MWTP estimates and SDG Index Scores and the scores for all the 17 underlying goals for all ecosystems. Analysis was also performed for all individual ecosystem services and also by using rank correlations with similar results, available upon request to the authors. Figure 15 restricts analysis to the three SDGs which are more relevant to ecosystem services, that is goals 13, 14 and 15. As expected, the correlation with SDG 15 is higher for terrestrial ecosystems, while marine and fresh water ecosystems are highly correlated with climate change (SDG 13).

v Fresh water ecosystem was covered by only 14 studies in our sample, so it was grouped together with marine ecosystem.

vi For example, for Hungary which is classified as Pannonian, we set all the biogeographical dummy variables included in our model equal to 0.2.

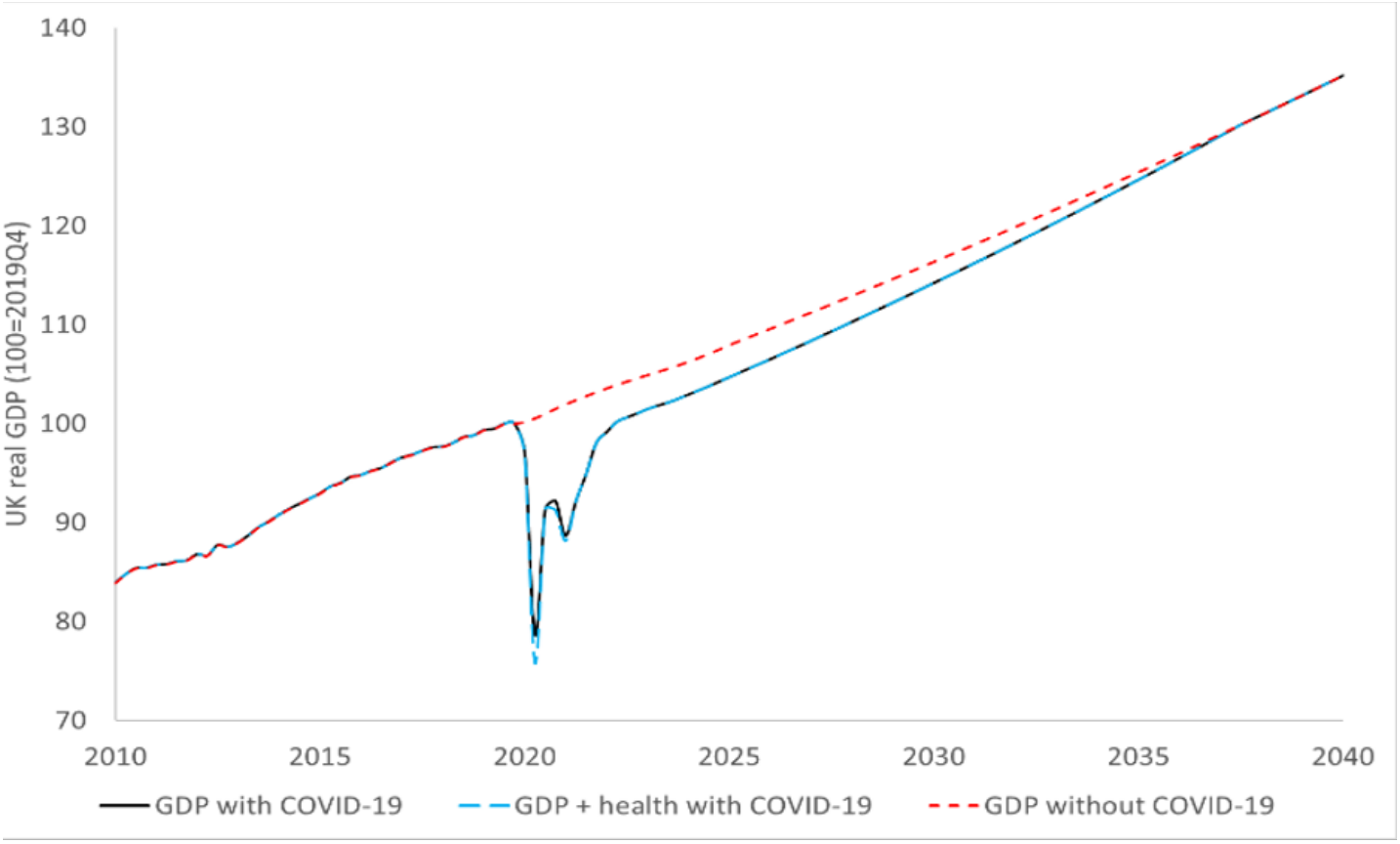

FIGURE 16 Observed and forecast actual GDP data for the UK. Forecasts are taken from the Office for Budget Responsibility

UK CASE STUDY: QUANTIFYING THE SOCIAL VALUE OF PANDEMIC PREPAREDNESS

According to the Office for National Statistics, the onset of the COVID-19 pandemic led to over 155,000 death-certificate mortalities and 7.2 million confirmed cases in the UK (as of August 2021). It also sent the UK economy into a significant recession, with 2020 GDP dropping by around 20%. In addition, like many other countries, the pandemic revealed capacity constraints in the UK's healthcare system. The capacity of the UK's National Health System (NHS) was one of the key determining factors for lockdowns during each COVID-19 wave, given their high economic and social costs. A lesson learned from this experience is that a better resourced NHS and better pandemic preparedness and response would have left the UK in a better position to limit excess deaths and potentially reduce or avoid the economic cost of repeated lockdowns and furlough schemes. Therefore, determining how government appraisal of public investments can be improved to consider catastrophic healthcare risks such as pandemics, signal the need for better preparedness, and invest in the long-term stability of health and well-being in light of these risks is needed.

In the UK, the appraisal of government investments, policies, and programs uses cost-benefit analysis (CBA) and follows the Green Book guidance,[166] which describes how to evaluate risks associated with project benefits. Its background documents show how the Social Discount Rate (SDR) should be altered when the overall economic growth rate and project benefits are risky.[181,207] While these approaches should be considered, CBA is not typically suitable for evaluating large, non-marginal shocks to the economy.[208] Despite this, welfare economics can still offer guidance on the benefits of preparedness in the face of dramatically costly, low probability events.[209,210,211]

To quantify what the UK government could justifiably have spent on the grounds of maintaining social welfare to have prevented the, albeit narrowly defined, economic costs (GDP) and loss of life (measured in QALYs) during the height of the COVID-19 pandemic, we took a non-marginal welfare analysis approach, as opposed to CBA. This maximum, welfare-neutral investment ranges from £475 bil-

lion to £1 trillion, depending on the time scale over which such investments can be spread. Given that it is not 'if' we experience the next pandemic, but 'when', this suggests that governments should currently be investing heavily in pandemic preparedness (preparing and adapting) and prevention (mitigation of pandemic onset risk). Below, we sketch an evaluation method and show how it can guide decision-making on pandemic preparedness investments. Yet, quantifying how much should be invested requires greater cooperation between economists evaluating catastrophic risk, epidemiologists, and other medical experts.

The economic impacts of the COVID-19 pandemic.

We consider two implications of COVID-19: the ongoing impact on GDP and the quality-adjusted life years (QALYs) lost. The red and black lines in Figure 16 show the effects of the COVID-19 crisis on the macroeconomy. The "GDP with COVID-19" line (black) plots quarterly real GDP in the UK over 2010–2040, normalized to 100 in 2019Q4. Data from 2010Q1-2020Q4 is actual data. For 2021Q1-2026Q1, forecasts are from the Office for Budgetary Responsibility's Economic and Fiscal Outlook - March 2021.[212] For the period after 2026Q1, we assume a growth rate (gc) which we set at 1.75%. The red-dotted "GDP without COVID-19" line in Figure 16 uses the Office for Budget Responsibility's forecasts from 2020Q1, before the COVID-19 pandemic, for 2020Q1-2025Q1. For the period after 2025Q1, we assume a growth rate (gn) which we set at 1.5% in the baseline calibration. We consider that once the post-COVID-19 GDP forecast catches up with the pre-COVID-19 GDP forecast, the path of GDP growth will be (gn) in both cases and, from a macroeconomic perspective, COVID-19 will be over; this occurs in 2037Q3. The gap between these two lines is a measure of the projected macroeconomic impact of the COVID-19 crisis.

To estimate the healthcare costs (the dotted-blue "GDP + health with COVID-19" line in Figure 16), we took death certificate reporting of COVID-19 mortalities for each quarter, as written by the UK's Office for National Statistics and with the assumption that there will not be a future spike in COVID-19 deaths. We multiplied these figures by 8.8 to account for the estimate that each end corresponds to an average of 8.8 QALYS lost, and then multiplied by a cost-per-QALY of £30,000.[213] These direct realized health costs are low compared to the loss in GDP. All 157,000 deaths amounts to a total health cost of £41 billion. While a prominent figure, it is only 2% of the annual GDP in the UK, which is approximately £2 trillion. Therefore, when assessed in economic terms, the decline in GDP is the dominant negative factor. The approach ignores the economic impact of the social and healthcare costs from a range of other factors, including mental health effects, and lost education and socialization of children and the lonely; this appraisal method could include such fees if estimates were available.

To understand the social welfare implications, we follow Green Book assumptions to characterize the relationship between GDP and welfare at each point in time. The resulting inter-temporal welfare function has a rate of pure time preference of 0.5% per year and logarithmic utility each year. The first of these parameters capture that society is impatient and prefers projects that give social paybacks sooner rather than later. The latter captures that welfare increases with more wealth, but each additional pound gives a decreasing additional amount of social benefit. Specifically, marginal utility is halved if GDP is doubled. Therefore, the social welfare from GDPt at time t is given by exp(-0.005t)ln(GDPt), where t is measured in units of years from 2019Q4, just before COVID-19 started. Total welfare across time is just the sum of welfare at each time: $W=\sum_t w_t$. We use Wc, Wn to denote total welfare from these calculations for the blue-dotted "GDP + health with COVID-19" and red-dotted "GDP without COVID-19" lines.

The change in welfare over the period from 2020Q1 until the effects of COVID-19 have disappeared from the macroeconomy (2037Q3) is $\Delta W=Wc-Wn=-2.06$. Had the policymaker been allowed to invest in the single quarter of 2019Q4 to prevent COVID-19, they would have been willing to forgo a maximum of 87.2% of that quarter's GDP. Welfare will then have dropped from ln(100)-ln(12.8) that quarter, and this also equals -2.06. In terms of the absolute decline in GDP, this equates to a cost of £475 billion in that single quarter.

By contrast, discounting the health and GDP costs of COVID-19 using the Green Book social discount rate of 3.5% to 2019Q4 gives a present value of almost exactly £1 trillion (the undiscounted prices are £1.18 trillion). This is greater than the absolute level of GDP in 2019Q4 (£545 billion), and therefore the government simply could not have spent this amount over such a short period even if it had wished to do so.

The discrepancy stems from the fact that COVID-19 has not had a marginal impact. Discounting in CBA only applies when costs and benefits are minor when measured against the overall macroeconomy, and so this approach does not reflect the full welfare effect of non-marginal changes.[208] The sequencing of investment cost is also important from a welfare perspective. Even if it were scientifically and fiscally feasible, diminishing marginal utility means that society prefers to smooth out costs over

time. If instead the costs of preparedness and prevention could have been spread over the whole decade, 2010Q1-2019Q4, society would have been willing to give up 4.9% of GDP each quarter to stop this pandemic, giving a total spend of £910 billion for the exact social welfare cost. This is much closer to the Green Book valuation because, in each separate year, the costs being borne are smaller, and while not precisely non-marginal, they are closer to the CBA paradigm. The takeaway points are twofold. First, non-marginal impacts require a more careful application of economic analysis than CBA, and second, smoothing out investments can either raise the maximum willingness to pay for pandemic preparedness or reduce the welfare cost for a given asset. In welfare terms, preparedness investments ought not wait until the last minute.

Planning for future pandemics.

So, what should the government's pandemic prevention and preparedness strategy now be? Our example illustrates that a systematic non-marginal analysis of the welfare effects of catastrophic risk is essential for the government to manage this risk at the least cost in terms of welfare. The outcome of this analysis depends primarily on four things: (i) how the overall welfare costs of the next pandemic compare with those of COVID-19; (ii) what the probability is each year of a pandemic starting; (iii) the period over which we can extend the preventative investment; and (iv) how effective any prevention and preparedness investments will be against future disease given that its pathological nature is currently unknown. From an economic perspective, it is straightforward to extend this analysis to these types of uncertainty; Martin and Pindyck have recently undertaken significant work in this space, which highlights another crucial point.[183,209] There are many different types of potential catastrophes that policymakers must weigh up, from nuclear accidents and terrorist attacks to asteroid strikes, volcanic eruptions, and climate change tipping points. What this analysis shows is that the economic case for making a significant social investment in preventive measures is strong. However, much more detailed work is needed to quantify this, which requires a more nuanced understanding of pandemic risk than economists currently have.

The possibility of rare events with significant consequences occurring in any given year, such as pandemics, should be accounted for in the appraisal of public projects. Doing so reveals that the UK government would have been justified in investing approximately 5% of GDP over the course of the 2010s if this would have prevented the COVID-19 crisis from occurring. What it should spend now depends on the estimated severity of the next pandemic, when it is likely to occur, the potential success of any mitigation or adaptive measure, and how long the investment can be spread over time. While economists can, and have, constructed models to deal with these situations, accurately calibrating them requires much greater cooperation with epidemiologists and other medical experts.

A further point concerns intra- vs inter-generational fairness. While the government's position on intergeneration justice is primarily embodied in the parameters of the welfare function and discount rate, particularly the rate of pure time preference, intra-generation fairness is also essential. It is widely agreed that the impacts of the COVID-19 pandemic have fallen disproportionately on the poor.[210] Investment in preparedness and prevention should therefore be distributionally progressive.

In sum, jointly reorientating investment appraisal methods to reflect these characteristics fits squarely not only with building back better but would also help to build back safer by managing risk and build about fairer by limiting the welfare impact on precarious low-income households.

EU CASE STUDY: DO NO SIGNIFICANT HARM (DNSH)

To achieve net-zero emissions, innovation is needed as well as a fundamental alteration of economies, production, and consumption patterns. As is widely documented in the literature, the majority of CO_2-eq emission reductions occur not through adaptation of existing productive capital stock but through new investment in more energy-efficient means of production. Thus, a method for developing business incentives that are compatible with ecological transition and proportional to the mitigation effect of new investments is needed. More precisely, public funding (in the form of guarantees or subsidized loans) should happen in proportion to the potential of new investments to diminish carbon dioxide emissions.

The report of the UN SDSN's Senior Working Group (SWG), which supports the European Commission in implementing the European Green Deal (EGD), focuses on the use of sustainable finance for SDG-based recovery. In this context, a practical approach for activating the guarantee or subsidy that is based on the lowest permissible levels of CO_2 abatement progress and adherence to the "Do No Significant Harm" (DNSH) concept is developed. Furthermore, for an investment to be eligible to qualify for the guarantee/subsidy, two conditions are specified:

i) The investment must meet a minimum CO_2 emission reduction, compatible with reaching net-zero emissions by 2050.

ii) The investment must result in a "green Pareto improvement," avoiding deterioration in other environmental areas compared to the counterfactual (i.e., business as usual without the investment).

Thus, it is critical to successfully apply this method to define measures and indicators that are appropriate for the task at hand. Environmental, social, and governance (ESG) factors are used to identify the most appropriate DNSH domains for sustainable finance. Numerous studies have demonstrated the importance of developing accurate metrics and rules to provide truthful information about organizations' sustainability claims by addressing environmental issues and actions related to sustainable financing. Numerous metrics and key performance indicators exist to aid in assessing and monitoring investments.

The EU Taxonomy Regulation, which aims to define the minimum criteria that economic activities must meet to be considered environmentally sustainable, with the ultimate goal of facilitating sustainable investments among financial market participants and improving non-financial disclosure, is very significant at the European level. The Taxonomy's criteria address six goals: (1) climate change mitigation; (2) climate change adaptation; (3) sustainable use and protection of water and marine resources; (4) transition to a circular economy; (5) pollution prevention and control; and (6) biodiversity and ecosystem protection and restoration.

The Taxonomy establishes that an environmentally sustainable economic activity must contribute to the significant improvement of at least one environmental target and the DNSH objectives. Defining all feasible investment types across the six DNSH domains and reaching an agreement among EU member states on the proposed taxonomy would, however, take time and compromise. There is a risk that the Taxonomy may become obsolete because technological advancement creates new investment types that are not covered by the taxonomy.

The methodology proposed offers an approach that is consistent with the ecological transition objective of reaching net-zero emissions by 2050, which is fundamentally a dynamic goal defined in terms of the rate of change. In addition, based on an analysis of the rates of change in the Taxonomy's six DNSH domains, key performance indicators (KPI) to quantify the investment's future effects are established. The approach entails identifying a set of LCA-enhanced KPIs that will allow businesses and policymakers to assess the environmental sustainability of new investments from a system perspective, that is, considering all upstream activities required to materialize an asset (for example, manufacturing and installing solar panels in a building) as well as post-investment effects (e.g. using and maintaining the solar panel until the end-of-life management process).

The KPIs are intended to contribute to achieving the following objectives: climate change mitigation, climate change adaptation, sustainable use of water, transition to a circular economy, pollution prevention and control, and protection and restoration of biodiversity and ecosystems. The KPIs are modular in design and may be used by both major corporations and small and medium businesses. Indeed, whether the costs of adoption are affordable, especially for small- and medium-sized enterprises (SMEs), is a critical issue for the successful introduction of such metrics, given that corporate social responsibility (CSR) reporting can quickly become a competitive barrier for SMEs when fixed reporting costs are too high.

Design of policy instruments for a green transition.

Much of the media debate on policies to restart the economy after COVID-19 hinges on providing money (subsidies) to various sectors to keep the economy spinning, increase employment, and avoid a severe recession. Naturally, targeting these funds to the right technologies and sectors would be very beneficial for a green transition, and the contrary (which all too often happens) is excessive funding of airlines, car companies, and fossil fuel companies that will not only delay the green transition but increase the risk of stranded assets and new crises in the future.

However, a green transition cannot only consist of subsidies and cash transfers. On the contrary, economists keep repeating that the most fundamental policy instrument for a green transition is universal pricing of climate forcers (carbon dioxide, methane, nitrous oxides, etc.). There is a vivid debate about this, as many people object to such pricing. This includes lobbyists for the fossil industry and energy-intensive sectors, and low-income individuals and countries (and many others) concerned with distributional effects. Many policy analysts have concluded that carbon pricing is a dead end and that other policies should be tried.[211] A quick and somewhat nuanced conclusion is that emission prices are needed and possible, but that sufficiently high prices will not always be possible in every sector and country, and that other instruments (such as subsidies for infrastructure and R&DD) are needed, both as complements to emissions pricing and to prepare the way for such pricing.

Much attention is needed to address two additional aspects, (i) fairness and perceived fairness issues on the one

hand and (ii) the (game theory) dynamics of creating agreements between sovereign states. It is vital and instructive to see what the European Union is proposing in its Fit for 55 strategies. The EU is a robust and ambitious coalition of countries, far short of a federation but more integrated than most other country blocks. The Fit for 55 strategy has the goal of carbon neutrality by 2050 and a 55% reduction by 2030 as a stepping stone. It includes proposals such as:

- Revision of the EU ETS to address shipping, aviation, road transport, and buildings
- Revision on land use, land-use change, and forestry (LULUCF)
- Revision of the renewable energy and energy efficiency directives
- Revision on alternative fuels
- Amendment of the regulation on emission standards for cars
- Revision of the energy tax directive
- A carbon border adjustment mechanism
- An EU forest strategy

In each of these areas, a complex pattern emerges where it is difficult for the EU to legislate on taxes (due to issues of national sovereignty).

Problems of policy acceptability may seem insurmountable; however, one should remember that much of the critique against, for example, fuel taxes (and thus implicitly carbon taxes) is that they are unfair. The yellow vest movement in France grew out of a complaint about high tariffs – partly because they saw that big industry or wealthy air passengers were paying much less than French motorists. Similarly, industries complain not over absolute tax levels but whether or not the playing field is level concerning their competitors. If we are to solve the climate problem, it must be solved in all countries (starting with China and the US, which account for half of all emissions). Paradoxically, it could be simpler to price all global emissions since the main obstacle of acceptability and fairness should vanish if the policies were really applied to all emissions. There remains, of course, the issue of how to get anyone to take the first step – and that, in a sense, is what the EU wants to do, and it is in this light that we need to read the suggestions in the 'Fit-for-55' package.

TABLE 7 Qualitative Summary of Resilience Indicators: Major Nations Ill-Prepared for Global Pandemic

	US	China	India	Germany	France	UK	Italy	Japan
Resilience Factor 1: Population and Demographic Risk								
At-Risk Population								
Risk of Spread								
Poverty/Inequality								
Communication and Information (Credibility)								
Resilience Factor 2: Healthcare and Social Protection								
Critical Care Capacity								
Virus Testing								
Social Protection for Job Loss								
Healthcare Access and Quality								
Resilience Factor 3: Economic Strength Against Macro Shocks								
Economic Growth								
Unemployment Rate								
Informal Employment								
Corp/Household Indebtedness								
Structural Risk								
Resilience Factor 4: Policy Capacity for Economic Stimulus								
Monetary Policy								
Ability to Introduce Stimulus								

ACHIEVING GREATER RESILIENCY AGAINST FUTURE PANDEMICS AND SHOCKS[VII]

The coronavirus pandemic has swept across the world, leaving a trail of human and economic destruction. In this crisis, the 'enemy' is a silent, invisible, deadly pathogen that has successfully overcome border protections. It has exploited interconnected and networked economies and societies to spread worldwide and threatened people's way of life, testing the resilience of public health and economic systems. Evidence to date suggests that defeating it requires mass mobilization of healthcare resources and financial tools, and community and individual action within and across countries of the kind that has usually been seen only during periods of war or significant economic dislocation.

The pandemic has revealed many cracks in the world's existing political, economic, and governance systems, including public health, international cooperation, monetary flexibility, and government effectiveness. These cracks are the results of a series of deeper, underlying issues facing the world today, including inequitable and disparate public healthcare systems within and between countries; unaddressed market and regulatory issues; the loss of political cohesion stemming from populist, isolationist, and exceptionalism politics across the world; and demographic challenges facing industrialized countries with large elderly populations.

An assessment, undertaken in April 2020 (Table 7) to provide risk assessments that might aid policymakers, examined the capability to resist and act to address the pandemic, with a primary focus on the resilience of eight major countries, along with five factors:[viii]

1. Population and demographic risk
2. Healthcare and social protection
3. Economic strength against macro-shocks
4. Policy capacity for economic stimulus
5. Global coordination, collaboration and cohesion

The analysis revealed that almost all countries examined are significantly underprepared for the potential impact of COVID-19 from multiple perspectives. Some of the critical figures are extracted in Table 8.

When the resilience indicators are looked at as a whole, they reveal that the world was critically ill-prepared for COVID-19, creating significant risks to human life and severe damage to substantial economies. While there were substantial gaps between the levels of resilience of individual countries, all major countries lacked preparedness to deal with a pandemic on the scale of COVID-19, along multiple fronts, with the data highlighting the following:

- The US was severely exposed due to systemic shortcomings and structural factors. For example, large segments of the US population lack adequate long-term healthcare coverage. In addition, the US's economic stability rested on its ability to increase the money supply (and co-opting its banking system, subject to its markets playing along), which seemed feasible. However, given its near-zero interest rates, high fiscal deficit, and indebtedness at the level of the Global Financial Crisis, the US may likely need to rely on effectively printing money in what may be seen as a 'heroic' or desperate fashion, depending on one's perspective, to shore up its economy.
- Aside from Germany, Europe was also exposed, with the UK appearing particularly vulnerable and therefore

vii Ketan Patel, Christian Hansmeyer et al. Summarised and extracted from, 'The Coronavirus Pandemic - A Global Test of Resilience, Leadership and Values,_April 2020', and 'The Coronavirus Pandemic - Waging the War, May 2020', with permission from the authors, Greater Pacific Capital Research, specifically authors Ketan Patel, Christian Hansmeyer et al.

viii Resilience Factor 1: Population and Demographic Risk. Risk Summary: The US stands out as among the most vulnerable from the perspective of its population, demographics, and long-term provision (or lack thereof) of healthcare to its population. At the other extreme, India as a large developing country also faces enormous challenges. **Resilience Factor 2**: Healthcare and Social Protection. Risk Summary: On the protection offered by the healthcare system for the population, the US stands out as the most vulnerable among richer countries (its excellent coverage for the well-insured notwithstanding), given its lack of testing capabilities, relative size of its hospital infrastructure, and the quality and breadth of general healthcare access. The UK stands out among the same group for its inadequate healthcare capacity but has provided universal coverage for a long period. India, as a developing country, has the least medical capacity to deal with such a crisis and is therefore the most exposed as a result, and so critically subject to the effectiveness of its containment and suppression measures. **Resilience Factor 3**: Economic Strength Against Macro-Shocks. Risk Summary: While low growth and high levels of corporate and household indebtedness poses a risk to the US and UK; China, France, and Japan are particularly exposed on corporate indebtedness; weak structural employment is likely to put pressure on the US in a prolonged downturn, just as Italy's dependence on these services is disproportionately impacting its economy during lock-down. **Resilience Factor 4**: Policy Capacity for Economic Stimulus. Risk Summary: The developed world is highly constrained in terms of headroom for monetary stimulus compared to during the Global Financial Crisis, increasing the importance of fiscal stimulus at a time when major countries, particularly the US and Italy, are already running deficits and debt levels well above the levels seen before the crisis. However, given the potential extent of the fallout from the coronavirus, this may not constrain them from injecting money supply into their economies and taking the impact on currencies and inflation, thereby diluting the qualities of their economies as a result. **Resilience Factor 5:** Global Co-ordination, Collaboration and Cohesion. Risk Summary: Major international financial institutions such as the World Bank and IMF are better funded relative to the global financial crisis, major global policy institutions such as the UN and WHO are also better financed than at that time. However, the US power is shifting away. The WTO has an important role in providing a level playing field. Central banks have substantial stocks of reserves to make international interventions, the highest risk in terms of reserves were the US, UK, and Italy, with China far stronger than all others. There was an important additional role for charitable and NGO funds to play in supporting relief efforts.

TABLE 8. Summary of Resilience to Coronavirus Pandemic for Major Countries (Sub-set of Parameters from 15 Key Quantitative Indicators for Four Major Areas)

	Population and Demographic Risk			Healthcare and Social Protection[2]			Economic Resilience against Macro-Shocks			Policy Capacity for Economic Stimulus		
Country	Pop. without Health Insurance[3]	% of Pop. below Poverty Line[4]	% of Pop. aged 65+[5]	Hospital Beds / 1,000 People[6]	Testing Capacity per Week / million Pop.[7]	% of Unemployed receiving Benefits[8]	Historic GDP Growth Rate[9]	Informal Employment[10]	Corp. Debt to GDP[11]	Fiscal Deficit as % of GDP[12]	Gov. Debt as % of GDP[13]	Sovereign Credit Rating[14]
US	9% (45%)	1.2%	15.8%	2.8	761	28%	2.6%	18.6%	150%	-4.6%	107%	AAA
China	5%	23.5%	10.9%	4.2	NA	19%	6.5%	54.5%	208%	-4.2%	51%	A+
India	56%	60.4%	6.2%	0.7	58	3%	6.7%	88.2%	55%	-3.3%	68%	BBB-
Germany	0%	0.2%	21.5%	8.3	4,581	100%	1.5%	10.2%	111%	1.5%	62%	AAA
France	0%	0.1%	20.0%	6.5	444	95%	1.7%	9.8%	201%	-3.0%	98%	AA
UK	0%	0.5%	18.4%	2.8	412	60%	1.5%	13.6%	171%	-1.8%	87%	AA-
Italy	0%	1.5%	22.8%	3.4	NA	38%	0.9%	19.0%	110%	-1.6%	135%	BBB
Japan	0%	0.9%	27.6%	13.4	415	20%	1.2%	18.7%	161%	-3.8%	237%	A

1. Key metrics have been highlighted to illustrate the assessment of resilience; please refer to the complete paper for detailed metrics
2. As of late March 2020
3. Source: OECD
4. Source: Word Bank, % of the population in 2011 earning less than US $3.20/day
5. Source: World Population Review
6. Source: OECD, American Hospital Association
7. Source: 2020, AEI, Institute, India Health Ministry, Public Health England, France-Director General of Health, German Health Ministry
8. Source: ILO
9. Average GDP growth from 2017 – 2019; Source: IMF
10. Source: ILO
11. Source: IMF
12. Source: US Treasury, Reserve Bank of India, Federal Statistical Office, INSEE, Office for Budget Responsibility – UK, Japan Ministry of Finance, China Ministry of Finance
13. Source: IMF
14. Source: Fitch Rating Agency

much at risk from poor policy and any failures in the execution of proper measures.

- India emerged as the most at risk, given its size, population density, and development stage. As a result, it had the most critical need for radical solutions covering multiple areas, including emergency healthcare and economic and social measures.
- China's overall resilience was strong, and so it stood to emerge in a relatively superior position from this crisis.
- Threats to a successful implementation of sound policy existed from the lack of adequate, reliable public information and a 'populist' approach. The prevalence of unreliable news on social media made clear and efficient communication a challenge in countries where trust in mainstream media is low and social networks are a significant source of information for the population, particularly given the alleged existence of targeted disinformation campaigns underway and the populist stances of confident political leaders.
- Global coordination, collaboration and cohesion were not of the level required for a pandemic, particularly given the US administration's political positions on the pandemic, its 'America First' stance, and lack of global leadership. Major international institutions, such as the World Bank, IMF, UN, and WHO were better funded relative to the global financial crisis. Central banks also had substantial stocks of reserves to make interventions. However, the US was not exerting the same leadership it had during the global financial crisis.

The work concluded that, given the significant gaps in

countries' resilience and preparedness and the lack of necessary urgent action upon the initial spread of the disease, there is a significant need to improve countries' ability to work effectively, both within and between countries, to cooperate to galvanize people and resources, including the vast body of knowledge in the world on medical illnesses; to manage crises (most recently, from the Global Financial Crisis, 9/11, and multiple wars from the last century); and the on-the-ground peace and aid experience of numerous international institutions and the strong legacy of post-war allied leadership.

COVID-19 has revealed just how large of a shock a pandemic can induce to economies and human health worldwide. However, those working on economic and public health issues were not surprised. Pandemics have long been at the top of significant threat lists.[183,213] The 1918 Influenza Pandemic provides a hard to ignore exemplar. What is surprising was how ill-prepared countries were to respond to this 21st-century pandemic, especially since most of the critical issues had been repeatedly seen in planning and preparedness exercises.[214]

The ability to absorb a significant shock while limiting harm and fostering expedient recovery is often referred to as resilience, a concept introduced in disturbed ecosystems by C.S. Hollings (1973). It has found its way into many disciplines as an organizing principle. Resilience was used early in the pandemic's course to assess countries' vulnerability to and capacity to deal with COVID-19.[215] More recently, to think about a post-COVID world that learns from that experience.[216] Our objective here is much more limited. How can investment in green infrastructure, now being undertaken or planned by many countries as a way of speeding recovery from the COVID-19 induced recession, be used to improve the ability to respond to and bounce back from a future pandemic or other global crisis?

A logical starting point is to consider how COVID-19 initially played out worldwide. COVID-19 started with the emergence of a novel pathogen whose pandemic threat was not identified and acted upon rapidly enough. While a few countries, such as South Korea, effectively intervened early, this was not the norm. Most other countries failed, with even more warning (the WHO declared a 'public health emergency of international concern' on 30 January 2020, and a pandemic on 11 March 2020) to mount the serious response required. The core problem is that the external threat exhibited exponential growth. This exponential growth is the predictable outcome from the workhorse epidemiology SEIR model for any airborne virus with an $R_0>1$ once it becomes established in a large population with a high contact rate where no one has full or partial immunity. The shock to the ecosystem nature of the problem now logically follows if the pathogen's virulence is the typical annual influenza wave or greater.

If unsuspected or warning signs are ignored, the virus itself strikes first. It causes a public health shock along multiple dimensions, ranging from a rapid increase in demand for particular medical services to the need to mount testing and contact tracing programs that far outstrip the capacity of public health agencies. Even well-resourced health care systems can be easily overwhelmed by a pandemic. This raises a critical issue that we will return to later—the need for particular types of large-scale, dual-purpose surge capacity. However, for now, the critical issue is what follows the immediate health crisis the pandemic induces.

One extreme libertarian view is that the core problem with COVID-19 was government efforts to slow the spread of COVID-19, such as lockdowns, facemasks, and testing. Those holding this view argue that COVID-19 should have been allowed to run through most of a country's population to minimize economic and social disruptions and achieve herd immunity as quickly as possible.[216] This strategy proved itself overwhelmingly deadly in many countries, particularly those with vulnerable populations and weak health care systems.

Irrespective of the actions taken by governments, economic and social activity fell precipitously in the face of the rampaging COVID-19 virus. Why? In today's media age, the public health shock is evident to most people, which causes other actions to follow. Even if the political system does not step in and require efforts to reduce transmission, many individuals will endogenously take actions to different degrees to avoid infection and reduce transmission. From the virus's perspective, this will come in the form of reductions in contact rates; in an SEIR model context, this mechanically drives down transmission rates by reducing the current effective R_0. From the individual's perspective, this is just a variant of the bottled water issue that environmental economists have long studied, where risk perceptions, specifically those of biological agents, play a crucial role in choice.[217] People tradeoff the benefits gained from contact with their cost. The number of contacts falls when the prices go up from the perceived risk of getting sick from a contact. Over time this reaction is likely to become more sophisticated, as the risk associated with undertaking particular types of contacts becomes differentiated on some basis and the proclivity to launch them reflects this. Call this the human behavior reaction to the new virus.
This deeply ingrained reaction of people sets off a series

of other shocks over time as people process information about hospitalizations and deaths. Predictable demand shocks follow quickly. Grocery store shelves are stripped bare of toilet paper. On the margin, reductions in contact rates hit restaurants and the hospitality sector hard. As people reduce travelling, gasoline consumption falls. Given this commodity's highly inelastic price elasticity of demand, prices at the pump plummet. There are corresponding supply shocks, too, as the sudden shift in the bundles of commodities demanded is challenging to accommodate quickly. Businesses, facing sizeable adverse demand shocks, are often forced to temporarily or permanently close. Laid-off workers are fearful about their future employment, parents worry about the safety of their children in school, and younger adults are concerned about the health of their elderly parents. In most countries, these demand and supply shocks were likely preceded by a trade shock due to disruptions in the countries that hit earliest. The inability to import personal protective equipment, such as N-95 masks, supplied mainly to the world by China, was evident for over a month before substantial COVID-19 case counts started to accumulate in Europe and the U.S. These trade shocks, including those to international tourism, tie countries together. Demand, supply, and trade shocks set in motion larger-scale societal shocks. Financial markets are in turmoil due to uncertainties over the pandemic's duration. This necessitates a fundamental reassessment of the value of various asset classes. Asset values can significantly fluctuate in response to rumors and shifting assumptions about potential government measures. A wealth shock follows as the value of financial assets, including real property, changes. While the overall wealth shock is downward, any economic shock tends to create losers and gainers, as early purchasers of shares in Clorox and Zoom can attest. The poor and, more generally, those without substantial savings to help ride out the disruptive effects of the pandemic are hit hardest. Coupled with job loss, bankruptcies, foreclosures, and evictions are set into motion. Finally, large scale human suffering and loss of life can create the defining generational moment often associated with major wars.

We now illuminate the first linkage with investment in green infrastructure. Most countries' public health infrastructure is not organized around responding to a large scale, a quick-moving disaster like a pandemic. However, in this regard, COVID-19 and pandemics more generally closely resemble extreme weather events, e.g., heat waves, hurricanes, and wildfires. These are becoming more numerous and intense as the climate changes compared to classic public health issues like programs to vaccinate children and manage HIV. Emergency management agencies in Florida and Southern California routinely deal with hurricanes and wildfires. A common component of many disasters is the need to prevent widespread waterborne disease when water utilities fail. Emergency response agencies have become adept at credibly communicating with the public, moving some people to safer locations, and getting others to shelter-in-place. Assessing the damage, coordinating medical and rescue teams, restoring communications, supplying large quantities of essential goods and temporary housing, keeping track of those impacted and what they need, and injecting money into the local economy are standard tasks of disaster management.

This emergency response force could be cross-trained to do contact tracing and distribute personal protective equipment. Later, it could set up mass vaccination centers. With adequate preparation, the disaster management system needed to respond to climate change could have provided the capability to implement short, strict lockdowns and undertake early mass testing, options that were not available for COVID-19. Already stockpiling bottled water and portable shelters, there is no reason why such agencies could not add protective gear for pandemics and commodities subject to panic buying like toilet paper to their inventory. Early distribution of these would help demonstrate to a country's worried public that their government had anticipated such outbreaks and foster confidence that it was prepared to confront them capably.
The role of existing emergency management agreements and coordination in moving scarce medical resources and patients across space and time to prevent the collapse of health care systems is unappreciated. Strengthening this capacity logically follows from dealing with extreme weather events, which are often strongly correlated and exhibit pronounced geo-temporal patterns. Whether the response force to deal with disasters should have the lead role, with health agencies serving in a supporting capacity, or the reverse, undoubtedly differs by country. What has been learned is that the lead agency needs the authority to act immediately and without political interference, once the threat of an impending global pandemic has been identified.

Other aspects of green infrastructure investment can make an economy more resilient to a pandemic. One of these involves a heavy-duty smart grid for electricity and communications. A key lesson learned during the COVID-19 pandemic was that much of the work traditionally done in offices, factories, and schools could be done remotely from home with the proper connectivity and often with increased productivity. Electricity generated from renewables is less susceptible to domestic production and

trade shocks. Vehicles run on it are not subject to the yo-yo effect of oil prices, which plummet in the initial phase of a pandemic due to a demand reduction, and later stoke inflation fears when production is slow to ramp up as the pandemic abates. The pandemic revealed exciting facets of supply chains and transportation networks that will need to be considered in plans for infrastructure investments in those areas.

A vital component of any green infrastructure plan is increased capacity to monitor and forecast various environmental factors, including weather. This may not seem relevant in a pandemic context to many policymakers and public health experts who have tended to view COVID-19 through a standard infectious disease lens. However, temperature and other weather variables play a central and underappreciated role in determining the path of pandemics, including the 1918 Influenza pandemic, COVID-19, and the annual wave of influenza.[204,218,219] Because airborne viruses tend to attack respiratory systems, air pollution is an aggravating factor. Because such viruses tend to kill through traditional means, statistical techniques designed to measure excess deaths induced by pollutants and extreme temperatures may serve as a sound alternative warning system. Recently developed methods for identifying COVID-19 in sewage effluent are already showing considerable promise for understanding where the virus is lurking and its prevalence. Environmental and health monitoring systems need to be coordinated. Their remit must also be expanded to include comprehensive, continual, and systematic monitoring for new threats. The Intergovernmental Panel on Climate Change (IPCC) has long recognized that changing weather conditions will alter the range of vector-borne diseases.[42] Zika is a recent example.

The dominant frame of thinking about the COVID-19 pandemic by many business leaders, economists, public health officials, and politicians worldwide is that it will be brought under control in their countries agressively more significant numbers of people are vaccinated. More nuanced versions of this view acknowledge the need to deal with within-country disparities, external threats posed by failing to bring the virus under control in other countries, and the evolution of the virus itself. This, however, is still an optimistic frame that violates the adage of hoping for the best and planning for the worst when it comes to the spread of highly infectious pathogens.

In developed countries, the way to deal with future pandemics is often seen as being able to develop vaccines even more quickly and have access to a broader spectrum of drugs. This ignores that experience with the shocks due to COVID-19, described earlier, is even more likely to be set in motion before the next pandemic. It also ignores that new pathogens are most susceptible to being stopped early in their life cycle. The first step in enhancing economic and social resilience to pandemics is to strengthen the ability to contain the pathogen spatially and break local community transmission chains quickly. Like dealing with major storms, investments in infrastructure to prevent damage are likely much more effective than expenditures to prevent harm after the event.[220] Work on detecting and controlling invasive species has many similarities and likely lessons for containing a pandemic.[221]

More generally, globalization has increased the threat of further pandemics, the speed at which they move, and the amount of harm they can do. However, it also raises the possibility of earlier detection, coordinated containment efforts, and larger markets for effective drugs and vaccines. Like climate change, pandemics represent negative global externalities. We have tried to make clear here that synergies between solutions to both persistent threats can be exploited to enhance resilience and lower overall implementation costs.

The pandemic has highlighted the potential to execute rapid transformation. The various responses to the pandemic illustrate the ability to implement changes not seen since the world wars. These include changes to taken-for-granted freedoms (large-scale lockdowns and billions of people voluntarily staying at home), the nature of work (mass online relocation of jobs previously performed in offices and stores), the nature of retail sales (digital economies supported by physical delivery and with dramatically less in-person contact with customers), industrial models (the rapid creation of new healthcare and industrial capacity to address shortfalls), and government intervention in capitalistic market economies (the willingness and ability to shoulder costs and economic burdens, printing money at unprecedented scale). There have been unintended consequences, such as the marked improvement in air quality across cities as industry and transport ground to a halt, and energy consumption precipitously fell.

Therefore, a green recovery that makes countries more resilient would address a number of risks and capacities, including population and demographic risk, healthcare and social protection, economic strength, policy capacity for economic stimulus, and global coordination, collaboration and cohesion.[186] In the light of the experience of the pandemic, the agenda to 'build back better' would leverage the acceleration of a global shift to a "Sustainable Information" age by accelerating the transition to a

digital world, including remote working, online education, digital finance, and exponentially higher digital participation. While many governments have demonstrated that they possess the ability to provide stimulus in crises, a far greater pool of private capital can make a difference. With a shift in focus to ensuring sustainable economic growth, there needs to be a clear recognition that investing widely available money in enhancing resilience to both climate change and pandemics is likely to have high returns.[159]

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