Title:
Post-COVID-19 recovery stimulus dwarfs near-term climate change investment needs

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Abstract: Governments around the world are taking unprecedented action to limit the human and economic costs of the COVID-19 pandemic. These efforts come at a make-or-break moment for another global challenge: addressing the climate change crisis. Here we show that committed economic stimulus packages are globally about 30 times larger than the additional annual low-carbon energy investments needs over the next five years consistent with putting the world on a path towards achieving the goals of the Paris Agreement. Stimulus packages and incremental investment needs diverge substantially across countries and regions, underscoring the need for international cooperation to support developing countries in pursuing a low-carbon recovery. Our findings illustrate that a climate-positive recovery is clearly within reach.

One Sentence Summary: Climate-positive COVID-19 economic recovery packages can put the world on track to achieve the Paris Agreement goals.

Main Text:

The COVID-19 pandemic is wreaking havoc, affecting communities and firms all around the world. After the initial public health shock, now comes a slower but equally disruptive economic crisis. The measures necessary to contain the virus are putting economies under tremendous strain, resulting in a global recession not experienced since the Second World War. Recent forecasts show a contraction of Gross Domestic Product (GDP) for the year 2020 across nearly all world regions (*1*). Given the uncertain dynamics of the pandemic, counter-measures such as social distancing might be required well into 2022 (*2*). Reduced economic activity might thus extend well beyond this first pandemic wave, continuing the societal hardship for several years hence. Governments around the globe are now responding to this crisis with unprecedented economic recovery packages (*3*). At the time of writing, announced COVID-19 fiscal stimulus (as a proportion of GDP) already exceeded the stimulus provided in the wake of the 2008-2009 Global Financial Crisis (*4*) by a factor of two.

A green or brown recovery

Yet, while COVID-19 is a massive disruption of the type not typically considered by most analysts (*5*), it has not surfaced in a world otherwise devoid of fundamental societal challenges – climate change being one of the most pressing. Over the past two years, several authoritative scientific assessments have re-emphasized the urgency of climate action and the need to combat the further deterioration of our natural and social environment (*6*, *7*). Meanwhile, current climate commitments by countries are grossly inadequate and imply double the amount of greenhouse gas emissions in 2030 than those compatible with limiting warming to 1.5°C (*8*), the most stringent limit referred to in the UN Paris Agreement of 2015. Adequately addressing the climate change challenge thus requires decisive action in the coming decade to set the emissions of the most important greenhouse gas – carbon-dioxide – on a path to net zero by mid-century (*6*), while simultaneously ensuring that livelihoods of billions continue to improve.

Consequently, many world leaders, including the UN Secretary-General, have called for post-COVID-19 economic recovery efforts to be directed towards catalyzing the necessary longer-term transformation to a more sustainable and resilient society. Demands for a green recovery have also been echoed by companies, investors, central banks and other institutional actors.

How governments choose to revive near-term economic activity and invest in longer-term structural change as a response to the COVID-19 crisis can either enable a green future or lead to a doubling-down on a brown one. The record decline in global greenhouse gas emissions in the first quarter of 2020 (*9*) will have a negligible impact on global warming over the longer-term unless the post-COVID-19 recovery promotes a structural shift in the underlying drivers contributing to those emissions. This can be better understood by looking at the sectors most affected by COVID-19 and the reasons for their lower emissions. Transportation and industry show the strongest decline in activity, while the electricity and energy conversion sectors have been affected to a lesser extent (*9*). Emissions reductions are thus being driven by lower activity levels, not by structural changes.

For example, people are driving and flying considerably less, but not because fossil means of mobility have been replaced by more sustainable options (biking, walking, public transit, or low-

carbon vehicles). Those same fossil-fueled vehicle fleets are simply sitting idle, ready to be redeployed (and generate emissions) when lockdown measures are lifted; and when that happens, greenhouse gas emissions will certainly rise as well.

After immediate responses to support health care, preserve livelihoods, and stabilize employment governments will be looking toward investments that can foster economic stability over the longer-term. What will be the total magnitude and nature of stability and investment instruments? Will they lean toward a green or brown recovery? We shine a light on this possibility by inventorying and classifying the latest information on governments' fiscal stimulus plans (*3*) (Supplementary Materials Table S1) and comparing the size of these measures to estimates of Paris Agreement-compatible low-carbon investment requirements.

Stimulus packages to date

To date, many governments have announced a variety of policy responses aimed at alleviating the consequences of the COVID-19 crisis (*3*). Here we focus on economic stimulus tools deployed explicitly through countries' fiscal systems, taking stock of the total value of the packages for 175 countries. As of 15 May 2020, our tracking framework showed aggregate fiscal stimuli amounting to USD 8.8 trillion, three quarters of which come from OECD countries (Fig. 1, Figures S1,S2). The US stimulus is the largest single package to date, comprising one-third of all global commitments, although the EU as a bloc accounts for even slightly more.

The level of disaggregation of countries' stimulus packages varies widely, as many details of the crisis remain unclear at this time. This heterogeneity limits our ability to understand the specific targets individual fiscal recovery packages aim to achieve beyond immediate support to the health sector (about 6% of the total global stimulus) and maintaining people's livelihoods (about 12%). What we can glean from available data is that approximately 50% of stimulus funding globally intends to support the economy at large, including measures such as loans and guarantees to incentivize continued investment by firms (see Table S1 for an overview). The remaining (~30%) global post-COVID-19 stimulus is at present unspecified. These shares vary strongly across countries with, for example, the US designating a combined 30% of total spending to direct payments to individuals and the health sector compared to only about half of that in the EU. Yet, even without knowing exactly how countries are planning to direct their recovery dollars, the sheer size of the numbers is testimony to how powerful the support could be – and how much momentum it could generate – in shaping the post-pandemic global economy (Fig. 1).

Investment needs consistent with 1.5°C

Quantitative modeling studies of Paris Agreement-compatible pathways agree that most immediately a low-carbon transformation is needed in the energy sector (*10*). This sector is currently directly responsible for more than a third of economy-wide greenhouse emissions, and to meet the Paris goals, it should fully decarbonize by mid-century, if not before (*10*). We compare the magnitude of post-COVID-19 recovery stimulus in specific countries, world regions, and globally to the levels of energy system investment required for putting the world on a path toward achieving the goals of the Paris Agreement (*11*), as assessed by the

Intergovernmental Panel on Climate Change (IPCC) in its recent Special Report on Global Warming of 1.5°C (*12*).

Average annual low-carbon energy and efficiency investments under a Paris-compatible pathway have been estimated at about 1.3 trillion USD per year over the near term between 2020 and 2024 (*11*, *12*). This amounts to about 15% of the total pledged post-COVID-19 stimulus to date (Fig. 1, Figures S3,S4). For comparison, this is a share similar to the fiscal measures that ultimately went into green stimulus in the wake of the Global Financial Crisis a decade ago (*13*). Simply put, if even a fraction of current stimulus funding would be directed toward a green recovery, the marginal benefits could be considerable.

This becomes even clearer when comparing the low-carbon energy and efficiency investment needs in a polluting, fossil-dominated energy system versus the incremental needs in a Paris Agreement-compatible pathway. These incremental low-carbon investments amount to about 300 billion USD per year over the coming five years, about 30 times less than total announced stimulus funding (Fig. 1, Fig. S5). This number in isolation, however, masks an important part of the story, as increases in low-carbon investments would necessarily be accompanied by divestment from high-carbon fossil-fuel investments –on the order of about 280 billion USD per year between now and 2024. Taken together, the additional net annual investments (investments minus divestments) to achieve an ambitious low-carbon transformation in the energy sector come to about 20 billion USD per year: around 0.25% of, or 400 times less than, the total announced stimulus to date.

These stimulus and green investment numbers need to be put into context. First, not all investment in the energy sector is expected to be government-driven (*14*), thereby significantly reducing the expected public contribution. One purpose of government funding and other measures (loans and guarantees) is to simultaneously catalyze private funding. This will be necessary because COVID-19 recovery stimulus will be available for a limited time only, whereas a deep decarbonization path requires growing low-carbon investments for years to come. Second, these investment estimates are based on a pre-COVID-19 situation and thus do not account for the potentially considerable costs that would be involved in 'recovering' to a pre-COVID-19 fossil fuel trajectory (*15*). Furthermore, green stimulus investment flows also reduce the risks for stranded assets and thereby medium- to long-term economic risks, in contrast to additional investments into the fossil fuel sector (e.g., unconditional oil and gas company bail-outs) (*16*). Finally, green stimulus policies, such as financial support for low-carbon energy, have been shown to be more attractive than traditional fiscal stimuli (*13*). Green investments, focusing on small, modular technologies like wind and solar power also provide many ancillary societal benefits that are currently not captured by these estimates (*17*). The benefits are of particular importance when considering renewable energy investments. Their small modular sizes imply much shorter project lead times which can contribute to a speedy recovery. They have also shown a larger potential for job creation, higher efficiency improvements, and an attractive risk profile for investors (*17*).

National and regional differences

The world is a heterogeneous and diverse place, and there are clear differences in stimulus packages and energy investment across regions and countries. The EU and US have issued the

largest stimulus packages globally, both in terms of absolute levels and relative to the size of their economies (Fig. 1, Figures S2,S6,S7). Total stimulus exceeds average annual low-carbon energy investment needs by a factor of 18 in the US and by 25 in the EU (Fig. 1).

The situation is quite different for developing economies. So far, stimulus packages in these geographies only amount to a small fraction (~15%) of what developed countries are putting forward. This will not only affect developing countries' ability to recover from the COVID-19 crisis but will also impact the world's collective ability to achieve the Paris Agreement climate goals, in particular because energy investment needs are relatively higher in developing countries (Fig. 1, Fig. S6). For example, India's total annual low-carbon energy investment needs relative to GDP are about 4 times higher than those of the EU; but the countries' stimulus package is only about half. Still, even India's stimulus is about 3 times higher than the countries' annual total low-carbon energy investment needs over the next five years and thus not insignificant. For China, as well as across the whole of Asia, current total stimulus at least matches near-term Paris-compatible annual low-carbon energy investment needs for a single year. For the Middle East and Africa as well as Latin America, stimulus packages exceed annual low-carbon investment needs by a factor of two. It is only for Russia and the reforming economies of the former Soviet Union that the officially announced stimulus does not (yet) match projected annual low-carbon investment needs (Fig. 1, Fig. S6). When also accounting for regional fossil fuel divestments, the resulting net additional annual low-carbon investment needs are always smaller than the stimulus for all regions considered (Fig. 1, Figures S1,S2,S5). Shifting investments to enable a Paris-compatible transformation in the following years is thus within reach for all regions and countries analyzed here.

The marked differences across countries and regions emphasize the need for international support and global partnership in the wake of the COVID-19 pandemic to ensure that stimulus funding contributes to a climate-positive recovery. Institutionalizing such support within the inter-governmental system (like, the United Nations Framework Convention on Climate Change or multilateral development banks) could help to cement these links. As we illustrate here, international support schemes of only a fraction of what is currently being put forward as post-COVID-19 recovery would be more than sufficient to catalyze both global economic recovery as well as a transformation towards a Paris Agreement-compatible future. A range of options with both near-term economic benefits and long-term climate-positive potential have been already identified (*18*).

The dual crises of COVID-19 and climate change are global problems requiring international cooperation and sustainable and inclusive solutions. While challenging politically, our findings show that these solutions are well within budget.

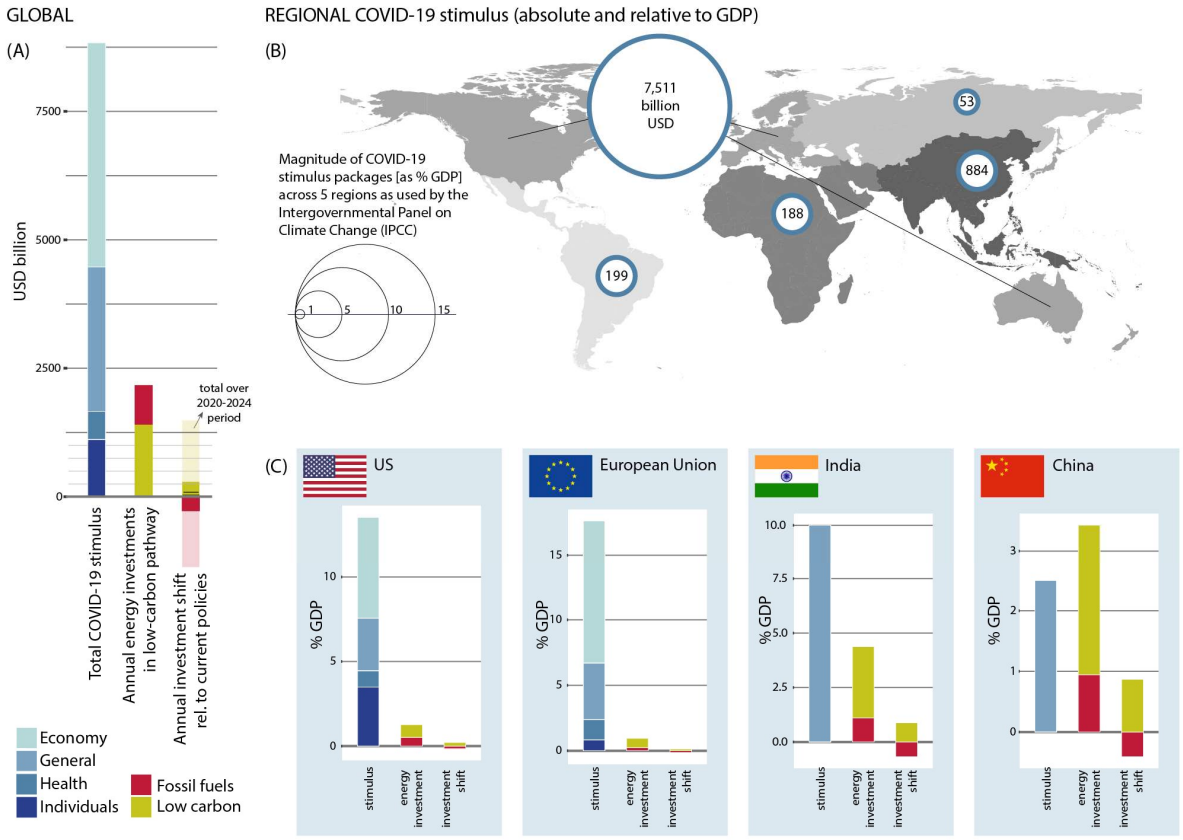

Fig. 1. Global and regional COVID-19 economic stimulus and energy investments in line with a stringent low-carbon pathway consistent with the UN Paris Agreement. (A) Global overview. Fiscal stimulus measures are grouped in four categories: those broadly targeted at the health sector (*Health*); measures aimed at supporting individuals and households (*Individuals*); measures that aim at the economy at large, including loans and guarantees (*Economy*); and then we pool the remainder of stimulus into a category of general measures (*General*). Portions of fiscal measures allocated to the general category are either unspecified or do not belong to one of the categories above. Investments are representative of average annual energy system investments over the near-term (2020-2024) in a stringent low-carbon pathway consistent with achieving the goals of the UN Paris Agreement, and are split up in investments in fossil fuels and low-carbon investments. Annual investment shifts represent the difference in fossil fuel and low-carbon investments between current policies and a stringent low-carbon pathway consistent with the Paris Agreement. The shaded area illustrates to shift in cumulative investments over the five years of the 2020-2024 period. (B) Overview of regional magnitude of COVID-19 fiscal stimulus in absolute terms and as a share of Gross Domestic Product (GDP). (C) As panel A but for four selected countries and magnitudes relative to GDP. Data and additional figures are available in the Supplementary Materials.

References and Notes:

1. IMF, "World Economic Outlook, April 2020: The Great Lockdown," *World Economic Outlook Reports* (International Monetary Fund, 2020), (available at https://www.imf.org/en/Publications/WEO/Issues/2020/04/14/weo-april-2020).

2. S. M. Kissler, C. Tedijanto, E. Goldstein, Y. H. Grad, M. Lipsitch, Projecting the transmission dynamics of SARS-CoV-2 through the postpandemic period. *Science* (2020), doi:10.1126/science.abb5793.

3. IMF, Policy Responses to COVID-19 - Policy Tracker. *International Monetary Fund* (2020), (available at https://www.imf.org/en/Topics/imf-and-covid19/Policy-Responses-to-COVID-19).

4. E. Barbier, How is the Global Green New Deal going? *Nature*. **464**, 832–833 (2010).

5. D. L. McCollum, A. Gambhir, J. Rogelj, C. Wilson, Energy modellers should explore extremes more systematically in scenarios. *Nature Energy* (2020), doi:10.1038/s41560-020-0555-3.

6. IPCC, in *Global Warming of 1.5 °C: an IPCC special report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*, V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, T. Waterfield, Eds. (World Meteorological Organization, Geneva, Switzerland, 2018; http://www.ipcc.ch/report/sr15/), p. 32.

7. IPBES, *Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services* (IPBES secretariat, Bonn, Germany, 2019).

8. N. Höhne, M. den Elzen, J. Rogelj, B. Metz, T. Fransen, T. Kuramochi, A. Olhoff, J. Alcamo, H. Winkler, S. Fu, M. Schaeffer, R. Schaeffer, G. P. Peters, S. Maxwell, N. K. Dubash, Emissions: world has four times the work or one-third of the time. *Nature*. **579**, 25–28 (2020).

9. C. Le Quéré, R. B. Jackson, M. W. Jones, A. J. P. Smith, S. Abernethy, R. M. Andrew, A. J. De-Gol, D. R. Willis, Y. Shan, J. G. Canadell, P. Friedlingstein, F. Creutzig, G. P. Peters, Temporary reduction in daily global CO2 emissions during the COVID-19 forced confinement. *Nat. Clim. Chang.* (2020), doi:10.1038/s41558-020-0797-x.

10. IPCC, in *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C.

von Stechow, T. Zwickel, J. C. Minx, Eds. (Cambridge University Press, Cambridge, United Kingdom, and New York, NY, USA, 2014), pp. 1–33.

11. D. L. McCollum, W. Zhou, C. Bertram, H.-S. de Boer, V. Bosetti, S. Busch, J. Després, L. Drouet, J. Emmerling, M. Fay, O. Fricko, S. Fujimori, M. Gidden, M. Harmsen, D. Huppmann, G. Iyer, V. Krey, E. Kriegler, C. Nicolas, S. Pachauri, S. Parkinson, M. Poblete-Cazenave, P. Rafaj, N. Rao, J. Rozenberg, A. Schmitz, W. Schoepp, D. van Vuuren, K. Riahi, Energy investment needs for fulfilling the Paris Agreement and achieving the Sustainable Development Goals. *Nature Energy*. **3**, 589–599 (2018).

12. J. Rogelj, D. Shindell, K. Jiang, S. Fifita, P. Forster, V. Ginzburg, C. Handa, H. Kheshgi, S. Kobayashi, E. Kriegler, L. Mundaca, R. Séférian, M. V. Vilariño, in *Global Warming of 1.5 °C: an IPCC special report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*, G. Flato, J. Fuglestvedt, R. Mrabet, R. Schaeffer, Eds. (IPCC/WMO, Geneva, Switzerland, 2018; http://www.ipcc.ch/report/sr15/), pp. 93–174.

13. ILO, IILS, EC, "Green Stimulus Measures," *EC-IILS Joint Discussion Paper Series No. 15* (International Labour Organisation, International Institute for Labour Studies, European Commission, 2011), p. 32.

14. Frankfurt School-UNEP Centre/BNEF, Global Trends in Renewable Energy Investment 2019 (2019), (available at https://wedocs.unep.org/bitstream/handle/20.500.11822/29752/GTR2019.pdf).

15. IEA, "Oil Market Report - April 2020" (International Energy Agency, Paris, France, 2020), (available at https://www.iea.org/reports/oil-market-report-april-2020).

16. J.-F. Mercure, H. Pollitt, J. E. Viñuales, N. R. Edwards, P. B. Holden, U. Chewpreecha, P. Salas, I. Sognnaes, A. Lam, F. Knobloch, Macroeconomic impact of stranded fossil fuel assets. *Nature Climate Change*. **8**, 588–593 (2018).

17. C. Wilson, A. Grubler, N. Bento, S. Healey, S. D. Stercke, C. Zimm, Granular technologies to accelerate decarbonization. *Science*. **368**, 36–39 (2020).

18. C. Hepburn, B. O'Callaghan, N. Stern, J. Stiglitz, D. Zenghelis, Will COVID-19 fiscal recovery packages accelerate or retard progress on climate change? *Oxf Rev Econ Policy* (2020), doi:10.1093/oxrep/graa015.

19. S. Fujimori, T. Hasegawa, T. Masui, K. Takahashi, Land use representation in a global CGE model for long-term simulation: CET vs. logit functions. *Food Security*. **6**, 685–699 (2014).

20. E. Stehfest, D. van Vuuren, T. Kram, L. Bouwman, R. Alkemade, M. Bakkenes, H. Biemans, A. Bouwman, M. den Elzen, J. Janse, P. Lucas, J. van Minnen, C. Müller, A. G. Prins, "Integrated Assessmnet of Global Environmental Change with IMAGE 3.0. Model Description and Policy Applications" (2014).

21. V. Krey, P. Havlik, O. Fricko, J. Zilliacus, M. Gidden, M. Strubegger, G. Kartasasmita, T. Ermolieva, N. Forsell, M. Gusti, N. Johnson, G. Kindermann, P. Kolp, D. McCollum, S. Pachauri, S. Rao, J. Rogelj, H. Valin, M. Obersteiner, K. Riahi, "MESSAGE-GLOBIOM 1.0 Documentation" (2016).

22. P. Criqui, S. Mima, P. Menanteau, A. Kitous, Mitigation strategies and energy technology learning: An assessment with the POLES model. *Technological Forecasting and Social Change*. **90**, 119–136 (2015).

23. E. Kriegler, N. Bauer, A. Popp, F. Humpenöder, M. Leimbach, J. Strefler, L. Baumstark, B. L. Bodirsky, J. Hilaire, D. Klein, I. Mouratiadou, I. Weindl, C. Bertram, J. P. Dietrich, G. Luderer, M. Pehl, R. Pietzcker, F. Piontek, H. Lotze-Campen, A. Biewald, M. Bonsch, A. Giannousakis, U. Kreidenweis, C. Müller, S. Rolinski, A. Schultes, J. Schwanitz, M. Stevanovic, K. Calvin, J. Emmerling, S. Fujimori, O. Edenhofer, Fossil-fueled development (SSP5): An energy and resource intensive scenario for the 21st century. *Global Environmental Change*. **42**, 297–315 (2017).

24. V. Bosetti, C. Carraro, M. Galeotti, E. Massetti, M. Tavoni, "WITCH. A World Induced Technical Change Hybrid Model" (2006).

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Author contributions: All authors were involved in the conceptualization of the study. MA led the data curation of the inventory of economic stimulus packages, and the development of the analysis code. All authors contributed to the design of the analysis and interpretation of the results. JR led the writing of the manuscript with contributions of all authors, and the design and development of the visual with contributions of MA.

Competing interests: Authors declare no competing interests.

Data and materials availability: All data and analysis code are available online.

Supplementary Materials:

Materials and Methods

Figs. S1 to S7

Table S1

References only cited in SM 19-24

Data

Analysis code

Science
AAAS

Supplementary Materials for

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This PDF file includes:

Materials and Methods
Figs. S1 to S7
Table S1

Other Supplementary Materials for this manuscript include the following:

Data
Analysis code

Materials and Methods

Energy system investments

Energy system investment portfolios (*11*) were derived from six global energy-economy models (IAMs; see ref. (*11*)): AIM/CGE (*19*), IMAGE (*20*), MESSAGEix-GLOBIOM (*21*), POLES (*22*), REMIND-MAgPIE (*23*), and WITCH-GLOBIOM (*24*). In this analysis we focus on the near-term (2020-2024) investment needs under the current-policies scenario ('CPol', used as each model's baseline) and on upscaling requirements necessary for the energy system compatible with the 1.5°C target of the Paris Agreement. The models cover different types of energy technologies, including resource extraction, power generation, fuel conversion, transmission and distribution, energy storage, and end-use demand services (transport, buildings, industry). We group these technologies into two broad sectors:

- fossil fuels**:** extraction and conversion of fossil fuels, electricity from fossil fuels without Carbon Capture and Storage (CCS), and hydrogen from fossil fuels
- low carbon sources**:** extraction and conversion of nuclear energy, CCS capture and CO_2 compression equipment, electricity from non-biomass renewables, hydrogen from non-fossil fuels, extraction and conversion of bioenergy, electricity transmission and distribution and storage, and energy efficiency

The investment figures from the underlying model-specific data were corrected for inflation (from USD 2015 to current USD), and are then reported as model averages (i.e., average across six models) for the each of the two broad sectoral categories (fossil and low-carbon).

Stimulus packages

The International Monetary Fund (IMF) has been tracking the policy measures announced by governments in response to the COVID-19 pandemic (*3*). For this analysis, we focus on the fiscal policy responses, which span a wide range of instruments such as spending and revenue measures (primarily in the health sector, as well as different types of liquidity support for affected businesses and workers), equity injections, asset purchases, extra-budgetary funds, guarantees on loans, etc. We extracted data for 175 countries and the European Union, announced as of May 15, 2020.

Countries have announced their immediate-term stabilization packages in different levels of detail and scope. Here we group the fiscal measures broadly into those targeted at the health sector (in figures labeled as *Health*); measures aimed at supporting individuals and households (labeled *Individuals*); measures that aim at the economy at large, including loans and guarantees (labeled *Economy*); and then we pool the remainder of stimulus into a category of general measures (labeled *General*). Portions of fiscal measures allocated to the general category are either unspecified or do not belong to one of the categories above. We do not account for governments' announcements to channel funds into international assistance, nor the recovery funds agreed between governments and the international finance institutions. See Table S1 for country-level detail.

References:

References are included in the complete reference list at the end of the main text.

Supplementary Figures:

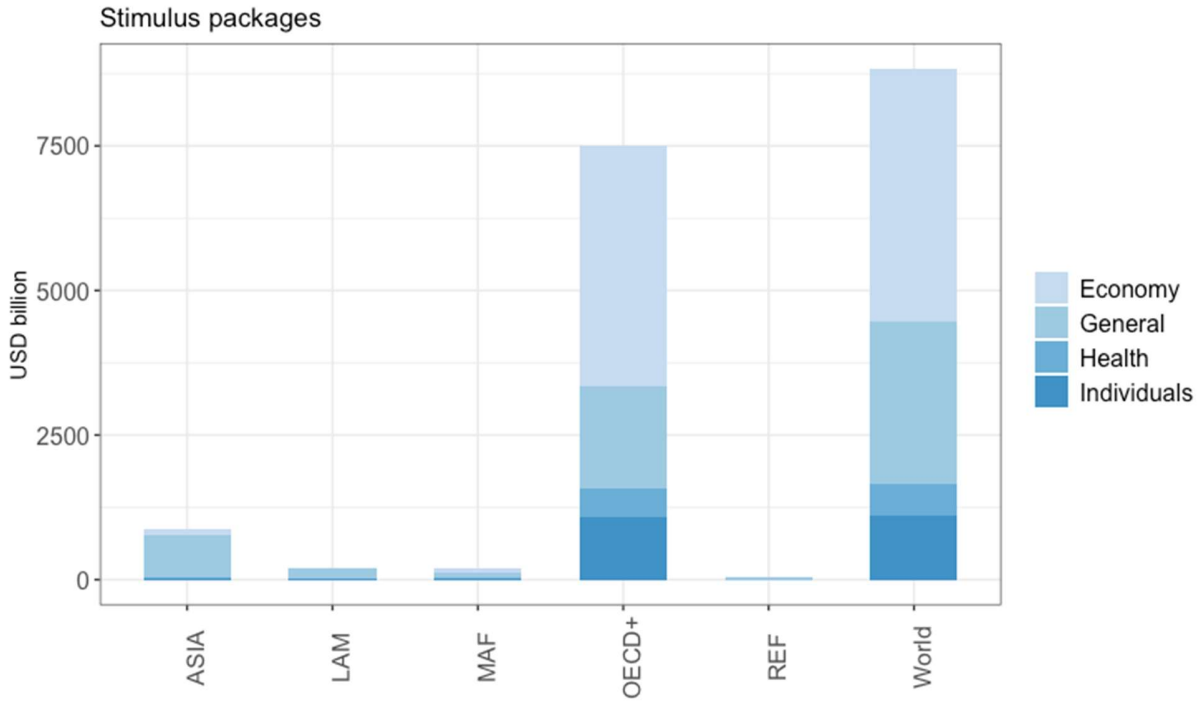

Fig. S1.
Total amount of stimulus packages for five macro regions and the world, disaggregated in four categories based on the targets of the fiscal instruments.

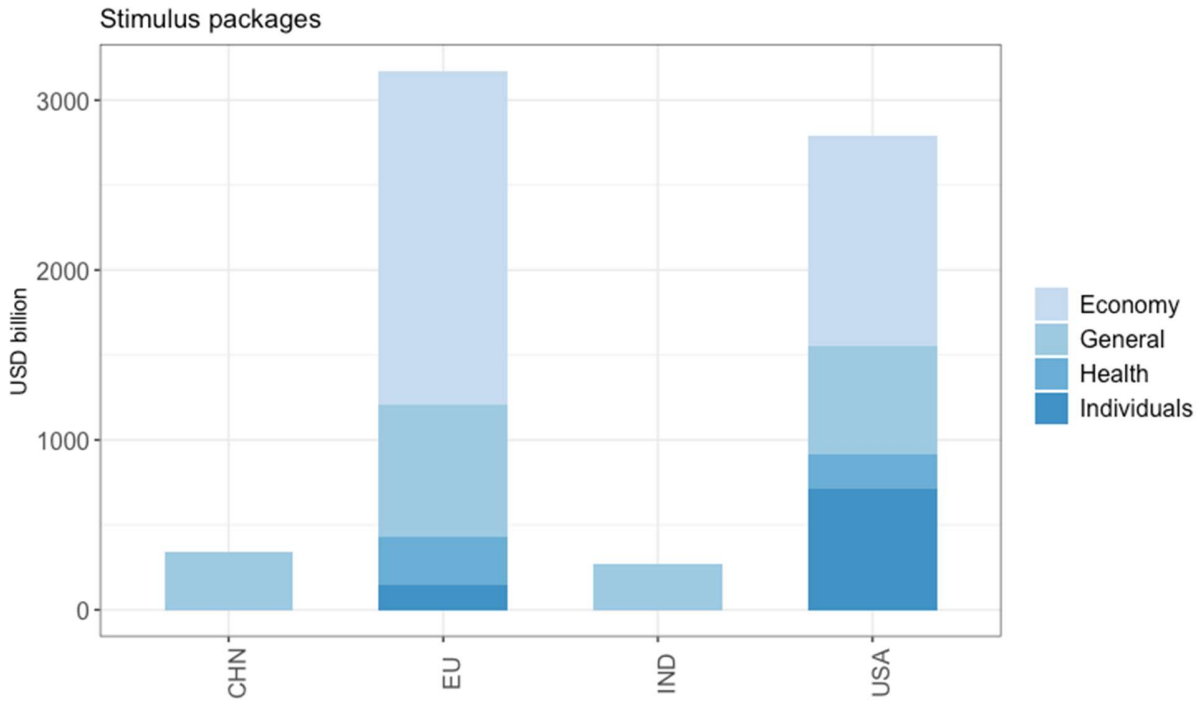

Fig. S2.
Total amount of stimulus packages for four large economies, disaggregated in four categories based on the targets of the fiscal instruments.

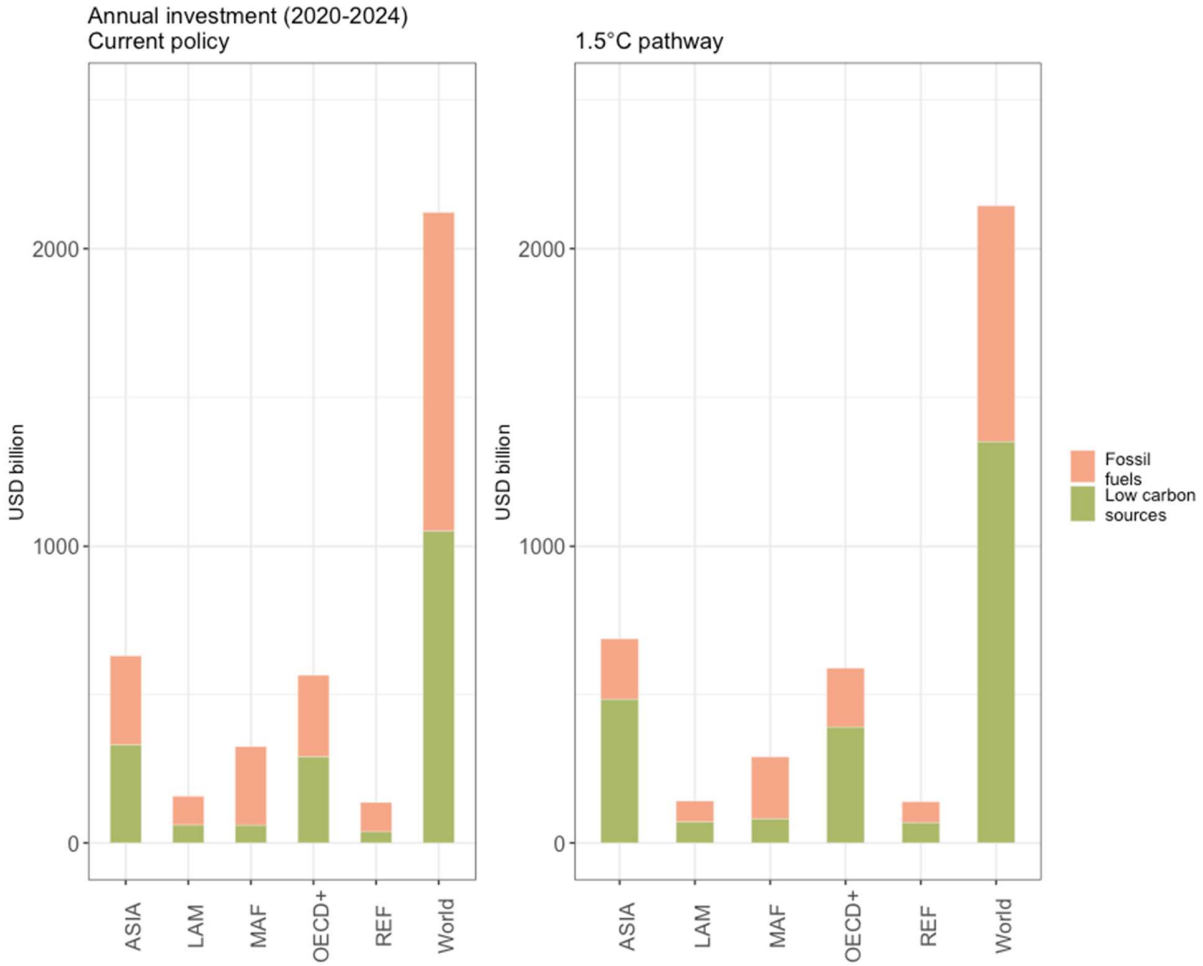

Fig. S3.

Annual energy system investments between 2020 and 2024 for the current policy baseline (left) and a pathway compatible with the 1.5°C limit of global mean temperature (right) for five macro regions and the world.

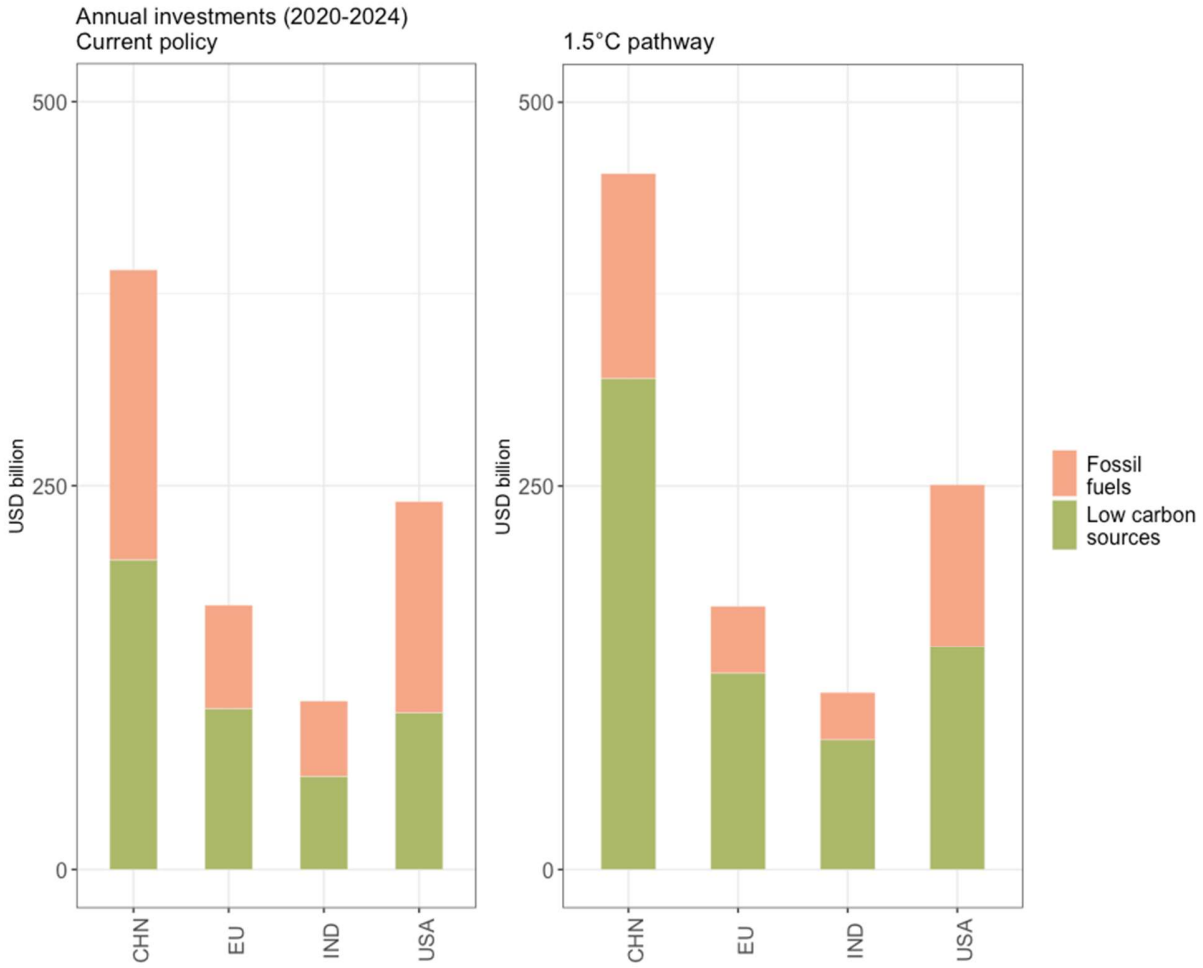

Fig. S4.

Annual energy system investments between 2020 and 2024 for the current policy baseline (left) and a pathway compatible with the 1.5°C limit of global mean temperature (right) for four large economies.

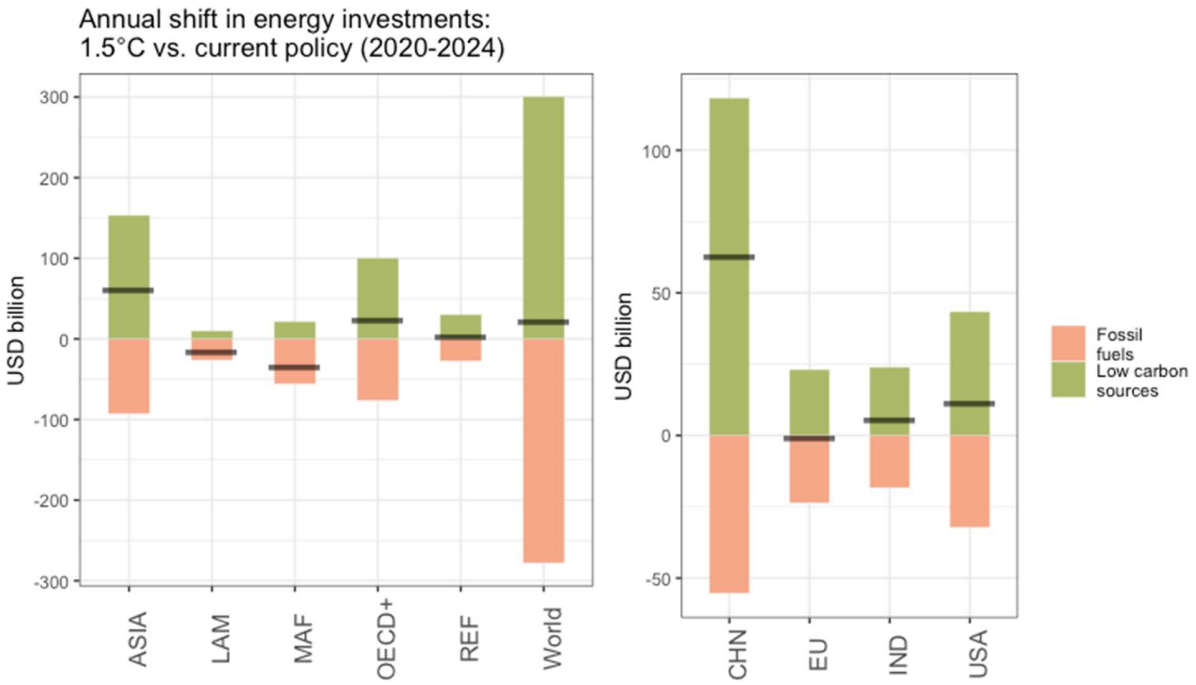

Fig. S5.

Annual shift in energy investments from the current policy baseline scenario to a pathway compatible with the 1.5°C limit of global mean temperature for five macro regions and the world (left) and four large economies (right).

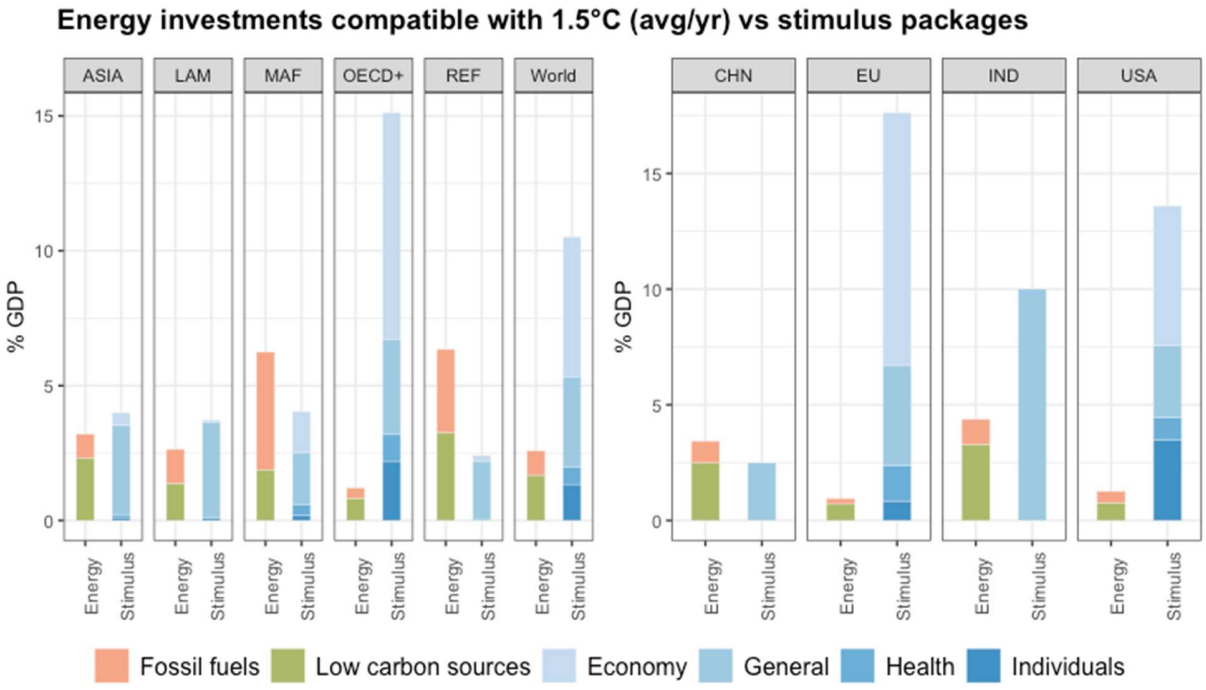

Fig. S6.

Average annual energy investments compatible with the 1.5°C global mean temperature limit, and fiscal stimulus packages in response to COVID-19, expressed as a percentage of the 2018 Gross Domestic Product (GDP) for five macro regions and the world (left) and four major economies (right).

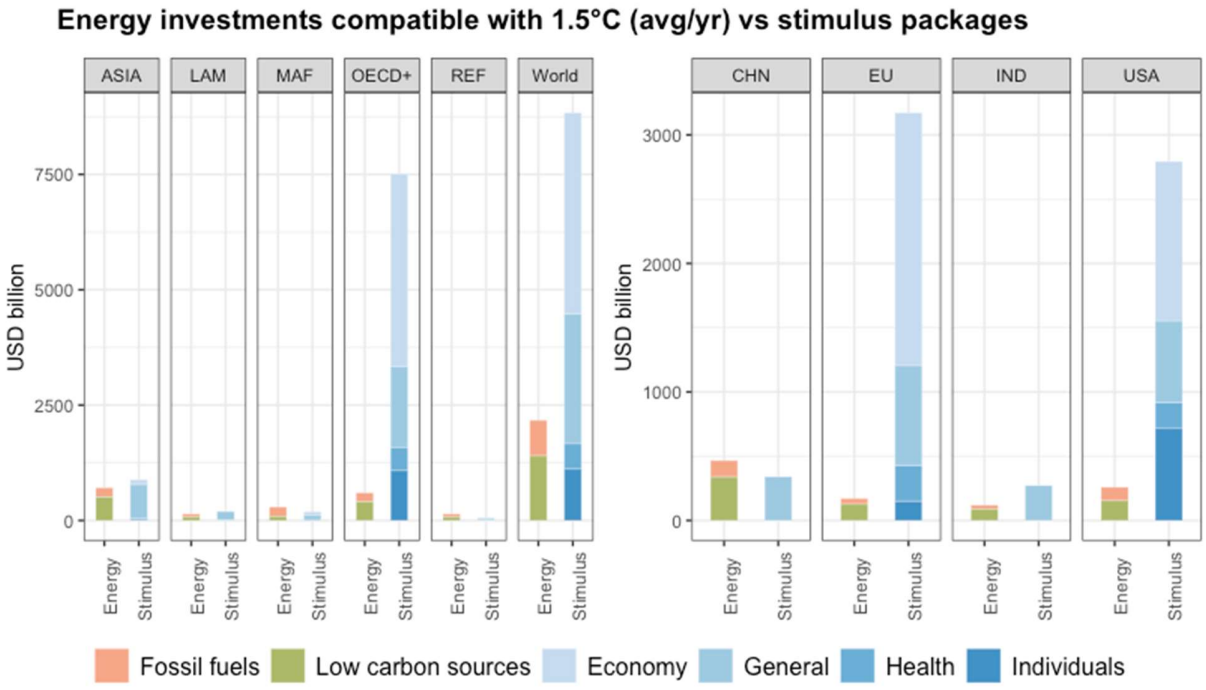

Fig. S7.

Annual energy investments compatible with the 1.5°C global mean temperature limit, and fiscal stimulus packages in response to COVID-19, expressed in current USD, for five macro regions and the world (left) and four major economies (right).

Supplementary Table:

Table S1:
Inventory and categorisation of stimulus packages in response to COVID-19, based on the IMF Policy Tracker (IMF, 2020) as of May 15, 2020. Explanations for categories can be found in the Materials and Methods section (SM p.2).

Country	Macro region	Economy	General	Health	Individuals	Total
		USD billion				
Afghanistan	ASIA	-	0.1	0.0	-	0.1
Angola	MAF	-	-	0.0	-	0.0
Albania	OECD+	0.4	0.0	0.0	-	0.4
United Arab Emirates	MAF	4.4	2.8	-	-	7.2
Argentina	LAM	-	3.7	-	-	3.7
Armenia	REF	-	0.1	-	-	0.1
Australia	OECD+	-	45.9	-	96.1	142.0
Austria	OECD+	10.9	33.7	4.3	-	48.9
Azerbaijan	REF	-	-	-	-	-
Burundi	MAF	-	0.1	-	0.0	0.1
Belgium	OECD+	56.5	10.9	-	4.7	72.1
Benin	MAF	-	0.0	-	-	0.0
Burkina Faso	MAF	-	-	-	-	-
Bangladesh	ASIA	6.6	-	-	0.4	7.0
Bulgaria	OECD+	-	1.4	-	-	1.4
Bahrain	MAF	-	1.1	0.5	0.0	1.6
Bahamas	LAM	0.1	0.0	0.0	0.0	0.1
Bosnia & Herzegovina	OECD+	0.3	0.9	0.0	-	1.2
Belarus	REF	-	-	-	-	-
Belize	LAM	-	0.0	-	-	0.0
Bolivia	LAM	0.2	-	0.2	-	0.4
Brazil	LAM	-	149.0	-	-	149.0
Barbados	LAM	-	-	-	-	-
Brunei	ASIA	-	-	-	-	-
Bhutan	ASIA	-	-	0.0	-	0.0
Botswana	MAF	0.1	0.1	0.0	-	0.2
Central African Republic	MAF	-	0.0	-	-	0.0
Canada	OECD+	65.6	-	2.5	81.0	149.1
Switzerland	OECD+	50.1	16.4	-	-	66.5
Chile	LAM	3.0	11.8	-	2.0	16.8
China	ASIA	-	340.0	-	-	340.0

Cote d'Ivoire	MAF	0.8	0.1	0.1	-	1.0
Cameroon	MAF	0.0	-	0.1	-	0.2
Congo - Kinshasa	MAF	-	0.1	-	-	0.1
Congo - Brazzaville	MAF	-	0.2	-	-	0.2
Colombia	LAM	-	9.3	-	-	9.3
Comoros	MAF	-	-	-	-	-
Cape Verde	MAF	0.0	-	-	0.0	0.1
Costa Rica	LAM	-	-	-	-	-
Cuba	LAM	-	-	-	-	-
Cyprus	OECD+	0.0	0.9	0.1	-	1.0
Czechia	OECD+	36.2	10.2	-	-	46.4
Germany	OECD+	902.0	115.0	-	107.0	1,124.0
Djibouti	MAF	-	-	-	-	-
Denmark	OECD+	10.7	22.8	-	-	33.4
Dominican Republic	LAM	-	0.6	-	-	0.6
Algeria	MAF	-	-	-	-	-
Ecuador	LAM	0.1	-	-	0.1	0.2
Egypt	MAF	0.0	0.0	0.0	-	0.0
Eritrea	MAF	-	-	-	-	-
Spain	OECD+	20.7	5.3	4.6	20.1	50.6
Estonia	OECD+	1.9	0.1	0.2	0.3	2.6
Ethiopia	MAF	-	0.3	0.4	0.9	1.6
European Union	OECD+	0.5	366.0	261.0	-	627.5
Finland	OECD+	5.6	-	1.1	4.4	11.1
Fiji	OECD+	-	0.5	-	-	0.5
France	OECD+	342.0	120.0	-	-	462.0
Gabon	MAF	-	0.7	-	-	0.7
United Kingdom	OECD+	37.4	-	19.6	9.3	66.3
Georgia	REF	0.4	-	0.1	-	0.6
Ghana	MAF	-	0.3	-	-	0.3
Gambia	MAF	-	0.0	-	-	0.0
Guinea-Bissau	MAF	-	-	0.0	0.0	0.0
Equatorial Guinea	MAF	-	-	0.0	-	0.0
Greece	OECD+	2.2	11.4	-	-	13.6
Guatemala	LAM	-	2.7	-	-	2.7
Guam	OECD+	-	-	-	-	-
Guyana	LAM	-	-	-	-	-
Hong Kong	ASIA	23.8	-	3.8	9.1	36.7
Honduras	LAM	-	1.9	0.2	0.3	2.4

Croatia	OECD+	-	-	-	-	-
Haiti	LAM	-	0.1	0.0	0.0	0.1
Hungary	OECD+	8.6	-	0.9	-	9.5
Indonesia	ASIA	10.5	20.3	-	-	30.8
India	ASIA	-	272.0	-	-	272.0
Ireland	OECD+	5.0	7.5	2.0	-	14.5
Iran	MAF	35.3	29.0	0.2	0.4	64.8
Iraq	MAF	-	0.0	-	-	0.0
Iceland	OECD+	-	2.1	-	-	2.1
Israel	MAF	11.4	6.1	3.1	5.6	26.2
Italy	OECD+	447.0	0.3	3.5	10.9	461.6
Jamaica	LAM	-	0.2	-	-	0.2
Jordan	MAF	-	-	-	0.0	0.0
Japan	OECD+	795.0	229.0	-	24.9	1,048.9
Kazakhstan	REF	-	-	-	-	-
Kenya	MAF	-	0.4	-	-	0.4
Kyrgyzstan	REF	0.0	0.5	0.0	-	0.6
Cambodia	ASIA	-	-	0.1	-	0.1
South Korea	ASIA	-	20.3	-	-	20.3
Kuwait	MAF	-	1.6	-	-	1.6
Laos	ASIA	-	0.0	-	-	0.0
Lebanon	MAF	-	-	-	-	-
Liberia	MAF	-	-	-	-	-
Libya	MAF	-	0.4	-	-	0.4
Sri Lanka	ASIA	-	0.0	-	-	0.0
Lesotho	MAF	0.0	0.0	0.0	0.1	0.1
Lithuania	OECD+	2.5	0.4	0.5	1.5	4.9
Luxembourg	OECD+	9.6	0.0	0.2	1.4	11.3
Latvia	OECD+	1.1	0.9	0.0	0.0	2.0
Macau SAR China	ASIA	-	6.7	-	-	6.7
Morocco	MAF	-	3.2	-	-	3.2
Moldova	REF	-	-	-	-	-
Madagascar	MAF	-	-	-	-	-
Maldives	ASIA	-	0.2	-	-	0.2
Mexico	LAM	1.3	8.1	-	-	9.4
Macedonia	OECD+	-	0.0	-	-	0.0
Mali	MAF	-	0.1	-	-	0.1
Malta	OECD+	-	0.4	0.1	-	0.6
Myanmar (Burma)	ASIA	0.1	-	0.0	0.0	0.1

Montenegro	OECD+	-	0.2	-	-	0.2
Mongolia	ASIA	-	-	0.0	0.3	0.3
Mozambique	MAF	-	-	0.0	-	0.0
Mauritania	MAF	-	0.1	-	-	0.1
Mauritius	MAF	0.1	0.2	0.0	0.0	0.3
Malawi	MAF	0.1	-	0.0	-	0.1
Malaysia	ASIA	-	10.3	-	-	10.3
Namibia	MAF	0.2	0.3	0.2	-	0.6
New Caledonia	OECD+	-	-	-	-	-
Niger	MAF	-	-	-	-	-
Nigeria	MAF	0.0	1.4	0.0	-	1.4
Nicaragua	LAM	-	-	-	-	-
Netherlands	OECD+	-	21.8	-	-	21.8
Norway	OECD+	-	17.1	-	-	17.1
Nepal	ASIA	-	-	-	-	-
New Zealand	OECD+	9.0	5.1	0.3	1.7	16.1
Oman	MAF	-	-	-	-	-
Pakistan	ASIA	0.8	7.1	0.1	1.8	9.9
Panama	LAM	0.2	-	-	0.0	0.2
Peru	LAM	0.1	-	0.3	1.0	1.5
Philippines	ASIA	2.3	3.9	1.1	3.9	11.2
Papua New Guinea	ASIA	-	1.7	-	-	1.7
Poland	OECD+	41.8	22.2	-	-	64.0
Puerto Rico	LAM	-	-	-	-	-
Portugal	OECD+	10.8	-	-	-	10.8
Paraguay	LAM	0.0	1.0	0.5	0.4	1.9
French Polynesia	OECD+	-	-	-	-	-
Qatar	MAF	-	20.6	-	-	20.6
Romania	OECD+	-	8.9	-	-	8.9
Russia	REF	-	46.4	-	-	46.4
Rwanda	MAF	-	0.3	-	-	0.3
Saudi Arabia	MAF	18.7	13.8	12.5	-	45.0
Sudan	MAF	-	3.5	1.2	1.0	5.8
Senegal	MAF	0.1	1.4	0.1	-	1.7
Singapore	ASIA	41.0	1.4	0.6	4.2	47.2
Solomon Islands	OECD+	-	0.0	-	-	0.0
Sierra Leone	MAF	-	0.0	-	-	0.0
El Salvador	LAM	-	-	-	-	-
Somalia	MAF	-	-	-	-	-

Serbia	OECD+	4.8	-	0.4	0.6	5.8
Suriname	LAM	-	-	-	0.1	0.1
Slovakia	OECD+	-	2.0	-	-	2.0
Slovenia	OECD+	0.7	5.8	-	0.1	6.5
Sweden	OECD+	52.0	16.0	-	-	68.0
Swaziland	MAF	-	0.0	-	-	0.0
Syria	MAF	-	-	-	-	-
Chad	MAF	-	-	0.1	0.0	0.1
Togo	MAF	-	0.1	-	-	0.1
Thailand	ASIA	12.4	46.4	18.6	-	77.4
Tajikistan	REF	-	-	-	-	-
Turkmenistan	REF	4.6	-	0.8	0.1	5.6
Timor-Leste	ASIA	-	-	-	-	-
Trinidad & Tobago	LAM	-	-	-	-	-
Tunisia	MAF	-	0.6	0.0	0.3	0.9
Turkey	OECD+	5.2	15.5	-	-	20.7
Tanzania	MAF	0.4	-	0.3	-	0.7
Uganda	MAF	-	0.1	-	-	0.1
Ukraine	REF	-	0.2	-	-	0.2
Uruguay	LAM	-	-	-	0.4	0.4
United States	OECD+	1,240.0	637.0	200.0	716.0	2,793.0
Uzbekistan	REF	-	-	-	-	-
Venezuela	LAM	-	-	-	-	-
Vietnam	ASIA	8.0	2.2	-	1.6	11.8
Samoa	OECD+	-	0.0	-	-	0.0
South Africa	MAF	0.0	-	0.0	-	0.0
Zambia	MAF	-	0.3	-	-	0.3
Zimbabwe	MAF	-	0.0	-	-	0.0

Data S1. (separate file)

All data underlying this analysis as well as analysis scripts are available at:
https://github.com/marina-andrijevic/covid_recovery/tree/master/data