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Will post-COVID-19 recovery packages accelerate low-carbon innovation?

Preliminary findings

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OECD Green Growth and Sustainable Development Forum

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Authorship & Acknowledgements

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Executive Summary

The recovery packages adopted in the wake of the COVID-19 pandemic constitute a unique opportunity to accelerate the transition to a low-carbon economy. This Issue paper summarises preliminary findings from ongoing research on the impact of recovery packages announced in response to the COVID-19 pandemic on the development and diffusion of low-carbon technologies. This paper is a contribution to the 2022 Green Growth and Sustainable Development Forum and complements a separate Issue paper on assessing the broader environmental impact of measures in the OECD Green Recovery Database.

This note builds on a new database – the OECD Low-carbon Technology Recovery Database (LTRD) – which seeks to assess the impact of recovery spending specifically on low-carbon technologies across OECD, G20 and EU countries. This database builds on available COVID-19 recovery databases, focusing on policy measures that support low-carbon technologies announced from January 2020 to December 2021. The LTRD currently covers 14 countries within the project's scope of OECD, G20 and EU. Together, these countries represent 66% of global GDP and 53% of global annual CO2 emissions. The final database, which will be released in June 2023 together with the final report, will include 52 countries, so that the results presented in this Issue paper should be considered as preliminary.

According to the data gathered so far, a total of USD 1.2 trillion funding in recovery packages has been targeted at low-carbon technologies. Half of the funding within the LTRD has been directed at the transportation sector and around one third to energy generation, transmission, or distribution. Around 85% of the measures target the adoption phase, and 15% the research, development and demonstration phase. Compared to the recovery packages following the 2007-2008 Global Financial Crisis, the response to the COVID-19 crisis appears to have placed more emphasis on R&D and demonstration. Among low-emission technologies that are still in the early stages of innovation and where significant investments in R&D and demonstration projects are necessary, hydrogen has been the main priority (especially in the United States, France and Germany), followed by Carbon capture, utilisation, and storage (CCUS) and Smart grids. Relatively small fractions of recovery packages are dedicated to nuclear innovation, zero-emission buildings, and large-scale storage technologies.

Comparing the funding identified within recovery packages to estimated average annual additional investment needs to reach net-zero emissions targets by 2050, the analysis shows that while recovery packages make a welcome contribution to closing the investment gap, they fall short of the substantial low carbon technology investments requirements to be on track to meet the net zero target. This overall shortfall however masks considerable heterogeneity across technologies. Low-carbon technology recovery funding contributes significantly to closing the investment gap for electric vehicles, CCUS and nuclear power; it is substantial for energy efficiency, clean fuel supply (hydrogen), electricity network and renewables; but marginal in EV charging infrastructure and negligible in battery energy storage.

In short, while post-COVID stimulus packages have oriented investment towards sectors and technologies key for the low-carbon transition, they cannot by themselves close the investment gap needed by 2030. They must now be accompanied by more ambitious complementary climate policies that would induce private investment and trigger the deeper structural changes made necessary by net zero targets and the current fossil fuel energy price crisis.

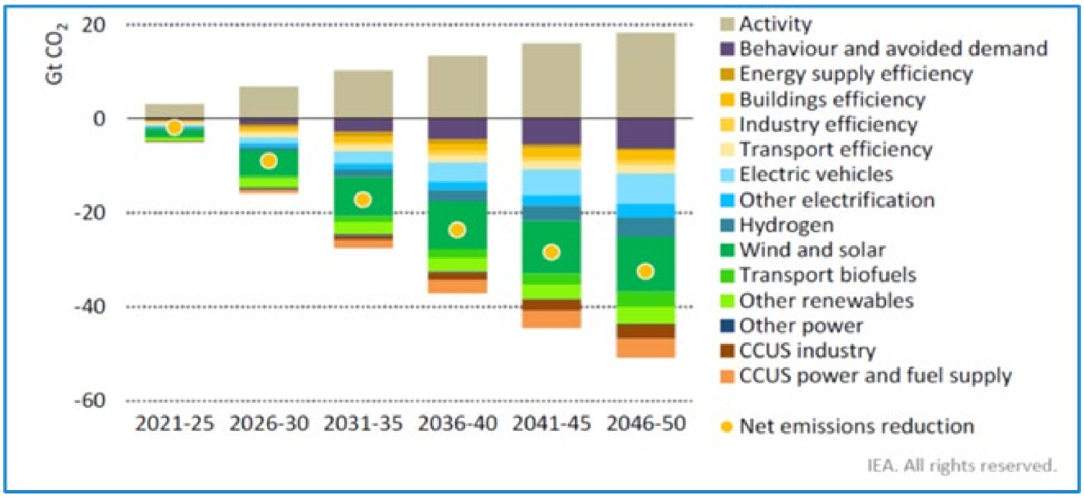
1 Introduction and background

1.1 The need for increased investment in low-carbon technologies

1. Countries representing more than 90% of the world economy have legislated or announced targets of climate neutrality by the mid-century. Reaching this objective requires rapidly adopting zero-carbon energy sources and production processes across all economic sectors (Figure 1), as illustrated by the International Energy Agency's Net-Zero Emissions by 2050 Scenario (IEA, 2021[1]).

Figure 1. The net-zero economy requires system-wide technological change

Average annual CO2 reductions from 2020 in the IEA's Net Zero Emissions scenario, by source



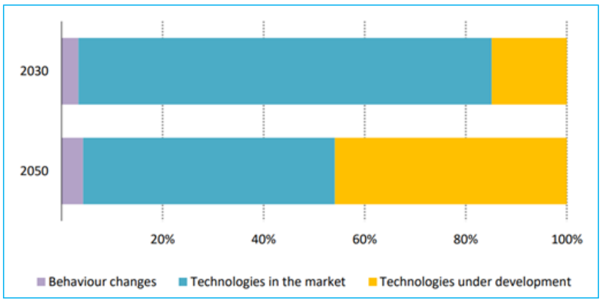
Note: Activity = changes in energy service demand from economic and population growth. Behaviour = change in energy service demand from user decisions, e.g. changing heating temperatures. Avoided demand = change in energy service demand from technology developments, e.g. digitalisation.
Source: (IEA, 2021[1])

2. Achieving climate neutrality requires both the large-scale deployment of existing technologies and the development and adoption of the technologies that are far from mature today. Some of the carbon-free technologies necessary to reach net zero emissions already exist, but their cost needs to be reduced so that they can become fully competitive with carbon-based alternatives and can be deployed rapidly and at scale (IPCC, 2022[2]). Other technologies are still in their infancy (e.g., advanced batteries, hydrogen electrolysers and direct air capture and storage) and need to be further developed. According to the IEA Net Zero scenario, while most of the global reductions in CO2 emissions through 2030 come from technologies readily available today, nearly half of the global reductions in energy-related CO_2 emissions through 2050 will have to come from technologies that are currently at the demonstration or prototype phase, such as electrification of production processes, CCUS, hydrogen and sustainable bioenergy. In

some sectors like heavy industry and long-distance transport, the share of emissions reductions from technologies that are still under development today is even higher.

Figure 2. Share of CO2 emissions savings from mature and early-stage technologies in the IEA net zero scenario

Annual CO_2 emissions savings in the net zero pathway, relative to 2020



Source: (IEA, 2021[1])

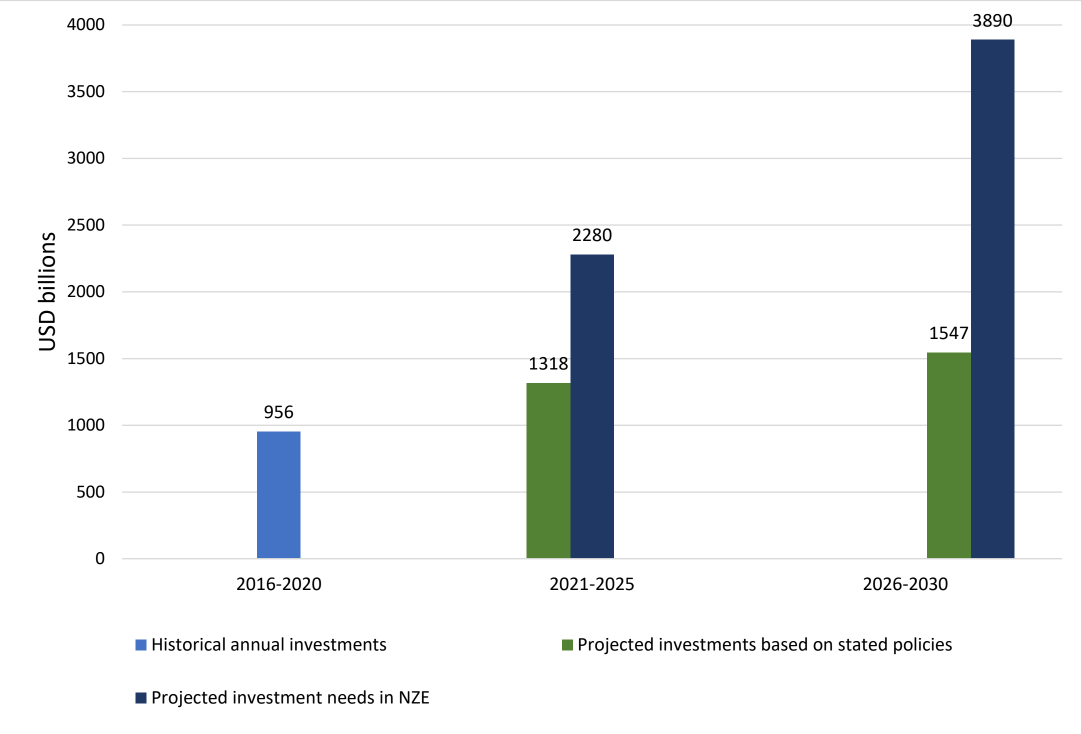
3. Therefore, the major emissions reductions implied by the net-zero transition require large investments in the development and deployment of technologies, products, processes and methods that reduce the greenhouse gas (GHG) emissions of production and consumption systems (IPCC, 2022[2]; OECD/The World Bank/UN Environment, 2018[3]). More specifically, the IEA (2021[1]) reports that an additional amount of USD 65 billion globally must be invested in demonstration projects as soon as possible, due to high capital intensity of low-carbon technologies (OECD/The World Bank/UN Environment, 2018[3]).

4. Comparing the IEA's Net Zero Emission 2050 scenario (NZE) to the Stated Policy Scenario (STEPS) suggests that approximately USD 1 trillion additional annual investments on average is needed in clean energy investments by 2025, and USD 2.3 trillion in additional annual investments between 2026 and 2030[1] (Figure 3). Power generation stands for the largest part of the required additional investments (especially renewable energy). It is followed by investments in end-use technologies (energy efficiency, clean vehicles), alternative fuels (hydrogen-based fuels and biofuels) and electricity networks[2].

[1] Note that these investments exclude investments in fossil fuels in energy generation without CCUS, and oil, gas and coal in fuel supply. Other estimates of the investment needed to achieve net zero by 2050 arrive at similar numbers: McKinsey & Company (2022[5]) estimate the incremental investment need relative to the baseline 'current policies' scenario at $0.8 trillion per year, while Vivid Economics et al. (2021[6]) estimate the gap at $1.7 trillion per year from 2021–2025 and $3.6 trillion per year from 2026–2050. IRENA (2021[57]) reports a total investment need of USD 5.7 trillion on average each year towards 2030, while BloombergNEF (2021[56]) reports at total of USD 5.8 trillion yearly 2021-2050. However, these investments are gross investments and not additional investment with respect to a current policy scenario.

[2] For a graphical representation, please consult Figure A A.1 in Annex A.

Figure 3. Clean energy investment needs in IEA's NZE scenario compared to foreseen investments under stated policies (IEA's STEPS scenario) and recent investment



Note: These numbers only include clean energy investment, and therefore exclude historical and projected investments in fossil fuels in energy generation without CCUS and coal, oil and natural in fuel supply.
Source: (IEA, 2022[4])

5. The scale of the transformation needed is such that neither the private sector nor governments will be able to provide the necessary investment on their own. Total climate-related finance flows were estimated at USD 632 billion in 2019/2020, of which public climate finance represented USD 321 billion i.e. 51% of the total (Meckling et al., 2015[7]). Going forward, available estimates suggest that governments or public entities (including sub-national governments and local authorities) would provide around 30% of this financing globally, while private actors would provide the remaining 70%, with firms the largest direct investors (40%), followed by commercial financial institutions (20%) and households at about 10% (Vivid Economics, UNFCCC Race to Zero campaign and the Glasgow Financial Alliance for Net Zero, 2021[6]).

6. Governments thus have a dual role to play: mobilize private finance by putting in place the right incentives via climate policy packages that support the rapid and radical transformations required (Fay, 2015[8]), but also by directly investing in low-carbon technologies. This includes support to research and development – both via public R&D expenditures and support to private R&D activities –, subsidies for demonstration projects, support to scale-up and deployment (via e.g. advanced market commitments, guaranteed public procurement, etc.) as well as direct funding of low-carbon infrastructure at scale.

1.2 Covid-19 recovery packages and low-carbon technology support

7. The Covid-19 crisis and the associated lockdowns across the world led to a massive drop in economic output.[3] Governments responded by implementing rescue and recovery packages to support economic activity in addition to protecting public health. In the second half of 2020, many governments announced large stimulus packages based on long-term oriented public investment. In the two years since the start of the Covid-19 pandemic, national governments announced up to USD 18 trillion dedicated to rescue and recovery economic stimulus as a response to the Covid-19 crisis, where approximately USD 3 trillion is marked as recovery funding, and the rest as short-term relief rescue (O'Callaghan et al., 2021[9])

8. This massive intervention by public authorities around the world could give an important impetus to the development and deployment of low-carbon technologies. The provision of public funding could play a particularly important role in the context of high economic uncertainty generated by Russia's war against Ukraine and the current energy price crisis, as economic uncertainty tends to induce firms to reduce or postpone investment and innovation activity as well as to reduce access to financing (Baker, Bloom and Davis, 2016[10]).[4]

9. Green recovery has been an important priority in the aftermath of the Covid-19 pandemic, and many governments integrated a significant environmental dimension into their stimulus packages, alongside digitalisation, health systems and social infrastructure. The European Union, for example, required that 37% of the Next Generation EU stimulus package be reserved to support the green transition. Recovery packages were thus presented as a way to "build back better" and address pressing environmental issues (in particular climate change) at the same time as the economic downturn. (OECD, 2022[15]) . Evidence shows that green stimulus funding adopted in the wake of the Global Financial Crisis (GFC) of 2007-08 contributed to generating economic growth and creating jobs and positively impacted the environment, although there are usually trade-offs between those objectives (Agrawala, Dussaux and Monti, 2020[13]). Box A A.1 summarizes the main features of the GFC stimulus and its estimated effect on low-carbon technologies.

10. Throughout the course of the pandemic, and as many countries announced and implemented recovery packages, various initiatives (think-tanks, research institutes and international organizations) have tracked and analysed different countries' recovery spending. These include Oxford University (together with IMF, UNEP, GFPN, GIZ) (O'Callaghan et al., 2021[9]), the IEA (IEA, 2022[16]), the OECD (OECD, 2022[15]), The Wuppertal Institute together with E3G (Wuppertal Institute and E3G, 2021[17]), Vivid Economics (Vivid Economics, 2021[18]), IISD (together with IGES, OCI, ODI, SEI, Columbia University) (Energy Policy Tracker, 2021[19]), Bruegel (Darvas et al., 2022[20]) and Nahm, Miller and Urpelainen (Nahm, Miller and Urpelainen, 2022[21]).

11. According to the most comprehensive recovery trackers, green[5] stimulus funding was higher after Covid-19 than after the GFC. The OECD Green Recovery Database reports that approximately 30% (around USD 1.1 trillion) of the recovery was positively environment-related, and the Global Recovery

[3] The Covid-19 pandemic also led to a significant drop in global CO2 emissions from energy combustion and industrial processes (34.2 gigatonnes CO2 in 2020 comparing to 36.1 GtCo2 in 2019), but this decrease was short-lived. As in previous economic crises, emissions quickly rebounded in 2021 to reach their highest ever annual level. A 6% increase from 2020 pushed emissions to 36.3 Gt (IEA, 2022[43]).

[4] Between 2019 and 2020, energy-related investment as measured by the IEA decreased by 20% (from USD 1 900 bn to USD 1500 bn) because of the Covid-19 pandemic (and before the recovery packages). This is due to a large part to lower energy demand because of lockdowns, restrictions and uncertainties on recovery.

[5] "Green" here refers generally to measures which are environmentally positive, and can therefore also include measures which have a positive impact on other environmental dimensions than climate change mitigation, such as water, forests etc.

Observatory (GRO) report that measures representing approximately USD 1 trillion can contribute to the reduction of greenhouse gas emissions. Nahm, Miller and Urpelainen (2022[21])[6] report similar results. For countries in the European Union, the Green Recovery Tracker (Wuppertal Institute and E3G, 2021[17]) finds a similar percentage of green measures in total recovery spending.

1.3 Objectives and outline

12. Against this background, the objective of this issue paper is to present preliminary evidence on the impact that post-covid recovery packages may have on the development and diffusion of low-carbon technologies across countries, sectors and innovation stages. The measures analysed in this paper build on the OECD Green Recovery database (OECD, 2022[15]) and the Global Recovery Observatory database (O'Callaghan et al., 2021[9])), which have been merged and expanded to create a new OECD Low-carbon Technology Recovery Database.

13. Compared with the OECD Green Recovery Database, which aims to assess the broad environmental impact of all covid-19 recovery measures, the new database used in this paper focuses exclusively on measures which can help to mitigate climate change mitigation, but offers a refined level of detail. Support measures are broken down by sector (eg. Transport, energy generation), technology (e.g. green hydrogen, renewable energy sources, Carbon capture and storage in industry, etc.) and by phase of the innovation cycle (research, development, demonstration, commercialisation, large-scale deployment). The methodology and resulting dataset are described in the next section.

14. The amounts of public investment into low-carbon technologies can then be compared to investment needs and carbon emissions reduction potential as available from existing modelling analyses, such as the IEA's Net Zero Scenario, in order to understand where remaining investment gaps are greatest. Such investment gaps could be filled by future public investment programs, but could also suggest the adoption of complementary policies to incentivize private investment.[7]

15. This Issue paper is organised as follows. Section 2 presents the methodology used to create the novel database constructed for the purpose of the study. Preliminary results are analysed in section 3, with breakdowns of funding by technology, economic activities, and innovation stages. Data are also compared with the investment needs reported in various net zero scenarios. Section 4 concludes.

[6] Based on the world's 20 largest countries. GRO includes recovery funding in more countries than both the OECD and Nahm, Miller and Urpelainen (2022).

[7] An upcoming modelling exercise (not presented in this issue paper) will assess the impact of covid-19 recovery packages on future carbon emissions reductions.

2 Methodology and data

2.1 Methodology

16. To analyse the impact of post-covid recovery packages on low-carbon technology, the OECD created a new database, building on two existing "green recovery trackers": the OECD Green Recovery database (OECD, 2022[15]) and the Global Recovery Observatory (GRO) database (O'Callaghan et al., 2021[9]) developed by the Oxford University Economic Recovery Project at the Smith School of Enterprise and the Environment. These two datasets have a similar geographic coverage, focusing on OECD countries and selected large economies for the OECD database, and on 50 leading economies for the Oxford tracker. They distinguish between rescue and stimulus measures, include some basic (binary) information on expected environmental impacts of the policies (positive or negative) and on the type of policy (investment in R&D, regulatory changes, etc.) and have been regularly updated. However, the level of detail and comprehensiveness differs, in terms of informational breakdowns for large and complex packages, missing policies or identification of targeted technologies. Combining the strengths of both databases allows including a larger variety of measures with a greater level of detail.

17. The OECD Green Recovery database and the GRO database respectively include USD 948 billion and USD 1 070 billion of green recovery measures related to climate change mitigation. In addition, the new OECD Low-Carbon Technology Recovery database also includes the US Build Back Better Act (of total value exceeding 450 billion USD), which targets numerous low-carbon technologies.

18. Of the initial measures in the two databases, only measures related to recovery (as opposed to rescue) and measures with a direct or indirect positive environmental impact are included, excluding for example for measures tagged as having an indeterminate effect.[8] Measures applying to countries covered in both GRO and OECD databases are retained.[9] The selected data cover measures announced from January 2020 until December 2021, thus putting the focus on the period during which the majority of Covid-19 related recovery measures were announced by OECD governments.[10] The scope of the dataset is summarized in Box 1.

[8] Measures with a negative impact include for example "Traditional energy infrastructure, traditional transport infrastructure, worker retraining and job creation". Measures with a potential indirect impact include for example measures tagged as "Communications infrastructure investment, education investment, general research and development investment, other large scale infrastructure investment".

[9] Out of the 50 countries in the GRO database, we include 36 countries (OECD, G20, EU member countries and OECD key partner countries) and the EU as a whole. The OECD database tracks 43 countries plus the EU as a whole. The final database will also include fiscal stimulus announced by the European Union and its institutions. Given their significant volume, attention will be particularly paid to elimination of potential double counts with corresponding policies already included in member countries' entries.

[10] Measures announced in 2022, such as the US Inflation Reduction Act, are therefore not included, as they were not announced as part of covid-19 recovery packages. They will be analysed separately in the next phase of this project. Note the focus is on announcement dates, not actual spending and disbursement period, which is generally unknown.

19. In the OECD Green Recovery database, recovery measures still under discussion were not included in the results, which is for example the case of the above-mentioned Build Back Better package. Given the narrower focus of the OECD Low-Carbon Recovery Technology database, the results might slightly differ from the results from the OECD Green Recovery database, which looks at the recovery packages from a broader perspective (including measures negatively impacting the environment and non-technology-related sectors).

20. The combination of the GRO and OECD databases is informed by extensive manual cleaning (e.g., to avoid potential double counting of resources) and information gathering directly from available government resources. Particular attention was paid to identifying the supported technologies, the implemented innovative processes, the sectors of application, and the likely stage in the “innovation cycle” in which the measures targeted technologies and their application. Secondary data sources were used for confirmation and validation.

Box 1. Key characteristics of the Low-carbon Technology Recovery database

The **Low-carbon Technology Recovery** database principally builds on two existing data sources: Oxford’s **Global Recovery Observatory** and the **OECD Green Recovery** database. It focuses on recovery measures related to **low-carbon technology and innovation, offers a greater level of detail and includes additional measures, such as the U.S. Build Back Better Act.**

Information available from these existing databases is complemented with additional detailed information collected from government sources (e.g., **economic activities, technology targeted, beneficiaries**) and contrasted with the measures in the EC/OECD STIP Compass “net zero portal”.

The database GTR includes measures **announced from January 2020 until December 2021.** Actual disbursement dates or new recovery packages announced after December 2021 are not considered.

The data so far includes comprehensive information on **14 countries out of 52** countries that will be ultimately covered (members of the OECD, the European Union and G20). The countries currently covered include major economies **(including six G7 countries)** and account for **66% of global GDP** and **53% of global annual CO2 emissions.**

The measures currently covered represent a total monetary value of **1.2 trillion USD**, but this figure is subject to further refinement and revisions. The results presented in this issue paper should therefore be considered as very preliminary.

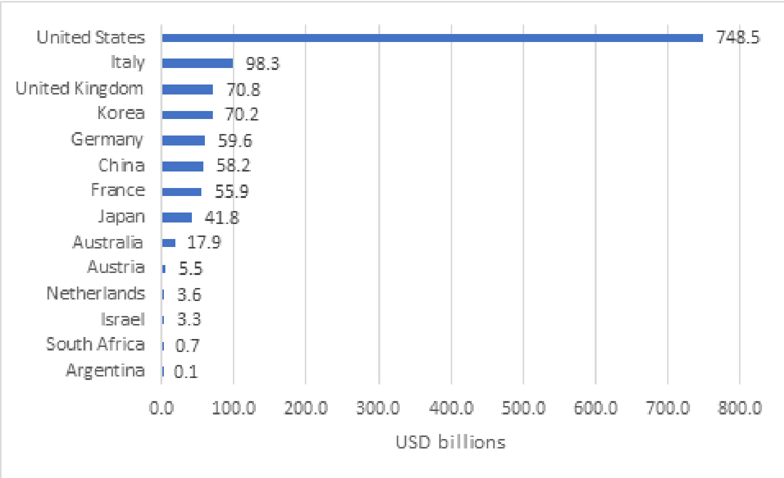
2.2 Data overview

21. This paper presents preliminary insights from the 14 countries (including six G7 countries) currently included in the Low-carbon Technology Recovery database, together representing 66% of global GDP and 53% of global annual CO2 emissions. These include Argentina, Australia, Austria, People’s Republic of China (hereafter, ‘China’), France, Germany, Israel, Italy, Japan, Netherlands, South Korea, South Africa, the United Kingdom, and the United States.[11] The total monetary value of measures covered so far accounts for 1.2 trillion USD, suggesting that these preliminary findings should reflect well the global

[11] In total, the database will include recovery packages announced in 52 countries: Member countries of the OECD, the G20 and the European Union (except Bulgaria, Croatia, Cyprus and Malta, for which the data is not available). For the total list of countries, see the Annex.

picture.[12] The distribution of the total low-carbon technology recovery funding across countries is presented below in Figure 4.

Figure 4. Total low-carbon technology recovery funding in the Low-carbon Technology Recovery database



Note: Preliminary results.
Source: OECD Low-carbon Technology Recovery database (interim version October 2022).

22. The investments made in the United States account for more than 61% of total low-carbon technology recovery funding (748.5 bn USD). Recovery spending of other G7 member states included in the database, China and Korea is also notable, ranging from 5% to 8% of the total budget covered so far (ranging from 56 bn USD in France to 98 bn USD in Italy).

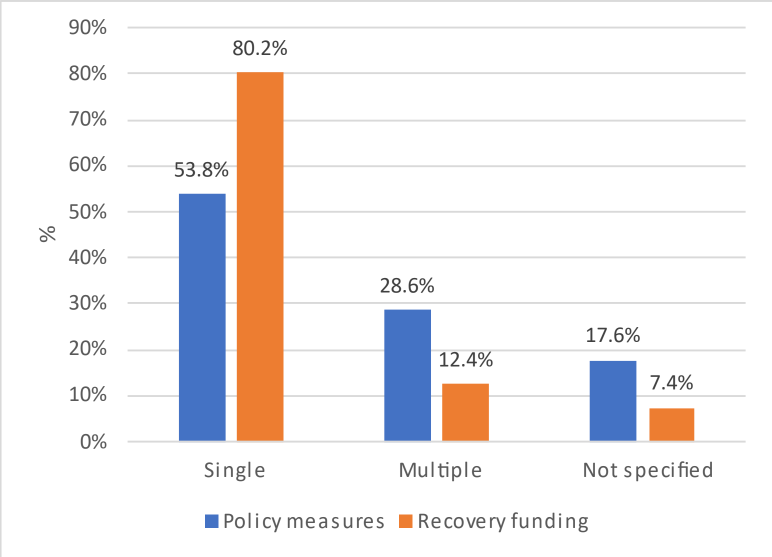
23. The main variables included in the dataset include: type of policy instrument, economic activity, targeted technology, innovation stage of the technology, beneficiaries of the policy and timeframe when available (start/end year). Economic activities are based on the International Standard Industrial Classification of All Economic Activities (ISIC) (United Nations, 2008[34]), focusing on the end-use of each technology. The categorization for the Innovation stage is inspired by the Frascati Manual (OECD, 2015[35]) as well as on the academic literature and IEA Technology Roadmaps. The technology category follows the existing low-carbon patent classification used by the European Patent Office (European Patent Office, 2022[36]) at the most detailed level possible. Technologies are classified based on the sector of end-use whenever possible (e.g., CCS for power generation vs CCS for industrial processes).

24. A remaining limitation of the database is that a number of measures cover multiple technologies and do not include a precise breakdown of funding allocated across sectors and technologies, while others do not specify any particular technology or sector. Figure 5 shows the distribution of measures and funding across ”Single-technology“ measures, ”Multiple“ technologies and ”Not-specified”. Almost 54% of the total number of entries in the database (representing close to 80% of total funding) have been allocated to a single technology. However, 29% of measures (representing 12% of total funding) cover multiple technologies for which no breakdown is yet available. Future work will seek to further breakdown these

[12] The final report will be published in June 2023. As the creation of the database is still in progress, the results presented in this paper are only preliminary and subject to change.

measures.[13] In Japan, France and Korea, significant parts of the total low-carbon technology recovery funding relate to policy measures targeting multiple technologies, whereas the breakdown by technology is more readily available in countries like Australia, Germany or Italy.

Figure 5. Distribution of measures targeting single and multiple technologies (in total low-carbon technology recovery funding and in number of measures)



Note: Results are provisional and should be interpreted with caution.
Source: OECD Low-carbon Technology Recovery database (interim version October 2022).

[13] The U.S. Build Back Better Act (BBB), which accounts for 450 billion USD, included multiple technologies but was broken down based on information on the U.S. Inflation Reduction Act (IRA), which was signed into law in August 2022, and superseded the BBB. Since information on the exact overlap of these two packages is not available, the results on the U.S. must be interpreted with caution and are subject to potential further refinements. See Table A A.5 in the Annex for more detailed information.

3 Impact of post-covid recovery packages: preliminary results

3.1 Recovery packages broken down by economic activity, technologies, innovation stage

25. The newly developed Low-carbon Technology Recovery database comprises approximately USD 1.2 trillion worth of low-carbon recovery spending. As discussed in section 2, 20% of total funding relates to policy measures that encompass more than one technology, or where we are unable to determine the technology. The results presented in this section therefore focus on 80% of the database, where funding can be precisely allocated to specific technologies and sectors (which amounts for USD 990 billions).

26. Figure 6 shows which technologies are supported in each sector for all the countries combined, and Figure 7 presents the distribution of recovery funding to different sectors across countries.

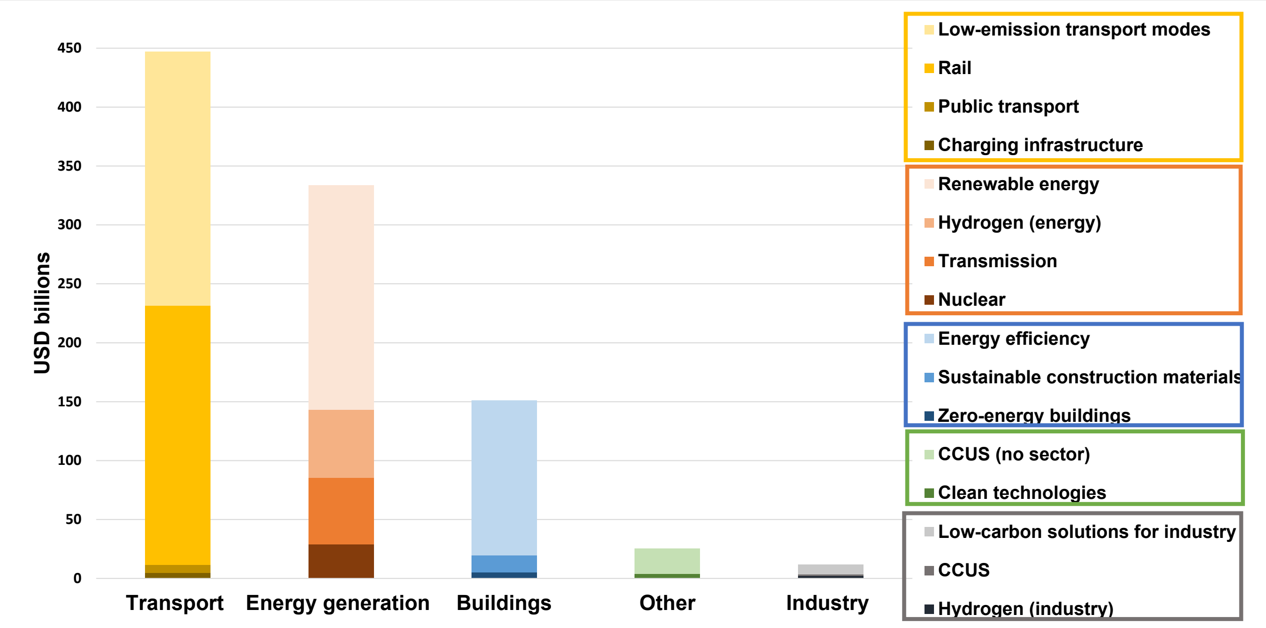
27. In total, less than half of total funding is dedicated to climate mitigation technologies related to transportation. Over a third of the funding was dedicated to the reduction of greenhouse gas emissions related to energy generation, transmission or distribution. Climate change mitigation technologies related to buildings stood for 16%, and climate change mitigation technologies in production/processing of goods ("industry") stood for no more than 1%. Finally, 2% of funding was dedicated to CCUS, and 1% to unspecified low-carbon technologies ("other").

28. Within transportation, Figure 6 shows that a significant share of the green recovery spending is channelled towards upgrading, expansion and electrification of railways (48%) and to low-emission vehicles, such as EVs, hybrids, hydrogen heavy-duty vehicles and charging infrastructure (47%), with the remaining distributed to charging infrastructure and public transport.

29. Figure 7 shows that recovery funding related to transportation is heavily prioritized in several countries, especially in South Africa, the United Kingdom and Australia. This shows the focus of recovery spending on large infrastructure investments, such as large investments to railways in Australia and low-emission public transport investments in South Africa and in the United Kingdom.[14]

[14] The sectoral distribution slightly differs from that reported in the OECD Green Recovery database (OECD, 2022[10]). This is mainly due to different scope and other methodological differences (see section 2.1). For example, not all the sectors presented in OECD (2022[10]) are included in the present paper (such as forestry or agriculture) and categories are broader (for example the OECD Low-carbon Technology Recovery database does not distinguish between aviation, maritime and ground transport, The specific focus on low-carbon technology is also responsible for differences in the transport and building sectors covered by both databases (for example, the OECD Low-carbon Technology Recovery database does not take into account broader measures targeting road transport and highways without concrete mentions of low-carbon technologies, whereas they fall in the scope of the OECD Green Recovery). Finally, the inclusion of the U.S. Build Back Better measures, where the U.S. Inflation Reduction Act is used as a proxy to break down the policy packages (see section 2.2 Data for more details), which are not included in the OECD Green Recovery Database, also contributes to possible discrepancies.

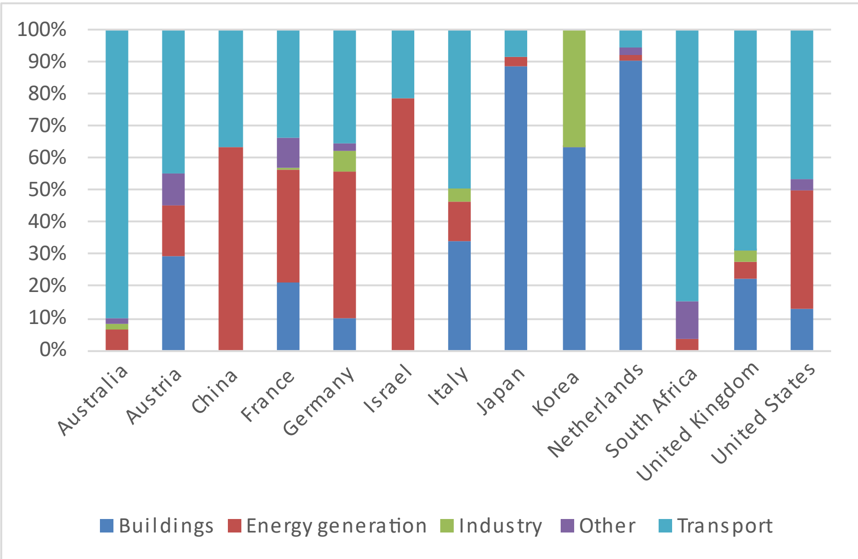
Figure 6. Low-Carbon Technology Recovery funding by sector and technology



Note: Results are provisional and should be interpreted with caution. The figure does not include recovery funding related to measures that support multiple technologies or to measures where the technology cannot be determined (20% of the database). In addition, USD 20 billion of the recovery funding that supports one technology is omitted from this graph since these measures allocate small amounts of funding dedicated to very specific small areas, such as recycling, environmental improvement, biofuels, semiconductors, marine transport and hydrogen refuelling infrastructure.
Source: OECD Low-Carbon Technology Recovery database (interim version October 2022).

Figure 7. Distribution of recovery spending to various economic sectors across countries

Percentage of total recovery spending in the country, focusing on single-technology measures



Note: Results are provisional and should be interpreted with caution. The figure does not include recovery funding related to measures that support multiple technologies or to measures where the technology cannot be determined (20% of the database). For this reason, Argentina is not included since almost 100% of the country's recovery funding targets multiple technologies.
Source: OECD Low-carbon Technology Recovery database (interim version October 2022).

30. As for technologies related to the reduction of greenhouse gas emissions from energy generation, transmission, or distribution, over half of the recovery funding is channelled towards renewable electricity, such as solar and wind power, close to 20% towards hydrogen production, either by electrolysis (green hydrogen) or from natural gas with carbon capture (blue hydrogen). A similar share supports power transmission – such as flexibility measures, general resilience and strengthening of transmission infrastructure – and energy storage such as batteries. Finally, investments in nuclear power capacity also stand for a substantial part of recovery funding in the energy production sector (10%). China, Israel, and Germany dedicate a significant portion of their recovery funding to technologies related to energy generation and transmission. In China, this is roughly equally spread across renewable electricity support, investment in transmission/distribution and in nuclear. In Germany, hydrogen investments play a significant role, and in Israel investments in solar energy capacity is a major priority (Figure 7).

31. In the buildings sector, the majority of recovery funding is dedicated to energy efficiency measures such as renovation (for example insulation or improved glazing of windows) and renewable energy related to buildings, such as solar PV on rooftops (85%). A smaller percentage is dedicated to clean construction materials in the U.S. (9%), and to green housing measures (6%), which is heavily prioritized in Japan, including support to zero-emission buildings, which is a priority in Korea.

32. Lastly, policies targeting low-carbon solutions in manufacturing industries, such as direct emission reduction and the use of renewables, stand for around 70% of the recovery funding dedicated to climate change mitigation technologies in the production and processing of goods. Policies targeting CCUS (11%) and hydrogen use in industries (20%) stand for the remaining part. A significant portion of recovery funding in Korea is related to emerging low-emission technologies in industry. In Germany, a significant portion is dedicated to hydrogen in industrial processes.

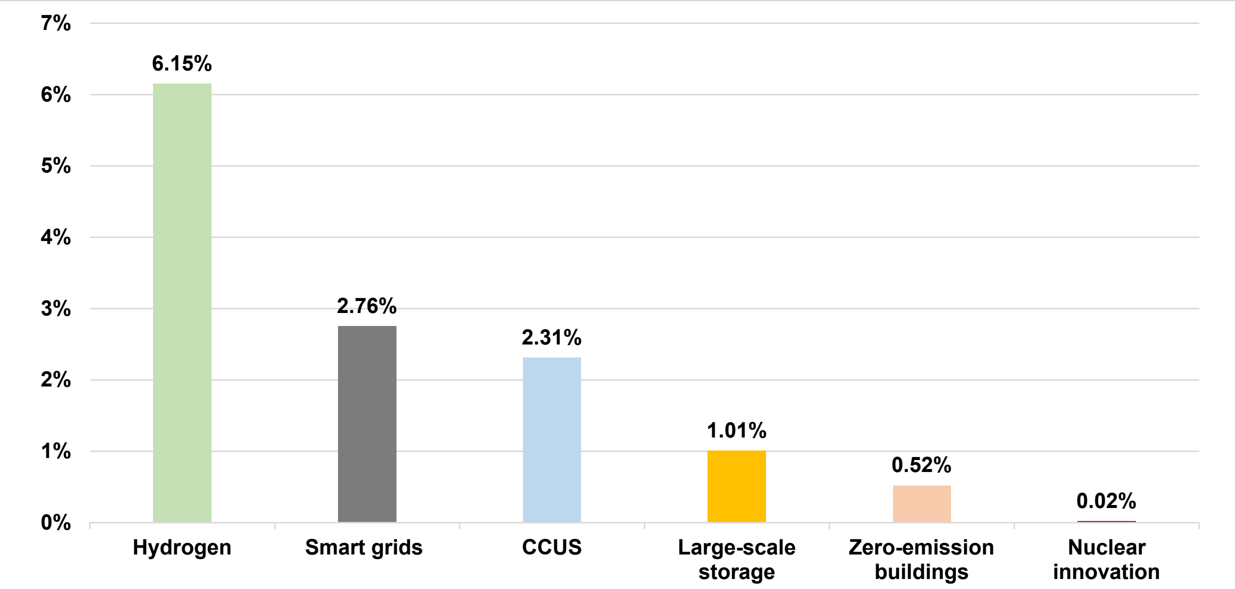
Support for emerging technologies

33. Funding dedicated to supporting emerging technologies amount to close to 20% of all low-carbon technology recovery funding (ca. USD 200 bn). Among emerging technologies, hydrogen has been the main priority (6% of total recovery funding targeted at a single technology). In addition, approximately 2% of low-carbon recovery funding supporting was channelled to CCS and to smart grids respectively, and 1% to large-scale storage. Lastly, significantly smaller portions dedicated to nuclear innovation and zero-emission buildings (Figure 8).

34. Figure 9 looks more closely at how each country has prioritised various emerging technologies within their national green recovery package. Hydrogen has been the main priority in France, Germany and Austria, while CCUS and smart grid technology are of significant importance in the UK, the U.S. and Italy. Support to zero-emission buildings plays an important role in the support to emerging technologies in Korea. Finally, long-duration storage is mainly a priority in the U.S.

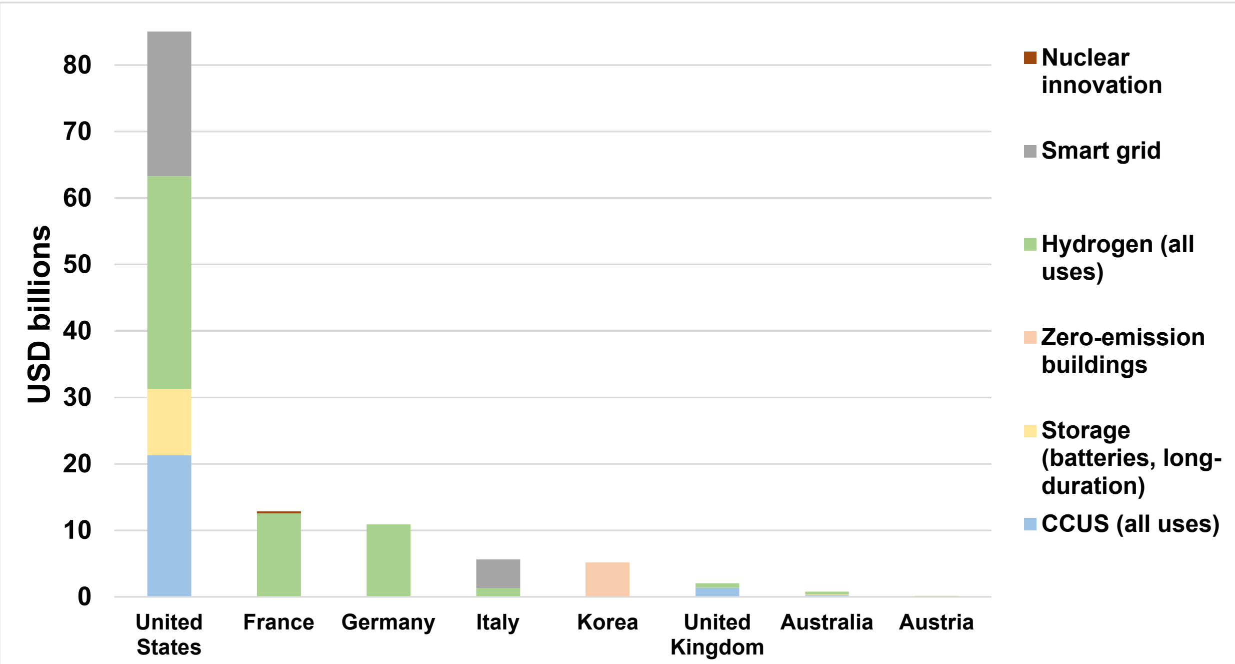
Figure 8. Emerging technologies in low-carbon recovery spending

Percentage of recovery funding dedicated to emerging technologies as a share of the low-carbon recovery funding targeting single technologies



Note: Results are provisional and should be interpreted with caution. The figure does not include recovery funding related to measures that support multiple technologies or to measures where the technology cannot be determined (20% of the database).
Source: OECD Low-carbon Technology Recovery database (interim version October 2022).

Figure 9. Recovery funding to emerging technologies across countries

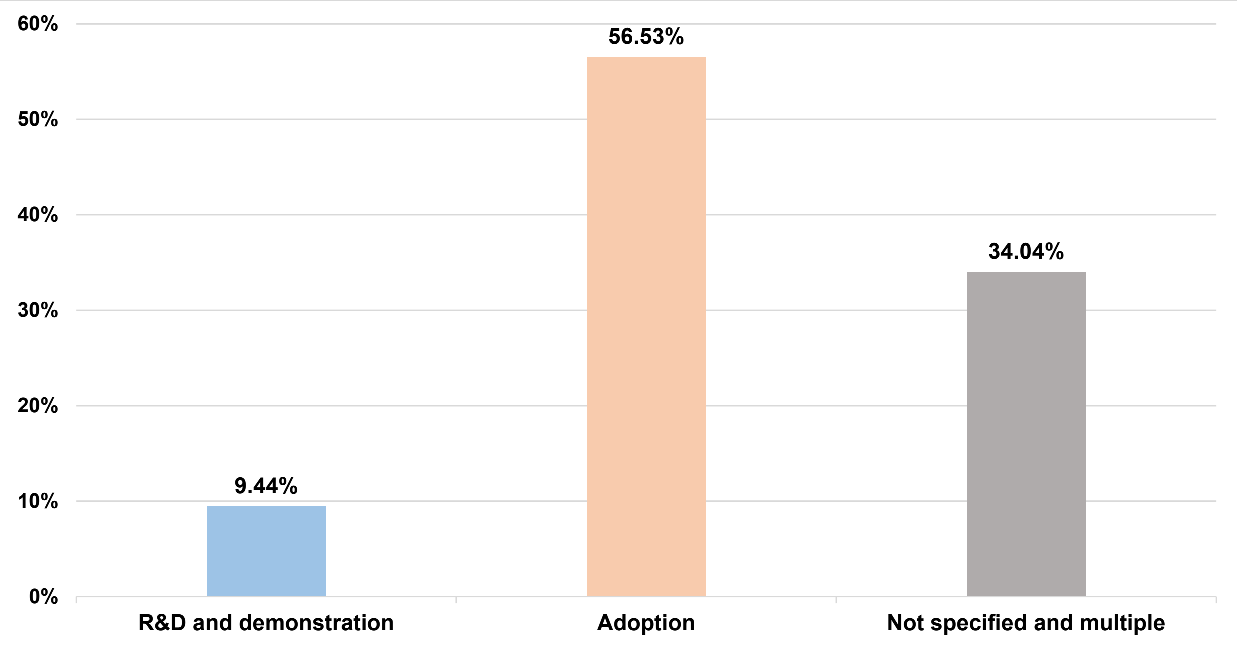


Note Note: Results are provisional and should be interpreted with caution. The figure does not include recovery funding related to measures that support multiple technologies or to measures where the technology cannot be determined (20% of the database). Due to the inclusion of single technology measures only, the actual amount of recovery spending related to emerging technologies could be higher in some countries.
Source: OECD Low-carbon Technology Recovery database (interim version October 2022).

35. Based on the overview of the prioritization of emerging technologies in green recovery spending in Figure 8, a majority of total green recovery funding prioritized funding to scaling up of existing technologies, as opposed to the early stages of technology development such as R&D and demonstration. However, this prioritization varies significantly across countries (Figure 9). Figure 10 shows that overall, roughly 9% of total green recovery funding is channelled towards support for R&D and demonstration projects, while 56% targets scale-up and adoption of existing technologies. The development stage could not be determined for the remaining funding, mostly because of measures targeting several stages for technology development. Among measures for which the innovation stage could be determined, around 85% of the measures target the adoption phase, and 15% the research, development and demonstration phase.

Figure 10. Low-carbon recovery spending by innovation stage

Low-carbon recovery spending targeting different innovation stages, as a percentage of total low-carbon recovery spending.



Note: Results are provisional and should be interpreted with caution. The figure does not include recovery funding related to measures that support multiple technologies or to measures where the technology cannot be determined (20% of the database).
Source: OECD Low-carbon Technology Recovery database (interim version October 2022).

3.2 Comparison with investment needs in low-carbon technology to reach net zero emissions by 2050

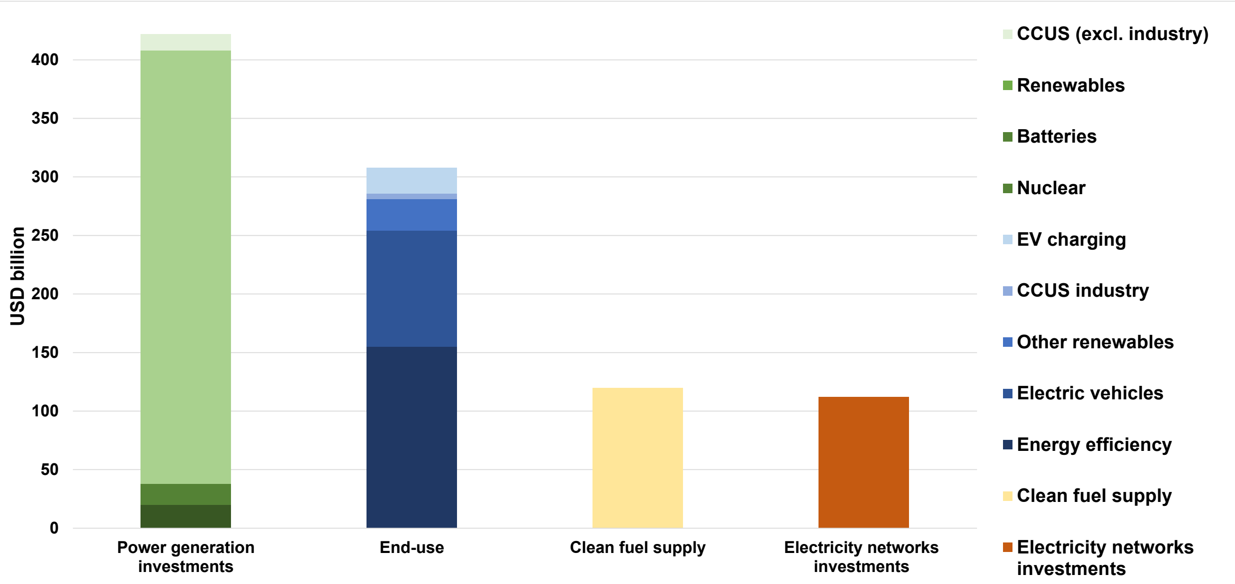
36. This section compares funding for low-carbon technologies in post-covid recovery packages to global investment needs to reach the carbon neutrality target by mid-century, in order to assess the remaining "investment gaps" between investment needs and the amounts mobilized within the framework of the post-covid recovery packages. Various studies have quantified the investments needed to ensure the deployment of low-carbon technologies at the necessary scale. These models however differ in several respects, for example in the choice of methodology (top-down versus bottom-up approaches), full versus

incremental costs and the exclusion or inclusion of consumer-level investments (IPCC, 2022[2]). These differences can generate different levels of investment needs in low-carbon technologies and innovation.

37. The IEA Investment Data Explorer (IEA, 2022[4]) suggests that a total of USD 2.3 trillion needs to be invested in clean energy on average annually by 2025, to be within reach of the net zero emissions by 2050 target (NZE). The Stated Policy Scenario (STEPS) by IEA (2022[37]) suggests that annually by 2025 this investment may already reach USD 1.3 trillion globally, based on the energy- and climate-related policy measures that have already been announced. This means that USD 1 trillion in additional annual investment in clean energy is needed towards 2025, including private and public financing.

38. Figure 11 depicts the *annual* additional needed clean energy investment by 2025 by sector and technology, to be in line with the NZE 2050 scenario. It shows that the majority of additional needed investments in clean power generation will need to come from renewables, while investments in electrical vehicles and energy efficiency together make up the majority of investment needs in end-use of clean energy. Furthermore, the investment needs in electricity networks play an important role in supporting the future energy system with high levels variable renewable energy.

Figure 11. Additional annual investment in clean energy needed by 2025 in the Net Zero Scenario



Note: The additional investment needs are calculated by subtracting the investment needs in the NZE scenario from the projected investments in the STEPS, withing each category and technology. Note that "CCUS (excl. industry)" in this figure is the represents the category "fossil fuels with CCUS" in the investments estimates by IEA.
Source: (IEA, 2022[4])

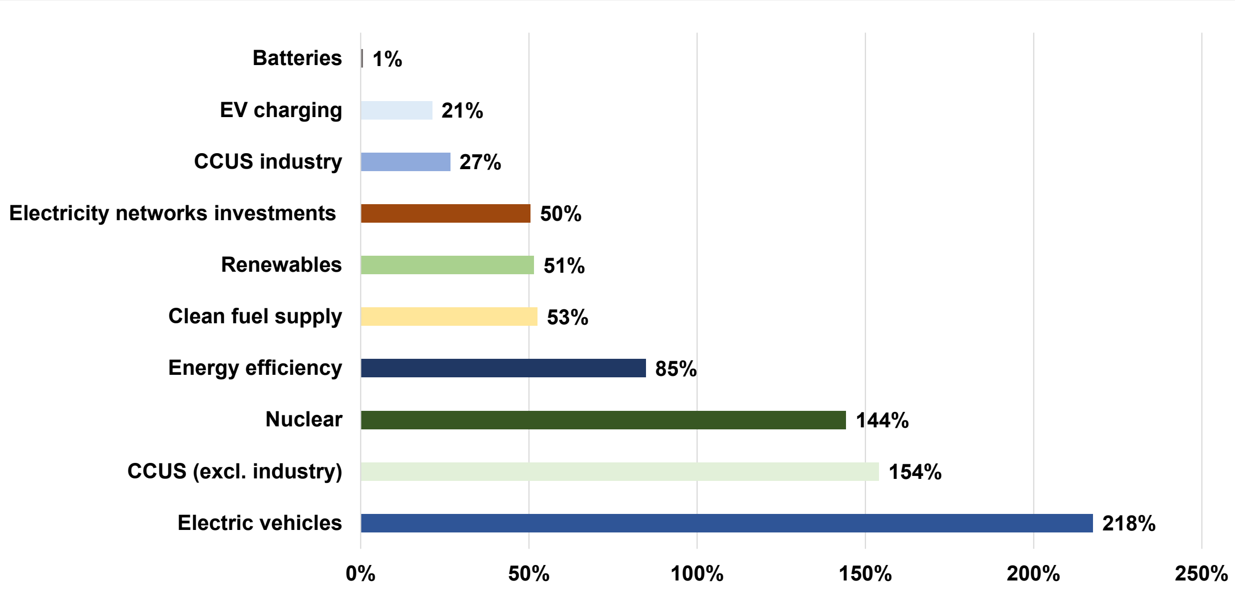
39. Figure 12 compares the low-carbon recovery funding by technology to the additional annual investment needed to be on track according to the Net Zero Emission 2050 scenario, depicted in Figure 11. It is important to keep in mind that the comparison is between a one-off public investment via recovery packages (which will most likely be smoothed over a small number of years) with *annual* investment needs, so that a value of 100% corresponds to 1 year of investment need in the respective technology.

40. For electricity network investments, energy efficiency and clean fuel supply, which includes hydrogen investments, the tracked recovery spending stands for about 50% of the additional average annual spending needed by 2025 to be on track with the net zero emission target in 2050. For EV charging infrastructure and CCUS in industry, this percentage is 20% to 30%, and merely 1% for batteries. However, low-carbon technology recovery investments related to energy efficiency is significantly higher (85%), and

for nuclear power, CCUS[15] and electric vehicles, the low-carbon recovery funding could cover 144%, 154% and 218% of the average annual investment needs, respectively. This means that covid recovery packages represent respectively 1.4, 1.5 and over 2 years of investment needs in these technologies.

Figure 12. Contribution of low-carbon recovery spending to annual investment needs in clean energy

Low-carbon recovery spending targeting different technologies, as percentage of additional *annual* investment needs (100% = 1 year of investment need in the respective technology).



Note: Results are provisional and should be interpreted with caution. The figure does not include recovery funding related to measures that support multiple technologies or to measures where the technology cannot be determined (20% of the database). The additional investment needs are calculated by subtracting the investment needs in the NZE scenario from the projected investments in the STEPS, withing each category and technology. Note that "other renewables" is missing from the figure, as this percentage is zero, and when comparing the low-carbon recovery funding to "fossil fuels with CCUS" in NZE, we include the CCUS-related low-carbon recovery spending that is not specified for any sector. Finally, note that the low-carbon recovery funding in the "electric vehicle" category in this figure is mainly constituted of electric vehicles support (including direct purchase support but also support to the manufacturing of electric vehicles), and also some funding related to other types of low-emission vehicles, such as hydrogen-fuelled vehicles.
Source: (IEA, 2022[4]), OECD Low-carbon Technology Recovery database (interim version October 2022).

41. At the more aggregate level, low-carbon recovery funding represents approximately 60% (i.e., 7 months) of the additional annual investment needs in power generation (including renewables, nuclear, batteries and CCUS) and 100% (one year) in end-use technologies (including mostly electric vehicles and energy efficiency). Therefore, while recovery packages make a welcome contribution, in particular for electric vehicles, CCUS, nuclear and energy efficiency, the recovery funding falls short of filling the investment gap which need to be filled to be on track with net-zero targets.

42. According to IEA (2022[4]), privately financed investments would stand for 64% of total needed investments, with variation across technologies depending on the level of technological development. This

[15] Note that a significant portion of the recovery funding targeting CCUS does not specifically mention industry use, and therefore this portion is left in the technology category "other" (Figure 6). However, we cannot exclude the possibility that parts of the recovery funding targeting CCUS without explicitly mentioning industry as end-use, will not eventually target the industrial sector.

could make the role of recovery packages in filling the public funding "investment gap" in low-carbon substantial in several areas. However, the additional public funding would need to be sustained annually past 2025 and increased further, as investment needs in low-carbon energy will need to increase towards 2030. It also remains that the ability for recovery investments to mobilize further private finance seems critical.

4 Conclusion

43. The recovery packages adopted in the wake of the covid-19 pandemic have been presented as a unique opportunity to accelerate the transition to a low-carbon economy. This Issue paper analyses how fiscal stimulus spending in response to the COVID-19 pandemic has supported the development and diffusion of low-carbon technologies, based on a new database building on existing covid-recovery trackers and covering measures announced from January 2020 until December 2021.

44. The new OECD Low-carbon Technology Recovery database currently covers 14 countries representing 66% of global GDP and 53% of global annual CO2 emissions. The final version of the database will include 52 countries and the results presented here should therefore be considered as preliminary.

45. The data shows that a substantial amount of public funding – USD 1.2 trillion – has been targeted at low-carbon technologies in the countries analysed so far. Half of this funding has been directed at the transportation sector and around one third to energy generation, transmission, or distribution. Among low-emission technologies that are still in the early stages of innovation and where significant investments in R&D and demonstration projects are necessary, hydrogen has been the main priority (6% of total recovery funding). In addition, approximately 2% of low-carbon recovery funding supporting was channeled to CCS and to smart grids respectively, and 1% to large-scale storage. Lastly, significantly smaller portions were dedicated to nuclear innovation and zero-emission buildings.

46. To put things in perspective, the analysis compares the amounts of funding in recovery packages to annual additional investment needs to reach net-zero emissions targets by 2050, as reported by the IEA. In general, recovery packages make a welcome contribution to these needs, but fall short of filling the massive investment gap. At the broad sector level, low-carbon recovery funding represents approximately 60% (i.e., 7 months) of the additional annual investment needs in power generation and 100% (one year) in end-use technologies. There is, however, vast heterogeneity across technologies. The contribution of covid recovery packages appears determinant in some areas such as electric vehicles (218%), CCUS (154%) and nuclear power (144% of the annual investment needs). It is substantial for energy efficiency (85%), clean fuel supply (including hydrogen) electricity network and renewables (all around 50% of the annual investment need). By contrast, the contribution is marginal in EV charging infrastructure (21%) and negligible in battery energy storage (1%).

47. An important difference of covid-19 green recovery packages compared to post-GFC stimulus is a relative focus on emerging and early-stage technologies. Of the total funding analysed in this paper for which the development stage could be determined, 15% (USD 116 billion) concern the R&D and demonstration phases of innovation (including USD 25 bn for demonstration alone), as opposed to adoption of more mature technologies. This appears as a very significant contribution to closing the USD 90 billion funding gap in R&D and demonstration until 2030 highlighted by the IEA Net-Zero Emissions scenario.

48. While public funding has a critical role to play for the net-zero transition, especially for early-stage technologies via support to R&D and demonstration, it remains that investment support policies are insufficient on their own, as the failure of CCS projects supported by green recovery packages adopted during the Global Financial Crisis illustrated. Available estimates suggest that private actors would provide

around 70% of the global investment needed to build the global low-carbon infrastructure over the coming decades.

49. Governments thus have a key role to play to also incentivise private funding, by introducing clear trajectories of gradually increasing carbon prices and implementing an array of other complementary policies. These policies are likely technology- and country-specific, and could include public infrastructure provision, standards and regulations, demand-side policies such as carbon pricing, carbon contracts for differences or public procurement, phasing out of fossil fuel subsidies, and structural policies such as skills and labour market policies or competition policies.

50. In this context, post-COVID stimulus packages may well have oriented investment towards sectors and technologies that will accelerate the low-carbon transition, but cannot by themselves close the investment gap until 2030, and now need to be accompanied by more ambitious complementary climate policies that would make them much more effective in the short run, and trigger the structural change in the economy implied by net-zero emissions targets.

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Annex A.

Box A A.1. Lessons from the Great Financial Crisis

Key features of the GFC stimulus

- Short-term fiscal stimulus mostly concerned boosting firm and household spending to provide relief to vulnerable households and small and medium-sized enterprises that were most at risk.
- Medium-to-long-term fiscal stimulus concerned infrastructure investment and technological development, with some environmental focus.
- Existing estimates suggest that 16% of all fiscal stimulus (over USD 500 billion) was directed toward activities with a positive environmental impact, such as renewable energy deployment or subsidies for electric cars and for insulation works (Robins, 2010[24]).

Main take-aways from research concerning the impact of GFC stimulus on low-carbon technologies

- Policies supporting the generation of electricity from renewable energy sources were effective at boosting innovation and deployment and at reducing emissions, but less so at creating jobs. For example, the 2009 American Recovery and Reinvestment Act largely contributed to the 50% reduction in capital costs for solar PV in the period 2008-2014 and saved 8.6Mt CO_2 annually (Council of Economic Advisors, 2016[25]), and that the number of renewable energy technology patents issued by the US patent Office grew from 2009 to 2012 (Mundaca and Luth Richter, 2015[26]). On the other hand, the job effects of renewable energy support were relatively small.
- Subsidies to fuel-efficient vehicles may also have had mixed effects, where the U.S. low fuel efficient car scrappage programme (CARS) may have saved 9-28Mt CO2 emissions (Mian and Sufi, 2012[27]), but where the cost per job created was USD 1.4 million, which is much higher than alternative fiscal measures (Gayer and Parker, 2013[28]).
- Policies supporting energy efficiency in buildings seem to have been effective at creating jobs in the short run, but their impact on emissions has likely been small, in particular because of the existence of significant rebound effects in energy demand (Agrawala, Dussaux and Monti, 2020[13]).
- Despite the fact that many governments provided support to clean technology development (Pollitt, 2011[29]), support to technology and innovation under the GFC stimulus did not work as well as planned. Within the total amount of funding to R&D and demonstration of Carbon Capture and Storage (CCS) projects, only one project was eventually completed in the EU (European Commission, 2018[30]), and in the U.S., the US Department of Energy (DOE) returned USD 1.3 billion of the initial CCS project support to the US Treasury Department in 2016, because the projects could not be realized.

Source: The information in this box draws heavily on (Agrawala, Dussaux and Monti, 2020[11])

Table A A.1. Overview of databases and trackers

	Scope	Measures covered	Updates	Environmental dimensions	Sources
OECD Green Recovery Database	43 countries in total plus the EU (as a whole)	Policies related to economic recovery from the COVID-19 crisis. This includes emergency measures where they have clear environmental implications (e.g. unconditional bail-outs of environmentally damaging firms)		Climate Change mitigation, Climate change adaptation, Air pollution, Biodiversity, Water, Waste & recycling	(OECD, 2022[10])
Global Recovery Observatory	The 50 largest economies	Data is focusing on 'recovery' spending as opposed to 'rescue' spending	The Observatory database is updated weekly and the full database is updated regularly	Greenness' based on potential impact on long- and short-term Green House Gas emissions, air pollution, natural capital, quality of life, inequality and rural livelihood	(O'Callaghan et al., 2021[8])
Energy Policy Tracker	38 major economies and eight Multilateral Development Banks (MBDs)		From January 2020 to December 2021	Clean energy in power generation, energy resource extraction, mobility and building sectors	(Energy Policy Tracker, 2021[15])
IEA Sustainable Recovery	Worldwide	Sustainable recovery spending	The Tracker is updated periodically	Sustainable recovery policies that are defined as policies driving spending on clean energy	(IEA, 2022[12])
Nahm, J., S. Miller and J. Urpelainen (2022)	20 largest economies	Inventory of fiscal stimulus spending during the COVID-19 pandemic		Areas that will also cut emissions, including electrifying vehicles, making buildings more energy efficient and installing renewables	(Nahm, Miller and Urpelainen, 2022[17])
Climate Action	16 Member States of the EU and ten other key economies	Rescue and recovery spending	In the present analysis as of May 2021	Low-carbon measures	(Hans et al., 2022[29])

Source: authors' own elaboration

Table A A.2. Comparison of monetary values covered in different trackers

	Total number (bn USD)			
Climate Action	Total stimulus	**Only recovery**	**Green measures**	**Green measures related to climate change mitigation**
OECD Green Recovery Database		$2,041	$1,090	$949
Global Recovery Observatory	$20,612	$3,895.00	$1,070	
Energy Policy Tracker		$1,256.00		$477
IEA Sustainable Recovery	$18,200			$714
Nahm, J., S. Miller and J. Urpelainen (2022)	$14,000			$860
Climate Action	$11,100		$641	

Note: The differences between the databases above lead to different results when comparing total numbers.
Source: authors' own elaboration

Table A A.3. List of countries in the final Low-carbon Technology Recovery database

Country	Covered	Country	Covered	Country	Covered	Country	Covered
Argentina	X	Czech Republic		Israel	X	Portugal	
Australia	X	Denmark		Italy	X	Romania	
Austria	X	Estonia		Japan	X	Russian Federation	
Belgium		European Union		Korea	X	Saudi Arabia	
Bulgaria		Finland		Latvia		Slovakia	
Brazil		France	X	Lithuania		Slovenia	
Canada		Germany	X	Luxembourg		South Africa	X
Chile		Greece		Malta		Spain	
China (People's Republic of)	X	Hungary		Mexico		Sweden	
Colombia		Iceland		Netherlands	X	Switzerland	
Costa Rica		India		New Zealand		Türkiye	
Croatia		Indonesia		Norway		United Kingdom	X
Cyprus		Ireland		Poland		United States	X

Source: authors' own elaboration

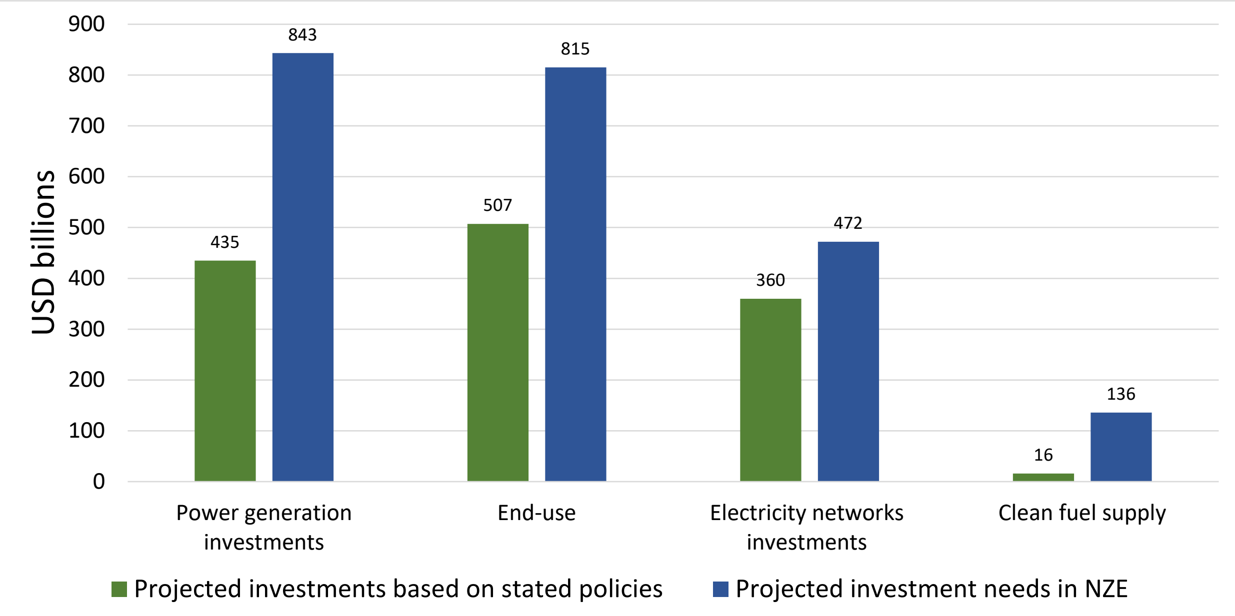
Table A A.4. Overview of world GDP and annual GHG emissions in the OECD Low-Carbon Technology Recovery database

	GDP		GHG	
	Total value (bn USD)	%	Total value (GtCO2-eq)	%
Countries covered so far	$57,920.25	66.079%	24.41089	52.737%
Countries in the final OECD Low-carbon Technology Recovery database	$77,762.62	88.717%	37.02073	79.980%
World total	$87,652.86	100%	46.28762	100%

Source: (World Bank, 2022[30]), (World Bank, 2022[31]), authors' own calculation

Figure A A.1. Projected investment in clean energy categories based on stated policies compared to investment needs in IEA's NZE scenario

USD billions



Note: The figure compares the various technology investments needed on average each year in the period 2021-2025. These numbers only include clean energy investment, and therefore excludes projected investments in both scenarios (STEPS and NZE) fossil fuels with and without CCUS in energy generation investments, and coal, oil and natural in fuel supply.
Source: (IEA, 2022[4])

Table A A.5. Breakdown of the Build Back Better package using the Inflation Reduction Act as a proxy

Build Back Better Act	Inflation Reduction Act	Monetary value	Innovation stage	Sector
OECD_USA73: The House-approved Build Back Better Act (not yet passed in Senate) includes Clean Energy Tax Credits ($320 billion): Ten-year expanded tax credits for utility-scale and residential clean energy, transmission and storage, clean passenger and commercial vehicles, and clean energy manufacturing.	Renewable Energy Tax Credits: Includes: - Extension of Renewable Electricity Production and Energy Tax Credits - Energy Tax Credit - Solar and Wind Credit for Low-Income Communities - Technology-neutral Clean Electricity Credits (both production and investment tax credits)	127	Adoption	Energy generation
	Production tax credit for hydrogen (new policy)	13	Pre-adoption	Energy generation
	Advanced Energy Project (Tax) Credit (includes long-duration storage)	10	Pre-adoption	Energy generation
	Tax credits for purchasing low-emission vehicles, for commercial medium- and heavy-duty electric vehicles and for charging infrastructure - Up to $40,000 in tax credits for commercial medium- and heavy-duty electric vehicles - Up to $7,500 in tax credits for new passenger electric vehicles and up to $4,000 for used electric vehicles (equals 30% of the vehicle cost) - A tax credit for building EV charging infrastructure in commercial vehicle lots, in the amount of 30 percent of the cost per charger, up to $100,000	56	Adoption	Transport
	Consumer rebates and tax credits for renewable energy and energy efficiency in buildings	53	Adoption	Transport
	Tax deduction for energy efficient commercial buildings	15.4	Adoption	Buildings
	Grid improvements	2.8	Adoption	Energy generation
OECD_USA75: The House-approved Build Back Better Act (not yet passed in Senate) includes Investments and Incentives for Clean Energy Technology, Manufacturing, and Supply Chains ($110 billion): Targeted incentives to spur new domestic supply chains and technologies, like solar, batteries, and advanced materials, while boosting the competitiveness of existing industries, like steel, cement, and aluminum.	Production tax credits for domestic production of solar and wind components	30	Adoption	Energy generation
	Loan guarantees and grants for production of electric vehicles Includes: - $10 billion investment tax for facilities making EVs - $2 billion in grants for converting auto manufacturing facilities to EV manufacturing - $20 billion in loans for clean vehicle manufacturing capabilities - $40 billion to the Advanced Technology Vehicles Manufacturing	100	Adoption	Transport

Build Back Better Act	Inflation Reduction Act	Monetary value	Innovation stage	Sector
	(ATVM) Direct Loan Program $30 billion loans available under the Tribal Energy Loan Guarantee Program (TELGP)			
OECD_USA76: The House-approved Build Back Better Act (not yet passed in Senate) includes Clean Energy procurement ($20 billion): Provide incentives for government to be purchaser of next gen technologies, including long-duration storage, small modular reactors, and clean construction materials.	Federal public procurement, labelling and verification of low-carbon concrete and construction materials	9	Adoption	Buildings
	Building materials	5.4	Adoption	Buildings

Note: The sum of the provisions in the IRA corresponding to the measures in the BBB is slightly lower than the original BBB budget (421.6 bn, whereas the original BBB budget was 450 bn). Results must be interpreted with caution since it is only a proxy and the exact overlap of these measures must be further studied.

Source: Authors' own elaboration, based on (United States Congress, 2022[32]), (The White House, 2022[33]), (The New York Times, 2022[34]), (US Senate Democrats, 2022[35]), (RFF, Energy Innovation, the REPEAT Project, and Rhodium Group, 2022[36]), (Cleantech for Europe, 2022[37])

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