Annex 2:
Economic impacts of urban mitigation investments

This three-part document outlines the methodology for the economic analysis by Vivid Economics that is presented in the Coalition's global synthesis report and country reports. **Parts 1** and **2** present the scope, data and limitations of the analysis. **Part 3** presents country-by-country results.

Part 1. Cost-benefit analysis

Method in brief

This analysis, conducted by Vivid Economics, calculated the incremental investments needed from now until 2050 to implement selected decarbonisation measures in urban buildings, transport, waste management, and the production of key materials for urban buildings and transport infrastructure, as well as the economic benefits – focusing only on energy and materials savings – and the potential for job creation. The economic analysis builds on the greenhouse gas (GHG) abatement potential analysis outlined in Annex 1 and draws on an extensive literature review to define key assumptions made in the modelling.

The outputs of the modelling include cumulative incremental investments to 2050; the net present value to 2050; and new jobs supported by the measures in 2030, including direct, indirect and induced jobs (see Box A2.1 in Part 2 for definitions). Selected data for specific categories of decarbonisation measures, and benefits within a single year (2030 or 2050), are presented as well as examples. The analysis does not directly consider how the modelled measures would be financed (for example, through additional public debt or private investment).

The results presented in the global report and country report represent a central scenario reflecting a 3.5% discount rate and projected real energy price increases of 2.5% per year from 2014 levels. In Part 3, we present a broader range of results, reflecting two sensitivity analyses: applying discount rates of 1.4% and 5.5%, and real energy price increases of 1% and 4% per year. The data for energy prices were obtained from the International Energy Agency (IEA) Energy Prices and Taxes database[1] for the OECD countries, and World Bank pump prices database[2] for the non-OECD countries. Additionally, learning rates were applied to each sector to model cost reductions over time. These include 5% for the waste and transport sectors and 1.53% for the buildings sector. These assumptions are in line with learning rates used in previous analyses,[3] as well as in complementary sector analyses.[4] Although higher learning rates were also considered, which would result in higher returns on investment, the results are not presented here.

Scope of analysis

This analysis builds on the urban abatement potential analysis outlined in Annex 1, estimating the economic impacts of implementing the technically feasible measures needed to realise that potential in China, India, Indonesia, Brazil, Mexico and South Africa, using existing technologies and practices. The approach builds on a previous analysis of the costs, benefits and employment impacts of urban interventions that could reduce emissions in line with a 2°C global warming scenario.[5] As noted in Annex 1, the analysis for this report reflects a higher level of ambition, aiming to reduce emissions in line with a below-2°C scenario. Like the abatement potential analysis, it considers the costs, benefits and employment impacts relative to a baseline scenario that reflects countries' first round of Nationally Determined Contributions (NDCs) under the Paris Agreement. More recent commitments, such as in updated NDCs being submitted in 2020–2021, are not reflected in the baseline scenario.

Like the abatement potential analysis, the economic analysis covers a bundle of urban mitigation interventions modelled by the Stockholm Environment Institute (SEI), as outlined in Annex 1 in the transport, buildings and waste sectors (see Table A2.1). It models the deployment of those measures from 2020 to 2050. Impacts are calculated for the countries by disaggregating calculations developed for the world's urban areas[6] to develop country-specific estimates.

Table A2.1. Urban mitigation interventions considered in this analysis

Urban mitigation interventions	**Economic model specifications**
Buildings	
New build at "passive house" levels	Residential – deep efficiency
Deep energy retrofits	Commercial – deep efficiency
Heat pumps installed in new and retrofitted buildings	
Aggressive implementation of efficient lighting and appliances	Residential – efficient lighting Residential – efficient appliances Residential – efficient cooking Commercial – efficient lighting Commercial – efficient appliances Commercial – efficient cooking
Decarbonise electricity and increase adoption of rooftop and building-integrated solar PV	Residential – rooftop solar PV Commercial – rooftop solar PV
Transport	
Freight logistics improvements	Freight – improved logistics
National and local policies drive reduced passenger travel demand	Passenger – compact urban areas and system efficiency

Urban mitigation interventions	**Economic model specifications**
Rapid expansion of cycling and public transit	Passenger – modal shift to mass transit
Improvements in fuel economy and high penetration of electric vehicles (EVs)	Passenger – fleet efficiency and electrification Freight – fleet efficiency and electrification
Decarbonisation of electricity	Rooftop solar PV is modelled in buildings sector
Faster transition to carbon-neutral biofuels	
Waste	
Reduced waste generation per capita and waste collection	Not costed (waste volumes reflected in landfill gas capture estimates)
Methane capture efficiency and electricity generation from landfill gas	Landfill gas capture and utilisation
Increased recycling rates	Not modelled
Reduced demand for building materials Increased efficiency of production of cement, steel and aluminium	Reduced demand for cement and steel

Data

Key data sources used in the economic impact analysis vary across sectors and are laid out in Table A2.2.

Table A2.2. Interventions, variables and data sources

Intervention	Variable	Source(s)
All	Discount rates – assumed to be 3.5% in the central scenario in-line with typical public sector discount rates, 1.4% in line with the Stern review and 5.5% in line with the lower end of commercial lending rates	HM Treasury, 2011, Stern, 2007, and assumptions by Vivid Economics[7]
Buildings		
Increased building shell efficiency	Costs of increased building shell efficiency	GBPN, 2015[8]
Increased appliance and lighting efficiency	Costs of increased appliance and lighting efficiency	Thema, 2018[9]
Increased solar power from rooftop	Costs of increased solar power from rooftop PVs in urban areas	IRENA, 2017[10]
All	Scaling of costs for buildings sector interventions across regions	Arcadis, 2018[11]
Transport		

Reduced travel demand from urban planning and modal shift	Costs associated with increased travel by e-bike	Mason et al., 2015, Litman, 2018, Cherry et al., 2009, IEA, 2016, GlobalPetrolPrices.com[12]
Reduced travel demand from urban planning and modal shift	Costs associated with increased travel by public transit	U.S. Department of Energy, UK Department for Transport, 2017, UK National Infrastructure Commission, 2018, EEA[13]
Reduced travel demand from urban planning and modal shift	Benefits from reduced travel by personal vehicles and public transit, including fuel savings and avoided operating costs	Litman, 2011, Gouldson et al., 2015, IEA, 2016, World Bank, VTPI, 2017 [14]
All	Regional scaling of transport costs and benefits	NUMBEO, WorldData.info, Reid and Chanda, 2017[15]
Fleet efficiency	Costs of increased fleet efficiency	IEA, 2014[16]
Fleet efficiency	Fuel savings from increased fleet efficiency	U.S. National Research Council, 2010[17]
Fleet	Costs of increased fleet electrification	Brennan and Barder, 2015, Goldie-Scot, 2019, Transport & Environment, 2018, IEA, 2018 and 2016, GlobalPetrolPrices[18]
Freight – system efficiency	Costs and benefits of urban consolidation centres	Martinez, Gadsby and Vargas, 2018; BMVI, 2010[19]
Freight – vehicle efficiency	Costs of improved vehicle efficiency	Moultak, Lutsey, and Hall, 2017; Hooper and Murray, 2018; IEA 2018, 2016[20]
Waste		
Increased methane capture and conversion to renewable energy	Costs of infrastructure to capture and convert landfill gas	US EPA, 2012;, Markgraf and Kaza, 2016; Global Methane Initiative, n.d.; Arcadis, 2018[21]
Materials efficiency	Benefits of reduced steel and cement consumption	World Bank Commodity Price Database; Imbabi et al., 2012[22]

Country data sources

The analysis by Vivid Economics complemented the use of reliable global data sources with data relevant for the focus countries in four ways. First, the analysis prioritised the use of global data sources that were informed through the voluntary reporting of national governments or in-depth study of conditions in different countries and regions. For example, IEA documents, including the World Energy Investment Outlook, drew on a wide range of literature, including data from outside the OECD, to develop trends for use in global and regional analysis.

Second, to develop region-specific cost estimates, the analysis drew on regional cost databases for buildings (GBPN) and renewable energy (IRENA). Third, where the analysis used example projects for cost estimates, a range of costs from different countries were used to test the applicability of a central value to different geographies (e.g. for landfill gas technologies, the analysis relied on U.S. and World Bank sources) and, where relevant price indices were available (e.g. for vehicle costs and construction costs), the analysis applied these scaling factors to calculations to arrive at appropriate estimates for each region. Fourth, for each country chapter, the analysis tested modelled outputs with in-country case studies and policy assessments, drawing on academic research; urban, energy and climate experts from the World Resources Institute and the Coalition; and policy research in relevant sectors.

The additional sources used for each country are listed below. For full references, see the reference list at the end of this Annex.

China: AIIB, 2019, “Asian Infrastructure Finance 2019: Bridging Borders: Infrastructure to Connect Asia and Beyond”; An et al., 2015, “China’s Market-Oriented Reforms in the Energy and Environmental Sectors,” in *National Bureau of Asian Research*; Becqué et al., 2019, “Accelerating Building Decarbonization: Eight Attainable Policy Pathways to Net Zero Carbon Buildings For All”; Chatzky and McBride, 2020, “China’s Massive Belt and Road Initiative,” Council on Foreign Relations; Gilbert and Zhao, 2017, “The Knowns and Unknowns of China’s Green Finance”; Ollivier, Sondhi, and Zhou, 2014, “High-Speed Railways in China: A Look at Construction Costs,” *World Bank*; Sherlock et al., 2018, “Constructing a New, Low-Carbon Future: How Chinese Cities Are Scaling Ambitious Building Energy-Efficiency Solutions.”

India: KPMG India, 2014, “Decoding Housing for All by 2022”; Government Of India, n.d., “Ministry of Power, Bureau of Energy Efficiency”; Government of India, 2019, “India Cooling Action Plan”; Government Of India, 2013, “National Electric Mobility Mission Plan 2020”; NITI Aayog and Rocky Mountain Institute, 2019, “India’s Electric Mobility Transformation: Progress to Date and Future Opportunities”; The Climate Group, 2019, “Driving Climate Action: State Leadership in India”; Kumar et al., 2018, “Mainstreaming Thermal Comfort for All and Resource Efficiency in Affordable Housing: Status Review of PMAY-U Mission to Understand Barriers and Drivers”; NITI Aayog and World Energy Council, 2018, “Zero Emission Vehicles (ZEVs): Towards a Policy Framework”; Mani, Pai, and Aggarwal, 2012, “Sustainable Urban Transport in India: Role of the Auto-Rickshaw Sector.”

Indonesia: Asia Green Buildings, 2016, “Indonesia: Bandung Released Green Building Regulation”; Rahman, 2019, “Poor Customer Awareness Holds Back Green Building Projects,” The Jakarta Post; Green Building Council Indonesia & IFC, 2018, “Measuring What Matters: Benefits of Green Buildings.”

Brazil: Brazilian Development Bank (BNDES) website articles and reports; Dall'Agnol et al., 2018, "Acelerando a Eficiência Das Edificações No Brasil"; Caccia et al., 2018, "Sustentabilidade em Habitação de Interesse Social."

Mexico: Elizondo et al., 2017, "Mexico's Low Carbon Futures: An Integrated Assessment for Energy Planning and Climate Change Mitigation by 2050," Futures; Gutierrez, 2015, "Why Is Mexico an Attractive Investment Destination ?," Society of Industrial and Office Realtors Professional Report; Rivera et al., 2011, "Implementing Sustainable Urban Travel Policies in Mexico," International Transport Forum Discussion Papers.

South Africa: Ramaphosa, 2020, "President Cyril Ramaphosa: 2020 State of the Nation Address," South African Government; McKay, 2020, "South Africa's Key Urban Transport Challenges," in *Urban Geography in South Africa: Perspectives and Theory*.

Cost-benefit analysis

The general cost-benefit approach is consistent across all interventions. First, the additional increase or decrease in demand for specific transport, energy or waste disposal services was calculated for the urban mitigation scenario, compared with a reference scenario, by emissions modelling conducted by SEI. Second, the additional investment costs of interventions included in the urban mitigation scenario were calculated by multiplying change in demand by the marginal cost of adopting a lower-carbon option (adapted for regional cost variation). Third, the value of the benefits associated with the deployment of all units was calculated in the urban mitigation scenario relative to the reference scenario (adapted for regional cost variation). Finally, the additional investment costs and benefits generated in the period to 2050 were compared, to assess the overall economic case for each intervention, and net employment impacts were calculated from expected investment in each intervention.

Changes in demand for energy, transport and waste disposal in the urban mitigation and reference scenario are modelled by SEI. See Annex 1 for reference and mitigation scenario emissions profiles, along with underlying demand factors that produced those profiles.

The following two assumptions apply to all the interventions:

- Projections on future energy prices: an assumption of a real annual price increase of 2.5% was applied to 2014 energy prices in the central scenario,[23] and sensitivities include annual energy price increases of 1% and 4%.[24] The data for energy prices were obtained from the IEA Energy Prices and Taxes database for the OECD countries,[25] and World Bank pump prices database for the non-OECD countries.[26]
- Sector-specific learning rates were applied to each sector to model cost reductions over time. These include 5% for the waste sector,[27] 7% for the transport sector,[28] sectors and 1.53% and 1.84% for different interventions in the buildings sector.[29] These assumptions are in line with learning rates used in previous analysis,[30] as well as in complementary sector analysis.[31] Variation in learning rates was also tested.

The costs and benefits included in this analysis have been limited to those that are directly monetisable. However, separate from the cost–benefit analysis, the impact of interventions on employment was also calculated (see Part 2 of this Annex).

Uncertainty

An important assumption underlying the benefits estimated in the economic impact modelling is a constant increase in energy prices, which translates to a growing value of energy savings over time. Given the recent global oil price volatility related to an increase in OPEC production as well as a decrease in demand for transport-related fuels induced by lockdowns across the globe to slow the spread of coronavirus, the analysis investigated whether the initial assumptions in the model remained robust.

Oil-related energy prices are currently volatile, as they have been in the past, but are showing signs of recovery from COVID-19 shock, sooner than had been forecast early on in the pandemic.[32] As evidenced by a return to pre-COVID emissions levels, demand for oil is already beginning to rebound, as projected, in 2021.[33]

Uncertainty from volatility is expected to remain past the short-term implications of the COVID-19 pandemic. This is driven by 1) unknown lag of capital investments that may be affected by economic downturn on production (supply) and 2) potential long-lasting transformative impacts of social distancing including mode shifts and non-motorised transport infrastructure investments in urban areas. Country-specific markets are likely to experience production shocks differently. For example, increases in coal production are expected to be driven by post-COVID-19 stimulus projects in Asia.[34] Oil price volatility may spur reductions in oil production in Latin America, where production costs are higher than in other regions, even as global energy markets continue to shape prices.

The implications of this analysis for the modelling assumptions applied are limited. Our analysis includes sensitivities around energy price increases, including a low energy price increase scenario of 1% annual growth in prices. The difference in global net benefits between these scenarios is US$8 trillion (36% lower than the central scenario). This is a significant difference, but even under conservative energy price assumptions, the model shows that urban climate action would yield substantial energy and material cost savings.[35]

Limitations

Costs and benefits are calculated at the country/region level for 11 countries/regions. City-specific values may vary within these regions.

A major limitation of the analysis that is particularly important for policy-makers to take into account is that **the economic benefits calculated do not include broader benefits beyond energy and materials cost savings**, which are likely to be significant. These benefits include, for example, the value of time saved through avoided traffic congestion and more efficient transport options, including public transport and non-motorised options; health benefits from improved air quality, increased physical activity (e.g. walking and biking), improved waste infrastructure, and upgraded buildings; additional productivity benefits related to more efficient buildings; increased appeal to businesses and individuals due to higher quality of life; improved access to jobs, public services and urban amenities for lower-income people who are now isolated in peri-urban areas; and the extensive benefits associated with avoided carbon emissions – that is, less severe climate change impacts in the medium and long term.

Auxiliary infrastructure costs were not considered for: (i) electric vehicle charging; or (ii) increased use of buses for public transport. In both cases, the assumption is that required infrastructure would be developed in the reference case, but this may warrant further research.

An important finding is that some interventions generate significant benefits (e.g. in transport), while others – such as deep retrofit in buildings – typically do not within the period of the analysis. This finding reflects the design of the analysis: significant capital investments are projected to 2050, but the analysis only accounts for economic savings to 2050. Investments in deep building efficiency would pay for themselves in all countries by 2089, if not sooner, and they continue to generate a stream of energy savings throughout the buildings' lifespans.

Part 2. Estimating employment potential

Method in brief

Vivid Economics applied region- and sector-specific employment impact multipliers to identified investment needs to estimate a high-level value of jobs associated with investment requirements to deliver ambitious climate mitigation targets in urban areas.

Jobs estimates per US$1 million invested across different sectors were drawn from international meta-analyses including those from the UK Energy Research Centre and the Intergovernmental Panel on Climate Change. A differential impact was applied to demonstrate differences in labour productivity for OECD and non-OECD countries. In each of the six countries, there was a positive increase in jobs and returns from initial annual investments.

The jobs estimates displayed represent full-time equivalent (FTE) jobs over the course of the investment asset including installation and operation (e.g. building upgrade, car, liquefied gas plant). Jobs are presented as net impacts for additional investments modelled in the urban transition scenario (with reference to a baseline scenario), considering a counterfactual investment in traditional fossil fuel technologies to account for displacement. While a range of estimates were drawn on, these can be interpreted as total jobs, including direct, indirect and induced employment.

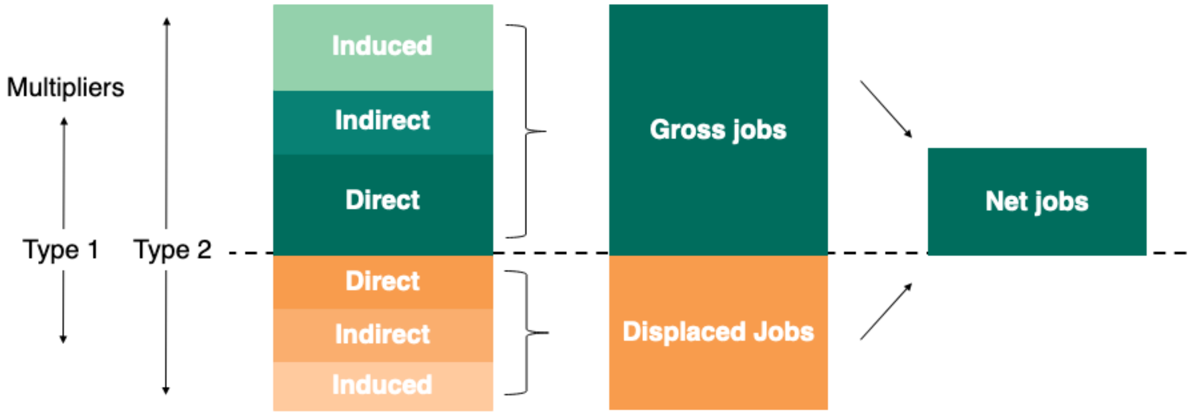
Scope of analysis

Vivid's approach to estimating jobs drew on a high-level literature review of low-carbon interventions across sectors to estimate the net jobs supported per million dollars invested (i.e., total project costs) for each intervention.[36] Net jobs were calculated by subtracting gross jobs associated with fossil fuel investments from gross jobs associated with low-carbon building, transport and waste interventions.

Gross job estimates are converted into net job estimates through comparing modelled low carbon investments to an investment of the same amount in fossil-fuel projects (Figure A2.1). These estimates are adjusted to reflect lower labour productivity in middle- and lower-income countries (Figure A2.2). Vivid Economics estimated net total employment (including direct, indirect and induced jobs) alongside investment requirements.

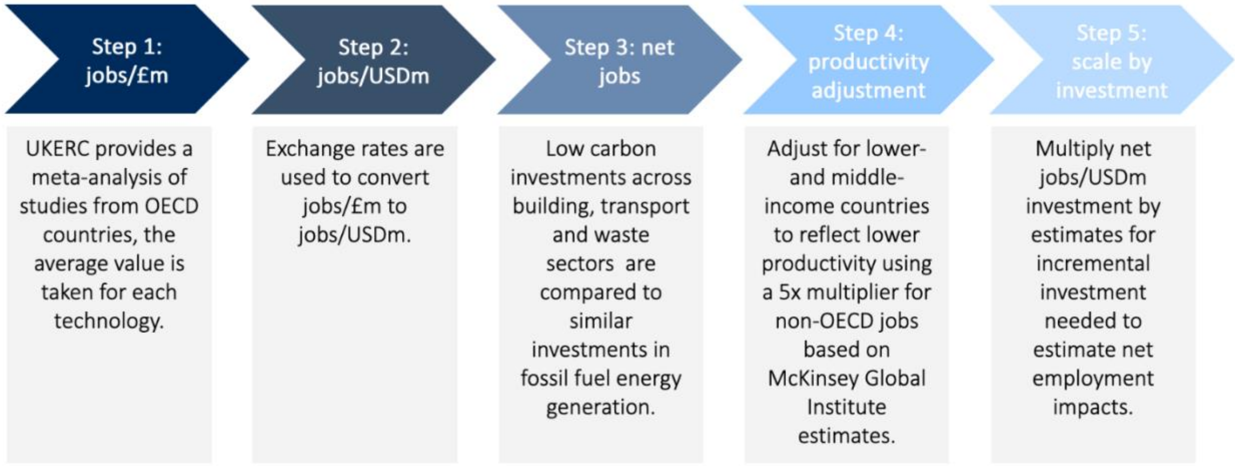
Given the diversity of modelling approaches, geographies considered and trends over time, these estimates should be considered as indicative, and give a sense of relative scale and impact of the modelled investments for various regions.

Figure A2.1. Relationship between direct, indirect, and induced gross and net jobs



Note: Schematic showing the relationship between different types of job impact, showing for illustrative purposes a positive net impact (negative net job impacts are also possible depending on the scale of displaced jobs). Source: Hughes et al., 2014.[37]

Figure A2.2. Approach to estimating net jobs creation



Step 1: jobs/£m
UKERC provides a meta-analysis of studies from OECD countries, the average value is taken for each technology.

Step 2: jobs/USDm
Exchange rates are used to convert jobs/£m to jobs/USDm.

Step 3: net jobs
Low carbon investments across building, transport and waste sectors are compared to similar investments in fossil fuel energy generation.

Step 4: productivity adjustment
Adjust for lower- and middle-income countries to reflect lower productivity using a 5x multiplier for non-OECD jobs based on McKinsey Global Institute estimates.

Step 5: scale by investment
Multiply net jobs/USDm investment by estimates for incremental investment needed to estimate net employment impacts.

Note: Job estimates include direct, indirect and induced full-time equivalent (FTE) jobs lasting over the duration of the asset.

Box A2.1. Key definitions relevant for our analysis[38]

Full-time equivalent (FTE) jobs are equivalent to 1'job' that lasts for the duration of the plant lifetime. This allows estimates that combine short-term construction jobs with longer-term operation and maintenance jobs.

Direct jobs are jobs that that arise directly as a result of the investment. Direct employment impacts are typically measured by surveying the companies contracted to complete the specific project.

Indirect jobs are jobs created within the supply chain supporting a specific project. Indirect employment impacts are sometimes measured through supply-chain surveys, or more commonly are estimated using macroeconomic modelling techniques.

Induced jobs are jobs created as a result of the increased household expenditure of direct and indirect employees. When discussing energy efficiency, a large portion of the induced jobs are the jobs created by the household savings and implied increase in expenditure on other goods & services. Induced employment is generally estimated using macroeconomic modelling techniques.

Data

To account for regional variation in the absence of other data, the analysis derived net job estimates based on labour productivity estimates of McKinsey Global Institute[39] which results in the parameters set out in Table A2.3.

Table A2.3. Net employment estimated by sector

	OECD		**Non-OECD**			
Sector	**Gross jobs per US$1 million**	**Net jobs per US$1 million**	**Gross jobs per US$1 million**	**Net jobs per US$1 million**	**Job type**	**Source**
Fossil fuel	3.92		19.61		Direct + indirect + induced	UKERC (2014)
Buildings	12.92	9.00	64.61	45.00	Direct + indirect + induced	IPCC (2014)
	1.31		6.54			UKERC (2014)
	7.19		35.95		Induced	UKERC (2014)
Transport	14.38	10.46	71.90	52.29	Induced	UKERC (2014)
Waste	40.52	36.60	202.61	183.01	Direct + indirect + induced	UKERC (2014)
	28.76		143.79			UKERC (2014)
	11.76		58.82		Induced	UKERC (2014)

Source: UKERC 2014, IPCC 2014, and McKinsey 2017 with Vivid Economics analysis.
Note: 1. Vivid Economics converted OECD jobs to non-OECD jobs utilising a multiplier of five. Vivid selected this multiplier of five because McKinsey, 2017,[40] estimates based on 2015 data that labour productivity in infrastructure construction sectors in developing countries is roughly five to ten times smaller than in large developed countries (Exhibit 11). This is roughly in line with differences observed in labour productivity across economies, discussed below (Box 1 and Table 2). 2. The analysis converted one British pound sterling (GBP) for the year 2014 to US$1.53. 3. Job estimates include direct, indirect, and induced full-time equivalent (FTE) jobs lasting over the duration of the asset.

The analysis explored two other considerations when considering appropriate country-specific jobs multipliers: country-level values for labour productivity (Box A2.2) and a review of trade data to identify the presence of local supply chains. The findings from these robustness checks produced similar findings to the high-level assumptions presented above and utilised in our preceding global analyses.

Box A2.2. Assessing the reasonableness of using a multiplier of 5 for OECD employment impacts in the six non-OECD countries analysed

To check the robustness of the job multiplier assumptions, the analysis further explored if using country-level labour productivity factors, as opposed to the OECD and non-OECD productivity assumptions applied in this analysis, would better capture country-level variation. There is evidence to suggest that investment induced job creation is higher in non-OECD countries. For example, Simas and Pacca, 2014, calculate the short-term jobs created by wind power projects in Brazil,[41] estimating 4.5 job years per installed MW. This is nearly three times higher than the equivalent figure in the UKERC meta-analysis of OECD country studies.

To test whether more cross-country variation would substantially affect the employment impacts estimates, the analysis compared GDP per person employed between OECD countries (excluding Mexico) and the six emerging economies of interest. The analysis applied a general labour multiplier, which was used to test the sensitivity of labour productivity factors across countries. As Table A2.4 suggests, that low labour productivity in India and Indonesia translates into high labour productivity factors, and potentially higher job creation potential from green investments than those implied in this analysis. This suggests that for certain countries with lower labour productivity, the jobs estimates could be underestimates. In others, they could be considered upper bound estimates. The jobs estimates should therefore be seen as indicative to provide a sense of the magnitude of potential impacts rather than exact figures which would be derived from any large investment programme.

Table A2.4. Country-level labour productivity factors

	GDP per person employed (US$)	**Labour productivity factor (OECD=1)**
OECD (excl. Mexico)	85,448	1.0
Brazil	20,300	4.2
China	15,856	5.4
India	4,941	17.3
Indonesia	8,392	10.2
Mexico	22,119	3.9
South Africa	21,602	4.0

Source: OECD with Vivid Economics analysis. Note: All figures are from 2017. Utilising OECD's databases Gross Domestic Product in national currency[42] was converted to USD using the 2017 average exchange rate.[43] This was to avoid using purchasing power parity (PPP) conversions, which would be inconsistent with the approach used to calculate investment needs. Given the UKERC (2014[44]) meta-analysis did not include any studies from Mexico and Mexico's labour productivity is lower than OECD peers, the analysis decided to exclude Mexico from the OECD benchmark.

The analysis use of a multiplier of 5 for employment impacts for our six countries appears reasonable given the labour productivity factor range of 4 to 17 times the OECD average, as outlined in Table 2. In the absence of further in-depth modelling for each country considered it is helpful to note that Perrier and Quirion, 2018,[45] find that shifting investment towards low-carbon sectors can achieve a double dividend by encouraging low-carbon labour-intensive sectors and that reducing imports in renewables may not boost employment as much.

Assumptions and limitations

It is important to note that the employment estimates included in this analysis are presented as illustrative of the magnitude of impacts expected from investments identified in the analysis. Employment estimates of low-carbon interventions are debated in the literature with relatively few data points to base conclusions on. These estimates have not been modelled to reflect specific supply chain or labour market dynamics and provide a short-term picture which may not account for the skills profile, absorptive capacity or disaggregated regional differences. These estimates can best be understood as "estimated potential jobs supported" by low carbon investments rather than used directly to support policy or investment decisions.

The approach in the analysis assumes that labour productivity is the main determinant of cross-country differences in job creation potential. Additional factors cited in the literature may also be important, including the presence of a local supply chain (accounting for 30–45% jobs created by green investments), the use of local labour for construction and operation and maintenance, and the ownership of assets. Furthermore, it assumes that all lower- and middle-income countries have the same labour productivity as one another. Additionally, in terms of identifying a credible counterfactual, Vivid's approach creates an estimate of net jobs by comparing green investment with an equivalent investment in fossil fuel projects. The most relevant counterfactual may vary by sector and country, depending on national priorities and finance source.[46] Given that the appropriate counterfactual is context-specific, our efforts focused exploring allowances for greater country-level variation.

There are some additional considerations to keep in mind when interpreting these numbers. First, employment estimates may include some uncertainty especially in countries with a high level of informal employment (e.g. 80% of non-agricultural employment in India).[47] Second, a concern with assuming that low labour productivity results in high job creation potential is that job quality is not accounted for. The ILO defines a green job as: *a decent job*[48] *that contributes to preserving or restoring the environment*.[49] Green jobs are not always high-quality, and to ensure the transition to an inclusive green economy, governments must enact appropriate economic and social policies, including large-scale investment in education and training.[50] While this is a contentious topic,[51] it is important to recognise that some jobs created in green sectors can be poorly paid, dangerous, or insecure. Finally, the labour productivity factors calculated in Table A2.4 are averaged over the whole economy and mask potential sector-level differences.

Given these limitations, caution should be taken in their interpretation. As more data becomes available, international organisations and scholars are gradually offering better data and estimates of green jobs. IMF calculated that renewable-based electricity generation and energy-efficiency-enhancing investment create more jobs – both in the short and long term – than the generation of electricity from fossil fuels.[52] IRENA's jobs database[53] estimates a total of 11 million direct and indirect jobs in renewable energy worldwide by industries for 2017–2018.[54] Garrett-Peltier, 2017, estimates for the United States that every US$1 million shift from fossil fuels to clean energy generates a net increase of five jobs, or for every US$1 million spent on renewable energy investments, created 7.49 full-time equivalent jobs or 7.72 jobs in energy efficiency programmes.[55] In contrast, US$1 million spending on fossil-fuel industries supports 2.65 jobs. Firms are utilising these estimates to articulate how a post-COVID economic recovery can be job-rich and climate friendly.[56] By 2025, C40 estimates that 50 million jobs can be created by investing in a green and just recovery in its approximately 100 member cities and associated supply chains.[57] This job-rich green and just recovery estimate is one-third greater than if comparable dollars were allocated for investments in a carbon-intensive brown recovery.[58] However, greening the stimulus may require concerted effort on job training and skills enhancement for smoothening the transition towards a greener recovery.[59]

Green job creation estimates also vary significantly in peer-reviewed macroeconomic modelling literature as well. Perrier and Quirion, 2018, examine methods used to assess these employment impacts of shifting investment to low-carbon sectors.[60] They offer two explanations for why literature on the subject offer mixed results and elusive conclusions. First is the heterogeneity of country conditions, modelling scenarios, data sources, assumptions of costs, technology, and production functions. Second is the diversity of economic models – such as Input-Output (IO) models and Computable General Equilibrium (CGE) models – used for energy-employment in peer-reviewed literature.[61]

Part 3. Country-by-country modelling results

The Vivid Economics results were calculated at the country level for China, India, Indonesia, Brazil, Mexico and South Africa and drew on national and regional data.

For Indonesia, estimates were derived from SEI's ASEAN[62] regional modelling results. Regional results were scaled down based on Indonesia's share of urban population in ASEAN (46%, UN DESA 2018[63]). Vivid considered other indicators – such as share of total population, GDP, energy-related emissions – for scaling down results and selected share of the urban population as a reliable proxy, thereby multiplying ASEAN results by .46 to estimate Indonesia's economic impacts.

For China, India, Brazil, Mexico and South Africa, estimates were derived drawing on SEI's country mitigation analysis modelling results, as outlined in Annex 1. These results are outlined in further detail below.

The summaries presented below show how different discount rates and annual real energy price increases affect the results across the six countries; a future analysis could also examine how different rates of technological learning might affect those results. In our global report and individual country reports, we present a central scenario across all six countries, for comparability purposes. However, the analysis also considers the economic case for each country under a range of different scenarios, which is outlined in further detail in the figures below, after the tables presenting results for the central scenario.

International data sources based on national statistics were used where comparative data were available, or where a national source was not available. The findings were supplemented by an additional review of national and local literature. The national sources are listed below, with full references given at the end of this document. These sources informed the economic analysis in particular; a much broader literature, listed at the end of the main report, outlines the sources used for the full country analysis.

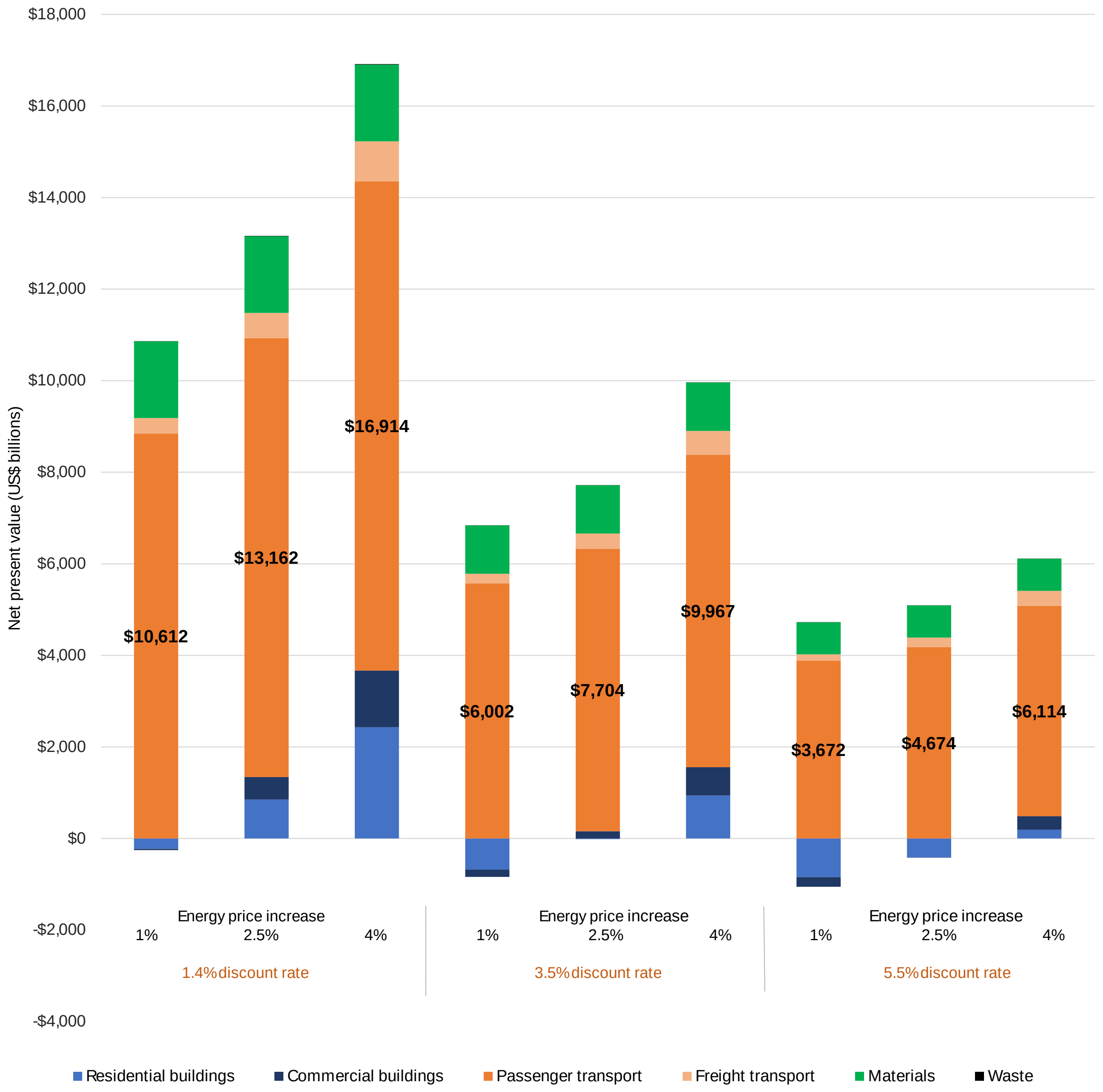
China

Table A2.5. Economics of urban decarbonisation investments in China, 2020–2050

	Incremental investment (US$ billions)	Annual returns (US$ billions)		Net present value, 2020-2050 (US$ billions)	Jobs supported	
		2030	2050		2030	2050
Residential buildings						
Lighting efficiency improvements	$3.78	$2.94	$1.01	$94.78	7,467	3,309
Appliance efficiency improvements	$227.85	–$0.27	$6.82	$209.55	274,072	501,263
Cooking solutions efficiency improvements	$0.00	–$3.48	$3.69	$6.88	0	0
Rooftop solar PV	$14.00	$1.15	$0.00	$14.25	58,056	0
Deep efficiency	$2,775.88	–$66.17	$54.54	-$341.84	10,085,108	0
Commercial buildings						
Lighting efficiency improvements	$2.35	$6.65	$13.32	$261.20	2,923	5,205
Appliance efficiency improvements	$0.67	–$2.97	$1.90	-$24.27	0	5,154
Rooftop solar PV	$4.01	$0.42	$0.00	$4.09	16,646	0
Deep efficiency	$1,510.85	–$23.53	$29.35	-$81.10	3,599,039	441,482
Passenger transport						
Compact urban development	$97.64	$59.04	$88.24	$2,123.86	180,356	242,695
Mode shift to mass transit	$172.48	$137.06	$151.39	$3,354.16	297,678	297,613
Energy-efficient vehicles	$5.60	$17.65	$18.66	$458.51	23,334	7
Electric vehicles	$603.08	$19.05	$41.01	$229.37	579,905	1,581,358
Freight transport						
Improved logistics	$53.49	$2.13	$5.33	$38.27	68,714	162,281
More efficient and electric vehicles	$41.57	$5.79	$26.80	$295.83	14,103	229,174
Materials						
Material efficiency	n/a	$44.86	$166.27	$1,055.89	n/a	n/a
Waste						
Landfill gas utilisation	$0.62	$0.09	$1.45	$4.42	1,326	10,519
TOTAL	**$5,513.86**	**$200.40**	**$609.80**	**$7,703.85**	**15,208,728**	**3,480,060**

Source: Vivid Economics for the Coalition for Urban Transitions. Note: These figures assume a discount rate of 3.5%, annual energy prices increase of 2.5% and low technological learning rates.

Figure A2.3. Net present value of urban decarbonisation measures in China, 2020–2050



Source: Vivid Economics for the Coalition for Urban Transitions. Note: Under the "low", "medium" and "high" scenarios, the real discount rates used are 1.4%, 3.5% and 5.5%, and the increases in real energy prices are 1%, 2.5% and 4%. Learning rates are sector- and technology-specific.

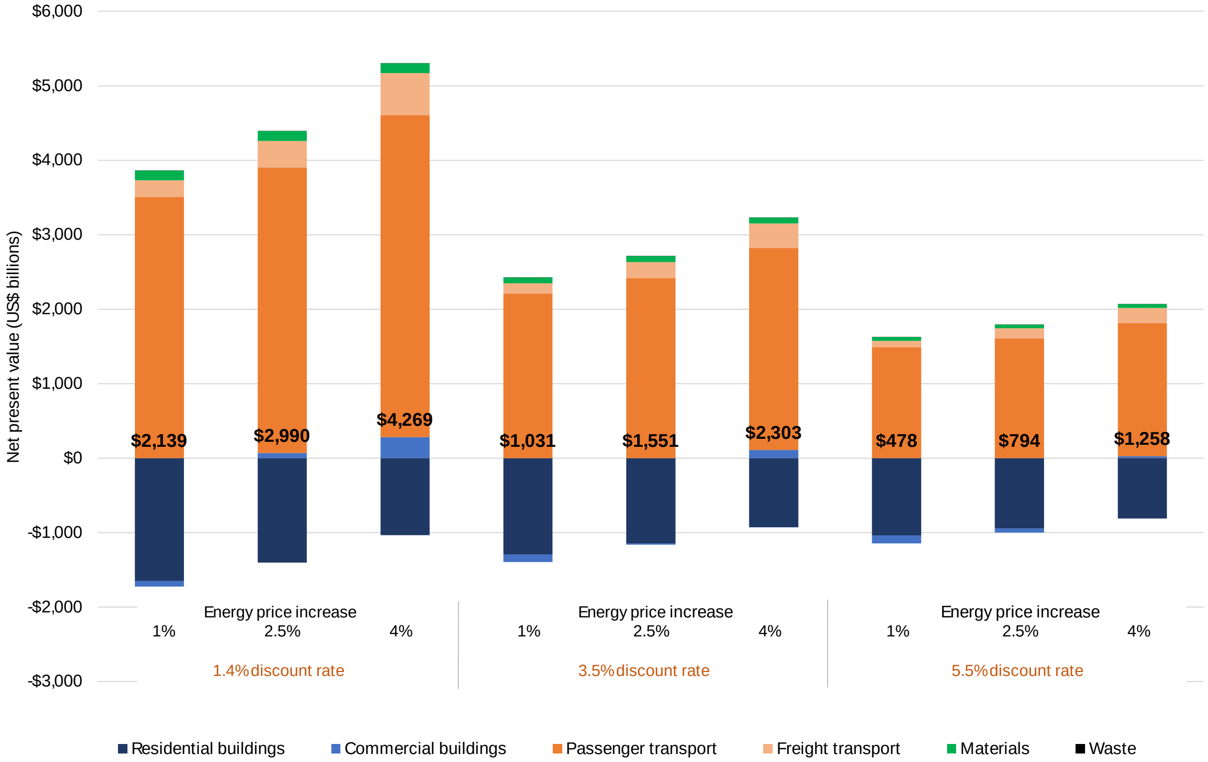
India

Table A2.6. Economics of urban decarbonisation investments in India, 2020–2050

	Incremental investment (US$ billions)	Annual returns (US$ billions)		Net present value, 2020–2050 (US$ billions)	Jobs supported	
		2030	**2050**		**2030**	**2050**
Residential buildings						
Lighting efficiency improvements	$0.20	$0.12	$0.11	$4.68	311	367
Appliance efficiency improvements	$14.38	$1.04	$1.32	$9.24	0	98,685
Cooking solutions efficiency improvements	$0.00	$2.30	$1.39	$82.48	0	0
Rooftop solar PV	$13.47	$0.00	$0.46	$23.34	0	13,548
Deep efficiency	$2,628.45	–$68.39	$6.16	-$1,265.65	6,645,589	1,194,203
Commercial buildings						
Lighting efficiency improvements	$1.10	$3.91	$6.89	$135.53	1,558	2,440
Appliance efficiency improvements	$1.74	$0.23	$3.05	$30.26	642	7,487
Rooftop solar PV	$4.12	$0.00	$0.22	$6.94	0	3,428
Deep efficiency	$451.22	–$13.37	$5.67	-$189.99	1,093,511	112,259
Passenger transport						
Compact urban development	$65.24	$16.73	$35.17	$805.94	108,272	181,967
Mode shift to mass transit	$79.08	$51.01	$76.66	$1,431.64	113,482	243,425
Energy-efficient vehicles	$0.88	$2.67	$10.86	$155.77	3,285	389
Electric vehicles	$289.71	$5.85	$21.31	$26.45	252,459	1,006,968
Freight transport						
Improved logistics	$20.02	$1.32	$3.94	$43.27	21,635	66,531
More efficient and electric vehicles	$15.09	$2.08	$15.62	$170.91	3,762	89,287
Materials						
Material efficiency	n/a	$2.27	$18.15	$79.72	n/a	n/a
Waste						
Landfill gas utilisation	$0.09	$0.02	$0.31	$0.88	178	1,738
TOTAL	**$3,584.79**	**$7.77**	**$207.30**	**$1,551.42**	**8,244,685**	**3,022,723**

Source: Vivid Economics for the Coalition for Urban Transitions. Note: These figures assume a discount rate of 3.5%, annual energy prices increase of 2.5% and low technological learning rates.

Figure A2.4. Net present value of urban decarbonisation measures in India, 2020–2050



Source: Vivid Economics for the Coalition for Urban Transitions. Note: Under the "low", "medium" and "high" scenarios, the real discount rates used are 1.4%, 3.5% and 5.5%, and the increases in real energy prices are 1%, 2.5% and 4%. Learning rates are sector- and technology-specific.

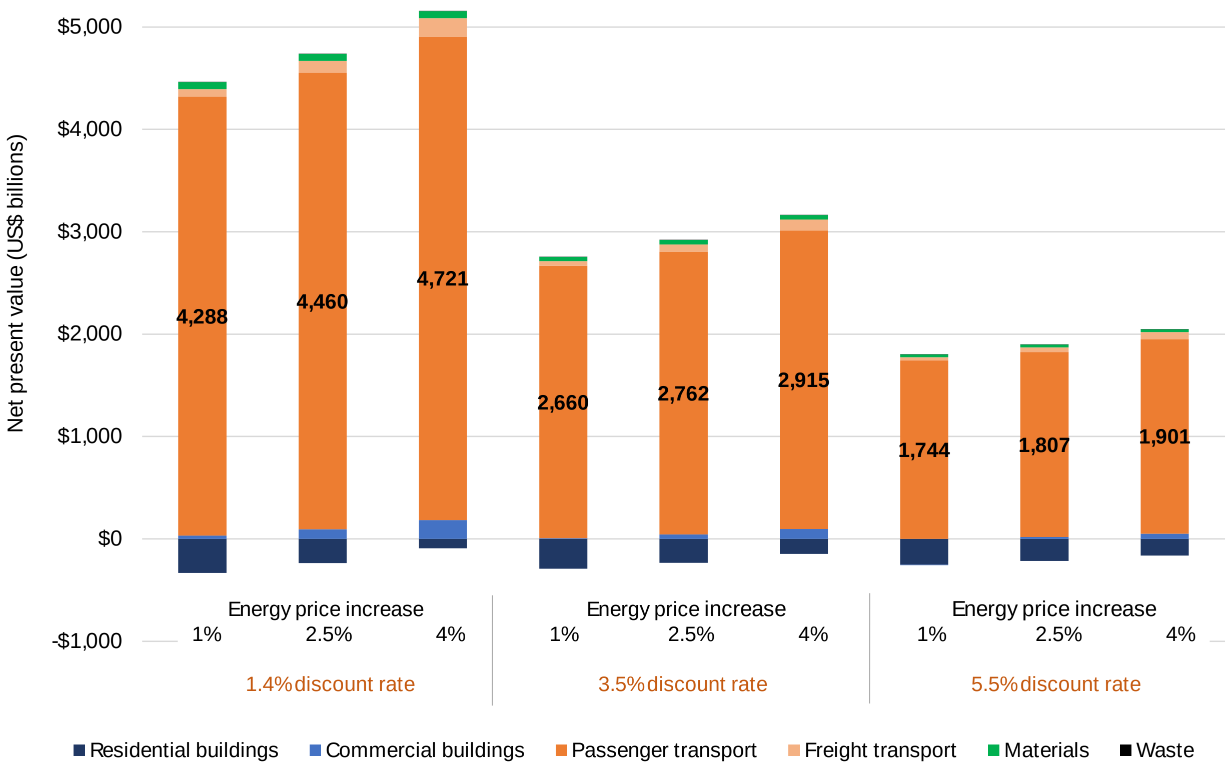
Indonesia

Table A2.7. Economics of urban decarbonisation investments in Indonesia, 2020–2050

	Incremental investment (US$ billions)	Annual returns (USD billions)		Net present value, 2020–2050 (US$ billions)	Jobs supported	
		2030	2050		2030	2050
Residential buildings						
Lighting efficiency improvements	$2.44	$0.22	$0.11	$7.70	4,462	2,599
Appliance efficiency improvements	$0.93	–$6.98	–$0.02	-$3.52	0	13,944
Cooking solutions efficiency improvements	$0.00	$1.61	$1.71	$73.50	0	0
Rooftop solar PV	$22.27	–$0.02	$0.69	$10.46	18,982	58,416
Deep efficiency	$611.12	–$17.42	$3.08	-$321.19	1,696,982	0
Commercial buildings						
Lighting efficiency improvements	$0.91	$1.40	$2.63	$52.10	1,202	1,996
Appliance efficiency improvements	$1.41	$0.00	$1.21	$10.85	0	6,491
Rooftop solar PV	$4.88	–$0.01	$0.27	$2.19	4,504	11,953
Deep efficiency	$112.22	–$2.46	$2.62	-$21.73	276,787	14,785
Passenger transport						
Compact urban development	$24.35	$21.44	$45.50	$731.24	38,716	70,315
Mode shift to mass transit	$90.93	$60.50	$136.97	$1,972.69	90,225	229,947
Energy-efficient vehicles	$4.38	$1.76	$4.17	$78.30	14,466	2,633
Electric vehicles	$157.81	$3.03	$6.79	-$19.91	132,128	406,470
Freight transport						
Improved logistics	$10.54	$0.55	$1.37	$13.35	12,787	32,354
More efficient and electric vehicles	$7.31	$1.09	$4.57	$57.03	2,784	39,123
Materials						
Material efficiency	n/a	$1.50	$8.21	$42.52	n/a	n/a
Waste						
Landfill gas utilisation	$0.07	$0.01	$0.12	$0.32	126	1,210
TOTAL	**$1,048.21**	**$72.98**	**$219.89**	**$2,681.72**	**2,289,688**	**875,692**

Source: Vivid Economics for the Coalition for Urban Transitions. Note: These figures assume a discount rate of 3.5%, annual energy prices increase of 2.5% and low technological learning rates.

Figure A2.5. Net present value of urban decarbonisation measures in Indonesia, 2020–2050



Source: Vivid Economics for the Coalition for Urban Transitions. Note: Under the "low", "medium" and "high" scenarios, the real discount rates used are 1.4%, 3.5% and 5.5%, and the increases in real energy prices are 1%, 2.5% and 4%. Learning rates are sector- and technology-specific.

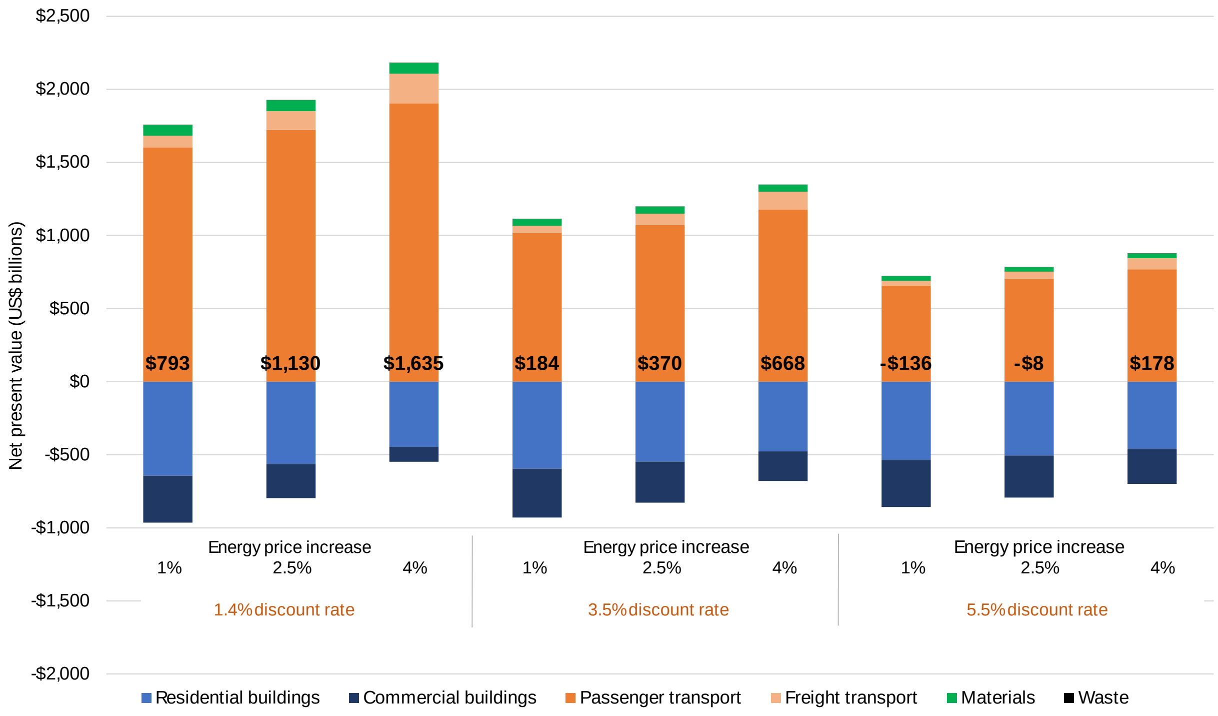
Brazil

Table A2.8. Economics of urban decarbonisation investments in Brazil, 2020–2050

	Incremental investment (US$ billions)	Annual returns (USD billions)		Net present value, 2020–2050 (US$ billions)	Jobs supported	
		2030	2050		2030	2050
Residential buildings						
Lighting efficiency improvements	$4.22	$0.57	$0.26	$21.63	7,394	4,040
Appliance efficiency improvements	$69.85	–$0.18	$0.00	-$9.43	43,962	211,029
Cooking solutions efficiency improvements	$0.00	–$0.10	$0.24	$0.56	0	0
Rooftop solar PV	$27.42	$0.00	–$0.28	-$5.61	0	168,985
Deep efficiency	$759.85	–$26.29	$7.98	-$553.43	2,562,287	0
Commercial buildings						
Lighting efficiency improvements	$1.16	$1.55	$2.91	$57.33	1,531	2,552
Appliance efficiency improvements	$4.69	$0.75	$1.60	$30.83	5,529	9,942
Rooftop solar PV	$8.39	$0.00	–$0.16	-$1.72	0	51,794
Deep efficiency	$516.99	–$21.03	$10.69	-$368.15	1,647,694	0
Passenger transport						
Compact urban development	$19.11	$8.93	$18.75	$356.18	31,666	52,827
Mode shift to mass transit	$69.05	$20.81	$45.21	$678.66	52,770	196,125
Energy-efficient vehicles	$2.97	$1.48	$3.81	$60.06	8,717	3,426
Electric vehicles	$144.03	$2.52	$6.65	-$23.29	128,383	450,080
Freight transport						
Improved logistics	$32.08	$0.90	$1.74	$3.45	43,723	86,977
More efficient and electric vehicles	$10.24	$1.56	$5.76	$74.71	3,336	56,450
Materials						
Material efficiency	n/a	$2.03	$7.42	$47.37	n/a	n/a
Waste						
Landfill gas utilisation	$0.11	$0.01	$0.16	$0.48	237	1,779
TOTAL	**$1,670.16**	**–$6.49**	**$112.73**	**$369.62**	**4,537,229**	**1,296,006**

Source: Vivid Economics for the Coalition for Urban Transitions. Note: These figures assume a discount rate of 3.5%, annual energy prices increase of 2.5% and low technological learning rates.

Figure A2.6. Net present value of urban decarbonisation measures in Brazil, 2020–2050



Source: Vivid Economics for the Coalition for Urban Transitions. Note: Under the "low", "medium" and "high" scenarios, the real discount rates used are 1.4%, 3.5% and 5.5%, and the increases in real energy prices are 1%, 2.5% and 4%. Learning rates are sector- and technology-specific.

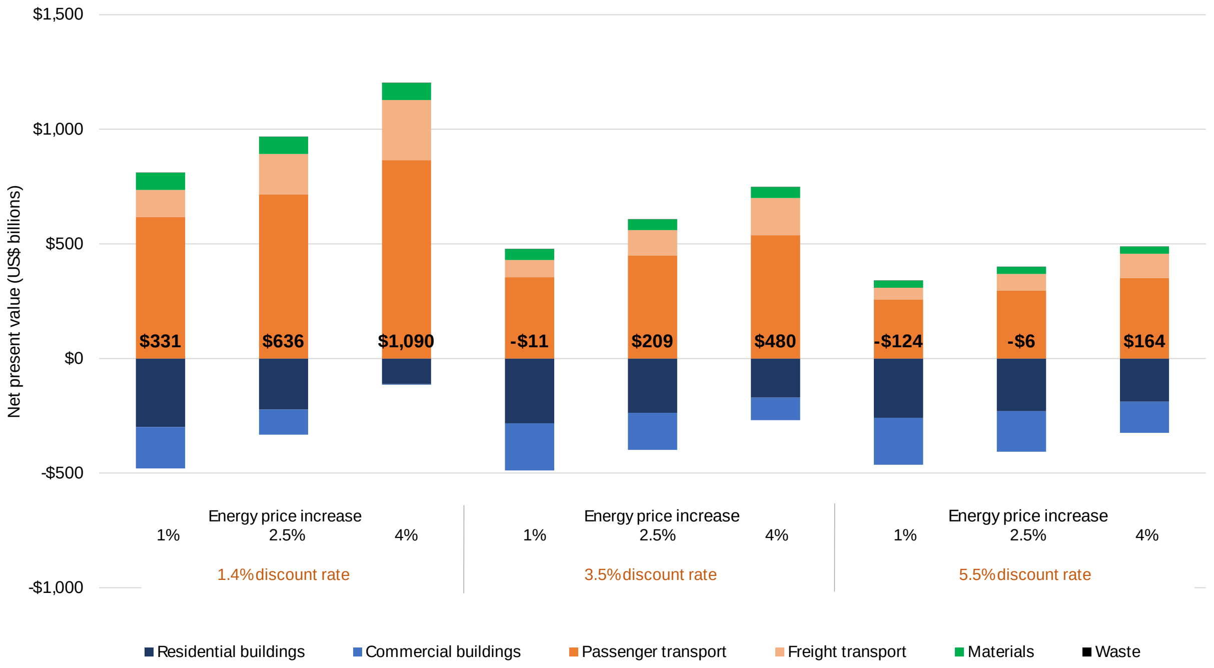
Mexico

Table A2.9. Economics of urban decarbonisation investments in Mexico, 2020–2050

	Incremental investment (US$ billions)	**Annual returns (US$ billions)**		**Net present value, 2020–2050 (US$ billions)**	**Jobs supported**	
		2030	**2050**		**2030**	**2050**
Residential buildings						
Lighting efficiency improvements	$2.78	$0.25	$0.19	$10.53	891	803
Appliance efficiency improvements	$78.35	–$0.34	–$0.32	-$14.39	0	73,503
Cooking solutions efficiency improvements	$0.00	$0.33	$0.22	$12.70	0	0
Rooftop solar PV	$0.98	$0.00	$0.00	$1.20	0	0
Deep efficiency	$426.56	–$12.88	$489.34	-$247.41	274,637	0
Commercial buildings						
Lighting efficiency improvements	$0.83	$0.93	$14.81	$31.35	240	336
Appliance efficiency improvements	$3.99	$0.44	$1.27	$20.63	862	2,072
Rooftop solar PV	$0.36	$0.00	$0.00	$0.44	0	0
Deep efficiency	$338.12	–$13.45	$9.24	-$214.14	221,797	0
Passenger transport						
Compact urban development	$14.07	$7.50	$10.51	$266.20	4,577	6,970
Mode shift to mass transit	$4.66	$0.77	$1.03	$78.24	1,873	122
Energy-efficient vehicles	$1.93	$1.35	$3.21	$51.80	1,027	501
Electric vehicles	$58.04	$2.48	$6.04	$53.20	10,809	31,086
Freight transport						
Improved logistics	$29.95	$1.22	$1.91	$13.09	8,576	14,104
More efficient and electric vehicles	$2.74	$2.55	$5.12	$97.71	252	2,659
Materials						
Material efficiency	n/a	$2.00	$7.65	$47.34	n/a	n/a
Waste						
Landfill gas utilisation	$0.09	$0.01	$0.12	$0.32	33	341
TOTAL	**$963.44**	**–$6.88**	**$52.57**	**$208.79**	**525,575**	**132,497**

Source: Vivid Economics for the Coalition for Urban Transitions. Note: These figures assume a discount rate of 3.5%, annual energy prices increase of 2.5% and low technological learning rates.

Figure A2.7. Net present value of urban decarbonisation measures in Mexico, 2020–2050



Source: Vivid Economics for the Coalition for Urban Transitions. Note: Under the "low", "medium" and "high" scenarios, the real discount rates used are 1.4%, 3.5% and 5.5%, and the increases in real energy prices are 1%, 2.5% and 4%. Learning rates are sector- and technology-specific.

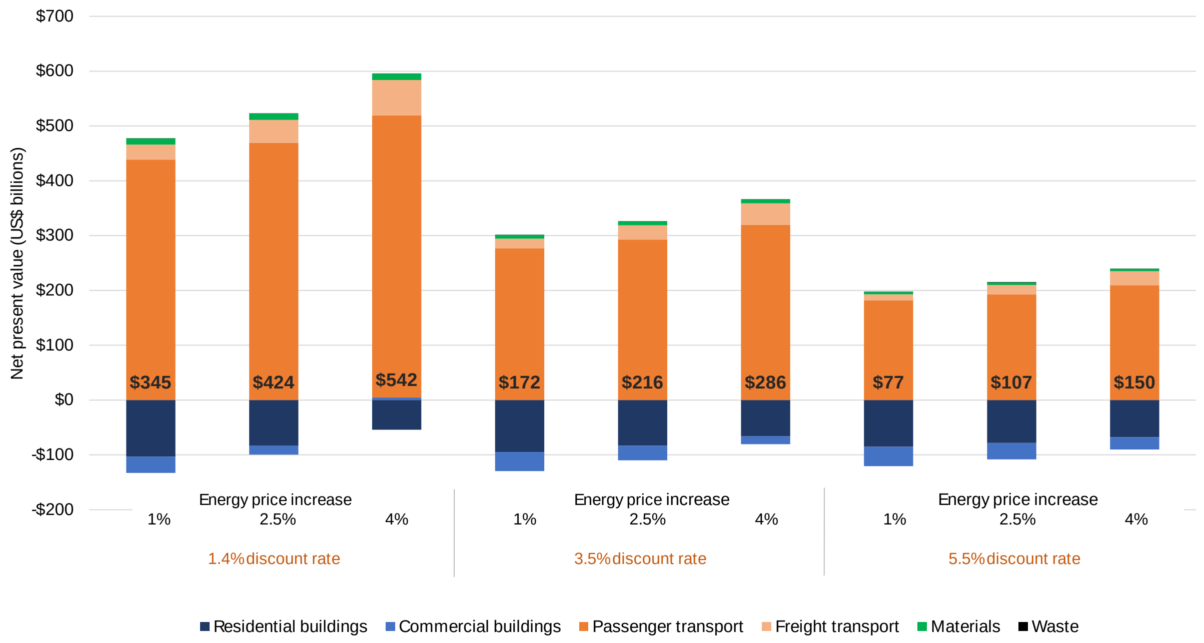
South Africa

Table A2.10. Economics of urban decarbonisation investments in South Africa, 2020–2050

	Incremental investment (US$ billions)	Annual returns (US$ billions)		Net present value, 2020–2050 (USD billions)	Jobs supported	
		2030	**2050**		**2030**	**2050**
Residential buildings						
Lighting efficiency improvements	$0.78	$0.05	$0.14	$4.13	562	2,160
Appliance efficiency improvements	$30.94	–$0.51	$0.03	-$6.46	0	167,471
Cooking solutions efficiency improvements	$0.00	$0.08	–$0.12	-$0.07	0	0
Rooftop solar PV	$8.84	$0.02	$0.14	$4.20	15,067	8,885
Deep efficiency	$114.82	–$3.87	$1.23	-$85.11	383,863	0
Commercial buildings						
Lighting efficiency improvements	$0.16	$0.25	$0.38	$8.34	236	324
Appliance efficiency improvements	$0.00	–$0.26	–$0.27	-$7.64	0	0
Rooftop solar PV	$2.47	$0.01	$0.07	$1.13	4,363	2,302
Deep efficiency	$57.62	–$2.16	$2.14	-$28.41	193,532	0
Passenger transport						
Compact urban development	$3.85	$1.84	$3.92	$64.69	6,225	10,908
Mode shift to mass transit	$29.58	$7.56	$16.26	$223.27	26,708	75,121
Energy-efficient vehicles	$0.35	$0.29	$0.26	$7.95	1,269	234
Electric vehicles	$17.97	$0.41	$0.42	-$3.26	19,082	39,452
Freight transport						
Improved logistics	$2.99	$0.25	$0.45	$6.05	4,163	8,072
More efficient and electric vehicles	$1.81	$0.45	$1.39	$20.13	647	9,806
Materials						
Material efficiency	n/a	$0.29	$1.24	$7.23	n/a	n/a
Waste						
Landfill gas utilisation	$0.02	$0.00	$0.04	$0.13	31	270
TOTAL	**$272.20**	**$4.70**	**$27.75**	**$216.30**	**655,748**	**325,005**

Source: Vivid Economics for the Coalition for Urban Transitions. Note: These figures assume a discount rate of 3.5%, annual energy prices increase of 2.5% and low technological learning rates.

Figure A2.8. Net present value of urban decarbonisation measures in South Africa, 2020–2050



Source: Vivid Economics for the Coalition for Urban Transitions. Note: Under the "low", "medium" and "high" scenarios, the real discount rates used are 1.4%, 3.5% and 5.5%, and the increases in real energy prices are 1%, 2.5% and 4%. Learning rates are sector- and technology-specific.

Endnotes

[1] See IEA data: https://www.iea.org/subscribe-to-data-services/prices-and-taxes.

[2] See World Bank data: https://data.worldbank.org/indicator/EP.PMP.DESL.CD.

[3] See, e.g., Gouldson et al., 2015, "Accelerating Low-Carbon Development in the World's Cities."

[4] See, e.g., Ürge-Vorsatz et al., 2015, "Monetary Benefits of Ambitious Building Energy Policies."

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[35] In interpreting results, the ranges for each country should be considered.

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[37] Hughes et al., 2014, "Low Carbon Jobs: The Evidence for Net Job Creation from Policy Support for Energy Efficiency and Renewable Energy."

[38] Hughes et al., 2014, "Low Carbon Jobs: The Evidence for Net Job Creation from Policy Support for Energy Efficiency and Renewable Energy."

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[46] All interventions represent a shift from fossil fuel-based energy to lower carbon sources.

[47] See International Labour Organization: https://www.ilo.org/newdelhi/areasofwork/informal-economy/lang--en/index.htm#.

[48] According to the ILO, a decent job involves opportunities for work that is productive and delivers a fair income; provides security in the workplace and social protection for workers and their families; offers better prospects for personal development and encourages social integration; gives people the freedom to express their concerns, to organise and to participate in decisions that affect their lives; and guarantees equal opportunities and equal treatment for all.

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