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Climate Finance Needs of Nine G20 EMEs

Well Within Reach

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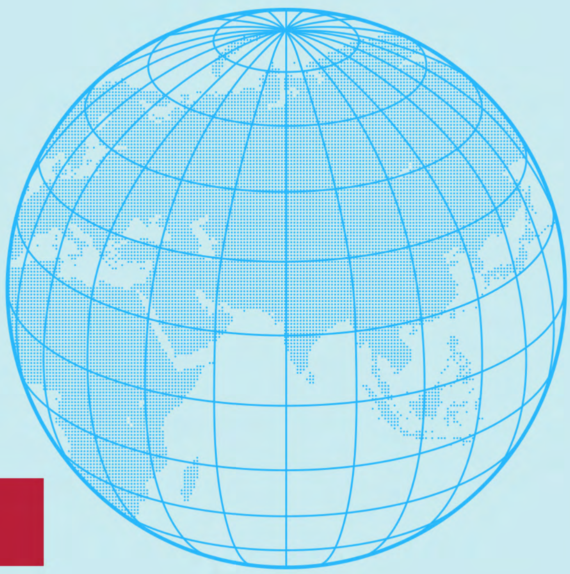

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Designed by Umesh Kumar

Climate Finance Needs of Nine G20 EMEs

Well Within Reach

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List of Abbreviations

ACE	Additional Capital Expenditure
AFOLU	Agriculture, Forestry, and Other Land Use
BAU	Business-as-Usual
BESS	Battery Energy Storage Systems
BF-BOF	Blast Furnace - Basic Oxygen Furnace
BOS	Basic Oxygen Steelmaking
CAD	Current Account Deficit
CAGR	Compound Annual Growth Rate
Capex	Capital Expenditure
CCDRs	Country Climate and Development Reports
CCS	Carbon capture and storage
CCUS	Carbon Capture, Utilisation, and Storage
CDR	Carbon Dioxide Removal
CO_2	Carbon Dioxide
CRF	Capital Recovery Factor
CSP	Concentrating Solar Power
DAC	Direct Air Capture
DRI	Direct Reduced Iron
e2w	Electric Two-Wheeler
EAF	Electric Arc Furnace
EOR	Enhanced Oil Recovery
EMDEs	Emerging Markets and Developing Economies
EMEs	Emerging Market Economies
EVs	Electric Vehicles
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GW	Gigawatt
HIC	High-Income Countries
ICEVs	Internal Combustion Engine Vehicles
IEA	International Energy Agency
IFC	International Finance Corporation
IHA	International Hydropower Association
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
kW	Kilowatt
kWh	Kilowatt-hour
LCOE	Levelized Cost of Electricity
LCV	Light Commercial Vehicle
LMICs	Low- and Middle-Income Countries
LT-LEDS	Long-Term Low Greenhouse Gas Emission Development Strategies
MDBs	Multilateral Development Banks
M0	Monetary Base
MT	Million Tonne
MW	Megawatt
NDAs	Net Domestic Assets
NDC	Nationally Determined Commitments
OECD	Organisation for Economic Co-operation and Development
OPEX	Operational Expenditure
PSH	Pumped Storage Hydropower
PSP	Pumped Storage Plant
PV	Photovoltaic
RE	Renewable Energy
SDS	Sustainable Development Scenario
tCO_2	Tonne of Carbon Dioxide
TWh	Terawatt-hours
UNFCCC	United Nations Framework Convention on Climate Change
WEF	World Economic Forum

Executive Summary

With the pressing need for climate action, it has become imperative to mobilise financial resources on a large scale, both for mitigation and adaptation. Several studies have estimated the capital investment needs, especially for mitigation measures, globally as well as for emerging market and developing economies (EMDEs). However, these estimates vary significantly due to differences in their underlying methodologies, objectives, time periods and baselines considered, and the scope of activities covered. More importantly, all these studies adopt top-down approaches and lack sectoral details.

Unlike other studies, this study follows a bottom-up approach to assess climate finance requirements purely on account of transition to a low-carbon economy over and above the investment needed in business-as-usual (BAU) scenario. This study focuses on the four major carbon emitting sectors, *viz.*, power, road transport, steel, and cement. While most other studies cover the energy sector, studies which cover the steel, cement, and road transport sectors are few and far between.

This study examines three related aspects. First, it examines the climate finance requirements of nine EMEs constituting G20 (Argentina, Brazil, China, India, Indonesia, Mexico, the Russian Federation, South Africa, and Türkiye) from 2022 to 2030.[1] An assessment of climate finance requirement for the distant future beyond 2030 is not attempted because of several risks that are inherent in making such long-term forecasts due to uncertainty with regard to technological and other potential developments. Very long-term projections of investments and costs are liable to be intrinsically unreliable. All the EMEs selected for this study together constitute 30 per cent of global gross domestic product (GDP), 47 per cent of global population, and 30 per cent of global carbon emissions.

Second, given the critical role of multilateral development banks (MDBs) in providing climate finance, this study also assesses the extent to which MDBs may be able to fund the climate action in the selected nine EMEs up to 2030.

Finally, the study examines the ability of the nine EMEs to absorb/manage climate finance flows from external sources over and above capital and financial flows (net of current account balance) in the BAU scenario. This is the first study to examine macroeconomic consistency of climate finance estimates.

This study focuses on assessing climate finance requirements that arise purely because of the need for mitigating climate change in four major carbon emitting sectors (power, transport, steel, and cement). These four sectors collectively contribute about 49 per cent, on average, to carbon emissions in the nine economies, and hence are crucial to decarbonise the global economy.

The study uses two distinct methodologies for the four sectors for estimating climate finance. For the power and road transport sectors, climate finance is estimated as an additional capital expenditure (ACE) required for switching over from fossil fuel-based sources to renewables (power) and from internal combustion engine vehicles (ICEVs) to electric vehicles (road transport), over and above the capital expenditure (capex) planned in the BAU scenario. Investment for the BAU scenario for these sectors is calculated assuming that there would be no efforts to mitigate climate change. For the steel and cement sectors, climate finance has been worked out as the total capex required to completely mitigate the carbon emissions in these two sectors, emanating from the existing capacity as well as the capacity that would be installed up to 2030.

Climate finance[2] requirement of the nine economies is estimated at US$ 2.2 trillion (US$ 255 billion annually) for all the four sectors, driven mainly by the steel sector (US$ 1.2 trillion or 51 per cent of total), followed by road transport (US$ 459 billion or 21 per cent), cement (US$ 453 billion or 21 per cent), and power (US$ 149 billion or 7 per cent). Climate finance requirement as percentage of GDP works out to 0.6 per cent on average. Thus, contrary to the common narrative, the transitioning of the power sector from fossil fuel-based sources to renewables does not require large climate finance. Of the estimated climate finance requirement, 60 per cent is attributable to

[1] The period covered is 2022–2030 for the steel and cement sectors, 2024–2030 for the power sector and 2023–2030 for road transport.

[2] Additional capital expenditure (ACE) or capex over and above the investment needed in the BAU scenario without considering climate change.

China. Excluding China, the climate finance requirement for the eight other economies works out to US$ 854 billion (US$ 100 billion annually or 0.5 per cent of their GDP).

The steel and cement sectors are hard-to-abate as there are limited options to reduce carbon dioxide (CO_2) emissions released during the production process in these sectors other than through carbon capture and storage (CCS). This is expensive but the only feasible technology to deploy at this stage. Hence, the steel and cement sectors require the largest chunk of the climate finance estimated. The road transport sector also requires significant climate finance. However, most of the capex requirement in the road transport sector is for developing the charging infrastructure rather than for transitioning from the ICEVs to EVs. The power sector requires the least amount of climate finance relative to other sectors in the study because the unit capital cost for solar and wind power plants has declined to the extent where it is now lower than that required for installing fossil fuel-based sources of power.

The study also assesses potential carbon emission reductions that can be achieved through climate related investment estimated in the study. Climate investment estimated for the nine EMEs for three sectors[3] (power, steel, and cement) has the potential to mitigate 33 billion tonnes of CO_2. The average cost to mitigate one tonne of CO_2 (tCO_2) is estimated at US$ 53. In terms of per unit cost, the power sector is found to be the most expensive to decarbonise at a cost of US$ 66 per tCO_2, followed by steel at US$ 53 per tCO_2 and cement at US$ 49 per tCO_2. These estimates rely on current market technologies and any future technological advances have the potential to significantly reduce the climate finance requirement for the steel and cement sectors.

In 2022, climate finance provided by MDBs to all countries constituted 36 per cent of their total annual loan book. The share of climate finance extended by MDBs to the nine EMEs covered in this study in their total climate finance portfolio was 16 per cent in 2022. MDBs' global climate finance portfolio is projected to increase at a compound annual growth rate (CAGR) of 14 per cent, from US$ 74 billion in 2022 to US$ 215 billion in 2030. During the same period, climate finance to the nine EMEs included in the study is expected to grow from US$ 12 billion to US$ 34 billion. At this level, climate finance by MDBs is projected to cover only 7–9 per cent of the estimated climate finance requirement of the nine economies. The situation improves somewhat when China is excluded, increasing the share of climate finance by MDBs in total climate finance requirement of the eight other economies to 15–25 per cent. MDBs finance multiple activities such as health, education, transport, agriculture, water and waste management, and urban infrastructure, among others. Since the cement and steel sectors in most of the economies are largely in the private sector, which MDBs normally do not finance, they need to treat decarbonisation of the cement and steel sectors as a public good for financing purposes. The International Finance Corporation (IFC), a part of the World Bank group, in any case finances the private sector.

A macroeconomic consistency analysis shows that it would be a challenge to manage both (i) external financial flows; and (ii) estimated climate finance flows from external sources for most of the nine economies. External financial flows (capital and financial flows net of current account balance) for the nine economies are estimated at US$ 2.7 trillion during 2023–2030 (US$ 1.1 trillion excluding China) in the BAU scenario. However, expansion in monetary base (M0) for the nine economies has been projected at US$ 3.1 trillion (US$ 1.2 trillion excluding China) for the period from 2023–2030. This leaves a small room of only US$ 423 billion (US$ 37 billion excluding China) for absorbing climate finance from external sources. At an economy level, while Türkiye can absorb external financial flows and estimated climate finance flows easily, three other economies (China, Mexico, and Russia) have some room to manage climate finance flows over and above the external financial flows in the BAU. All other EMEs would need to skillfully manage both external financial flows in the BAU scenario and climate finance from external sources.

[3] The CO_2 mitigation for the road transport sector could not be assessed due to lack of availability of relevant data.

1. Introduction

The Paris Agreement, adopted in 2015 under the United Nations Framework Convention on Climate Change (UNFCCC), aims at addressing the risks and impacts of climate change globally. Its primary objectives are to (i) limit the increase in global average temperature to below 2°C above pre-industrial levels, with an aspirational target of limiting the temperature increase to 1.5°C; and (ii) strengthen the adaptability and resilience of countries to climate change. Achieving these goals will require ambitious and accelerated actions by all the countries in tandem (UNFCCC, 2015). To enhance the global response to climate change in alignment with the goals set, the Paris Agreement requires countries to develop and communicate nationally determined contributions (NDCs) and long-term low greenhouse gas emission development strategies (LT-LEDS). These are plans by each country, outlining their efforts to reduce greenhouse gas (GHG) emissions and adapt to climate change (UNFCCC, 2015).

The UNFCCC indicated that, as of May 2024, 195 countries communicated their commitment to climate mitigation and adaptation goals. Climate action to achieve the goals outlined in NDCs and LT-LEDS will require significant climate finance to facilitate the transition to low-carbon economies and strengthen the climate resilience of the countries. Mitigation efforts, including transitioning to renewable energy (RE), an electric transport fleet, and enhancing energy efficiency, will require huge investments in new and emerging technologies. Similarly, adaptation measures such as building resilient infrastructure and protecting natural ecosystems, also need considerable investment.

Apart from large associated costs, climate action would have adverse macroeconomic impacts as well. The International Monetary Fund - IMF (2022) estimates that the low-carbon energy transition could slow down global GDP growth by 0.15 to 0.25 per cent per year by 2030. The Organisation for Economic Co-operation and Development (OECD) finds that climate action would cost 5.5 per cent of global GDP in 2050 (OECD, 2012). However, inaction or delayed action would only worsen the economic impact. Around 10 per cent of the world's total economic value stands to be lost by 2050 if temperature increases are not restricted and the goals laid out under the Paris Agreement and the net-zero targets are not fulfilled (Swiss Re, 2021). Moreover, the impact of inaction is even worse for emerging markets and developing economies (EMDEs). It has been estimated that the economic losses in developing countries, in the absence of mitigation and adaptation efforts, could rise to 20 per cent of GDP (Ludwig *et al.,* 2007). In addition to economic benefits, climate action would also yield health benefits due to improved air quality and lower chronic mortality (Mersmann, 2021; West *et al.,* 2013).

Climate action is necessary to reduce the adverse impacts of climate risks on the global economy. For EMDEs, the need for climate action is even more pressing due to their disproportionate exposure to the impacts of climate change (Intergovernmental Panel on Climate Change, 2001; Ludwig *et al.,* 2007; US Global Leadership Coalition, 2021). The global economy, especially EMDEs, faces significant capital requirements for effectively combating climate change.

There have been several estimates of climate finance requirements for the global economy and EMDEs. These estimates highlight the substantial capital investments necessary for transitioning towards a low-carbon economy and enhancing adaptation measures to combat climate impacts. Existing global climate finance estimates range between US$ 40 and US$ 104 trillion by 2030 (US$ 4–7 trillion per year) and US$ 100–275 trillion by 2050 (US$ 3–9 trillion per year). For EMDEs, the estimates range between US$ 6 and US$ 35 trillion by 2030 (US$ 1–4 trillion per year).

The global and EMDEs' climate finance estimates show large variations (Appendix 1). These estimates are often incomparable due to different objectives, time horizons, baselines, and the scope of sectors covered. Another challenge with many of these estimates is that they rely on top-down approaches, which make broad assumptions and do not account for local and sectoral variations needed to estimate sector-specific climate finance needs.

An important outcome of the global negotiations on climate change has been the commitment by developed countries to provide financial resources to EMDEs in accordance with the principle of "common but differentiated responsibility and respective capabilities" set out in the UNFCCC. This is based on the recognition that the developed economies are largely responsible for the current high levels of GHG emissions in the atmosphere. The Kyoto Protocol, 1997, binds developed countries and places a heavier burden on them under the aforesaid principle. The Paris Agreement reaffirmed the obligations of developed countries, while for the first time also encouraging voluntary contributions by other Parties. MDBs have also been exhorted to considerably augment their lending capacity to provide funding to EMDEs for climate action.

The report of the Independent High-Level Expert Group on Climate Finance suggested that US$ 1 trillion per year needs to be mobilised in external finance for EMDEs, other than China, up to 2030 (Songwe *et al.,* 2022). However, an important issue that arises is whether the EMDEs are able to absorb such large climate finance flows. Capital flows can be absorbed in any economy only to the extent of its current account deficit (CAD). Capital flows greater than the CAD cannot be absorbed for the needed investment. For those economies which have current account surpluses, capital flows cannot be absorbed. By definition, their gross domestic savings exceed their gross domestic investment; hence these economies have no need for capital flows to finance their investment needs. In both cases (capital flows greater than the CAD and countries with current account surplus), additional capital flows would need to be managed. Therefore, the response of each economy may have to be different to deal with the large climate finance flows that emanate from external sources. The assessment of external climate finance flows will need to meet this reality test. The current studies estimating climate finance needed do not address this issue at all.

In the above setting, this study focuses on three aspects. First, in view of the limitations of the existing estimates of climate finance in general and EMDEs in particular, we estimate climate finance requirements for select EMEs in a more comprehensive and transparent manner at a sectoral level. This study covers nine EMEs (Argentina, Brazil, China, India, Indonesia, Mexico, the Russian Federation, South Africa, and Türkiye). Climate finance requirements of India have been assessed comprehensively in a separate study (Raj and Mohan, 2025). Therefore, granular details relating to India are not covered in this study. However, India is included while aggregating the numbers to facilitate an overall assessment of all the nine economies.

All the nine economies are a part of the G20. They together constitute 30 per cent of global GDP, 47 per cent of the world's population, and 30 per cent of global carbon emissions. Carbon emissions from these economies have been rising at 5 per cent annually, more than double the growth rate in global emissions (Our World in Data, 2024).[4]

The study covers four sectors (power, road transport, steel, and cement) for the period from 2022 to 2030.[5] While most other studies on climate finance focus on the energy sector, there is hardly any research covering industrial sectors that are significant emitters, particularly steel and cement. A comprehensive assessment of climate finance hinges on the targets set for achieving carbon neutrality. Some EMEs selected for this study have committed to becoming carbon neutral by 2050, others by 2060, while India has committed to reaching net zero by 2070 (Appendix 2). However, we believe that an assessment of climate finance requirements for the distant future is fraught with several risks and subject to too many imponderables. Hence, this study restricts its assessment of climate finance up to 2030 only.

The study focuses on assessing climate finance requirements that arise purely on account of climate change, *i.e.*, transition to a low-carbon economy over and above the investment required in the BAU scenario for four major carbon-emitting sectors (power, transport, steel, and cement). These four sectors collectively contribute, on average, about 49 per cent to carbon emissions in the nine economies studied and are, therefore, crucial for decarbonising the global economy.

The study uses two distinct methodologies for estimating climate finance across the four sectors. For the power and road transport sectors, climate finance is estimated as the additional capital expenditure (ACE) required for progressively switching from fossil fuel-based sources to renewables (power) as currently projected by each country, and from ICEVs to EVs (road transport) over and above the capital expenditure that would have taken place in the BAU scenario. For the steel and cement sectors, climate finance has been calculated as the total capital investment required to completely mitigate carbon

[4] The growth rate is calculated from 1908 to 2022, given that the data for the select countries are available from 1907.

[5] The period covered is 2022–2030 for the steel and cement sectors, 2024–2030 for the power sector, and 2023–2030 for road transport.

emissions, both from existing capacity and capacity planned till 2030.

MDBs are expected to play a critical role in providing climate finance, especially because the requirements for climate change, both mitigation and adaptation, are large, and climate mitigation should be regarded as a global public good. Thus, the second objective of the study is to examine to what extent MDBs will be able to meet the climate finance requirements of the nine EMEs within their existing resources.

The third objective of the study is to check the macroeconomic consistency of estimated climate finance individually for each of the nine economies, as well as for all the nine economies combined. This is done by estimating external financial flows (capital and financial flows net of current account balance) in the BAU scenario up to 2030, and the capacity of each of the nine economies to absorb/manage such flows. This is the first study to focus on the macroeconomic consistency of climate finance estimates.

Several key findings emerge from the study. The nine economies are estimated to need ACE or climate finance of US$ 2.2 trillion up to 2030, with an annual requirement of US$ 255 billion, equivalent to 0.6 per cent of their combined GDP, to mitigate CO_2 emissions in the power, steel, cement, and road transport sectors. However, excluding China, the climate finance requirement has been estimated lower at US$ 854 billion (US$ 100 billion or 0.5 per cent of GDP annually). These estimates are much lower than those made in earlier studies and can be deemed to be within the realms of feasibility.

The steel sector in the nine economies is estimated to require US$ 1.2 trillion for 2022–2030 (51 per cent of the total climate finance), and the cement sector US$ 453 billion (21 per cent of the total climate finance). Steel and cement are hard-to-abate sectors with limited scope for reduction of carbon emissions through energy efficiency, alternative fuels, and clinker substitution (cement). Hence, the removal of CO_2 emissions in these sectors requires the use of carbon capture and storage (CCS) technology, which is expensive, but the only feasible technology option available at present. These investment estimates will probably decrease if technological developments over time make CCS progressively affordable.

The climate finance requirement for the road transport sector (including two-wheelers, three-wheelers, passenger cars and taxis, trucks/goods vehicles, and buses) is estimated at US$ 459 billion (21 per cent of total climate finance) for 2023–2030, both for progressive electrification of the road transport fleet (switchover from ICEVs to EVs) and for developing the charging infrastructure for EVs. While the additional capex for electrification of the road transport fleet is moderate due to rapid advancements in battery technology, making EV costs similar to ICEVs, the charging infrastructure for EVs entails a heavy capital cost. Our projections for the switchover from ICEVs to EVs are based on the existing available projections of vehicle sales for each economy.

Climate finance for the power sector[6] (including increasing power generation through renewables and the associated storage costs) is estimated at US$ 149 billion for 2024–2030. Thus, contrary to the common narrative, the requirement of climate finance for the power sector is not large. Renewable energy (RE) technology is fast maturing and has witnessed drastic cost reductions in recent periods, though the cost of battery storage continues to be high.

The study also assesses the carbon emission reduction potential which could be achieved by climate finance estimated in this study. The estimated climate finance of US$ 1.7 trillion for the nine economies for three sectors[7] (including power, steel, and cement) could potentially mitigate 33 billion tonnes of carbon emissions (tCO_2) over the period considered. The average cost of mitigation in the nine EMEs is estimated at US$ 53 per tCO_2. In terms of per unit cost, the power sector is the most expensive to decarbonise (US$ 66 per tCO_2), followed by the steel sector (US$ 53 per tCO_2), and the cement sector (US$ 49 per tCO_2).

The estimates arrived at in this study are based on current technologies that are available in the market. Since the technologies are evolving fast, it is possible that newer technologies could become less expensive and may require lower climate finance than that estimated in this study.

The study estimates that the total annual lending capacity of MDBs will increase from US$ 230 billion in 2023 to US$ 334 billion by 2030. Climate finance extended by MDBs annually is projected to increase significantly from US$ 74 billion in 2022 to US$

[6] CCS estimates for the power sector have also been worked out, but not included in the aggregate estimates because of availability of other decarbonisation solutions such as renewables, unlike hard-to-abate cement and steel sectors.

[7] Excluding transport for which data on carbon reduction could not be calculated due to non-availability of relevant data.

215 billion in 2030 to all countries, and from US$ 12 billion in 2022 to US$ 34 billion in 2030 to the nine economies covered in this study. Despite this significant increase in climate finance by MDBs, their share in the climate finance requirement of the nine economies estimated in this study would be in a range of 7–9 per cent from 2022 to 2030. Excluding China, which does not avail much financing from MDBs, the share of climate finance by MDBs for the eight other economies is projected at 15–25 per cent of the total climate finance requirement.

While MDBs finance diverse public infrastructure projects, they currently do not support the cement and steel industries, which are predominantly privately owned in most of the emerging economies covered in the study. Given the large carbon emissions from the cement and steel sectors, MDBs would need to consider decarbonisation of these two sectors a public good for financing purposes. The IFC, the World Bank arm, already finances the private sector. Financing by MDBs can play a catalytic role in promoting private investment for mitigating CO_2 in these sectors. The MDBs could play a significant role in the mitigation of emissions from these sectors by helping in developing an appropriate incentive framework that can leverage scarce public resources to generate much larger private financing.

Total capital and financial flows (net of current account balance) to the nine economies are estimated at US$ 2.7 trillion during 2023–2030 (US$ 1.1 trillion excluding China) in the BAU scenario. Monetary base in the nine economies is projected to expand by US$ 3.1 trillion (US$ 1.2 trillion excluding China). This leaves a small room of US$ 423 billion for all the nine economies (US$ 37 billion for the eight economies, excluding China) to absorb climate finance flows from external sources.

At a country level, of the nine economies, only Türkiye can comfortably absorb both (i) external financial flows and (ii) estimated climate finance flows from external sources. China, Mexico and Russia can manage climate flows to some extent over and above the external financial flows in the BAU. All other economies would need to skilfully manage both external financial flows in the BAU scenario and climate finance from external sources.

The study comprises eight sections. Section 2 details the various climate finance estimates available at the global and EMDE levels. Section 3 discusses the position of the nine economies in the global economy and their major carbon emitting sectors. Section 4 assesses the climate finance requirement for the four sectors (power, transport, cement, and steel) for each of the nine economies - other than India - which is covered in a separate study (Raj and Mohan, 2025). Section 5 aggregates the climate finance requirements across all the four sectors and the nine EMEs and assesses the carbon reduction potential. Section 6 explains how far climate finance requirements could be met by the MDBs. Section 7 examines the macroeconomic consistency of climate finance estimated in this study. Section 8 sums up the key findings of the study and sets out some final reflections.

2. Global Estimates of Climate Finance

In view of escalating climate risks, it is crucial to understand the financial requirements for investments needed for effective climate action, both for mitigation and adaptation measures. There have been several estimates of climate finance in the recent period as set out in Appendix 1. Some of the key studies on the subject are detailed below.

Bhattacharya *et al.* (2016) provided a relatively comprehensive estimate of the climate finance requirements for the global economy, as it included investment across four broad categories of core infrastructure - energy, transport, water and sanitation, and telecom and digital. They estimated that US$ 80 trillion was required as the total investment for sustainable infrastructure between 2015–2030, of which 70 per cent of the investment needs was driven by EMDEs. A large chunk of investment was envisaged to flow towards the power and transport sectors, given their importance in the low-carbon transition.

New Climate Economy (2016) estimated the infrastructure investments of the global economy of US$ 90 trillion for 2015–2030. This estimate excluded natural infrastructure such as forests and wetlands.

The Intergovernmental Panel on Climate Change (IPCC, 2018) estimated global climate finance needs at US$ 48 trillion from 2016 to 2035: US$ 2.4 trillion annually for limiting the temperature rise to 1.5ºC. However, this requirement corresponded to the energy systems transformation alone, and the bulk of the investments were estimated to be needed for clean electricity generation from renewable sources. OECD (2018) estimated the financial needs cumulatively at US$ 103 trillion between 2015–2030 or US$

6.9 trillion annually for energy, transport, building, and water infrastructure.

The International Energy Agency (IEA, 2021) estimated climate finance requirements for the energy sector in a net-zero emissions by 2050 scenario of US$ 5 trillion annually for the global economy by 2030. This implied a cumulative investment of US$ 50 trillion between 2020 and 2030 in the clean energy sector. The low-carbon pathway till 2030 outlined in the report focused on ramping up technologies already in the market, especially wind and solar, and electrification of vehicles, as opposed to the pathway till 2050, which put more emphasis on technologies under development.

Turner *et al.* (2021) assessed the global capital investment needs in the energy, transport, water and sanitation, and telecommunication sectors at US$ 74–79 trillion cumulatively between 2020–2030, or US$ 7.4–7.9 trillion annually. This assessment, based on estimates made by various other studies, was improved upon and refined by applying necessary assumptions (such as the pace of hydrogen uptake, the construction rate of renewables, and storage requirements), and arrived at a comprehensive estimate of climate finance requirements for the global economy. Similar to the findings of Bhattacharya *et al.* (2016), almost 40 per cent of investment was estimated in the energy sector, followed by the transport sector requiring about 35 per cent of capital.

Bhattacharya *et al.* (2022) estimated that EMDEs, excluding China, would require additional capital of US$ 35 trillion for the period 2020–2030. This estimate included investments for both mitigation and adaptation activities, making it quite a comprehensive assessment of climate finance requirements for EMDEs. However, it also included developmental capital needs, and the estimate was not solely for climate-related activities. The assessment by Songwe *et al.* (2022), which was aligned with achieving the 1.5°C temperature goal, estimated an investment requirement of US$ 20–28 trillion between 2020–2030 for mitigation and adaptation measures in EMDEs (excluding China). The IEA (2023) provided an estimate of US$ 28 trillion, similar to Songwe *et al.* (2022). However, IEA's estimate was only for the clean energy sector, whereas that by Songwe *et al.* (2022) was for loss and damage, adaptation and resilience, natural capital, and mitigating methane emissions, in addition to energy system transformation. The objective of the climate finance requirements was also different in both studies. While Songwe *et al.* (2022) study was aligned with the goal of limiting temperature rise to 1.5°C, IEA focused on achieving net-zero emissions by 2050.

A synoptic view of these various estimates can be had from Table 1.

Table 1: Climate Finance - Major Global and EMDE Estimates

Source	Cumulative Climate Finance Requirement (US$ Trillion)	Annual Climate Finance Requirement (US$ Trillion)	Target Year	Objective/ Scenario	Sectors Included
Global					
Bhattacharya *et al.* (2016)	80	5.4	2030	Paris Agreement goals	Power, transport, water and waste, and telecommunication
New Climate Economy (2016)	90	6	2030	Paris Agreement goals	Urban, transport, water, telecommunication and energy systems
Organization for Economic Co-operation and Development (2018)	104	6.9	2030	Paris Agreement goals	Energy, transport, building and water
Intergovernmental Panel on Climate Change (2018)	48	2.4	2035	1.5ºC temperature goal	Energy related
International Energy Agency (2021): Bouckaert *et al.*	50	5	2030	Net-zero emissions by 2050 scenario	Energy
Grantham Research Institute (2021): Turner *et al.*	74–79	7.4–7.9	2030	-	Energy, transport, water and sanitation and telecom
EMDEs					
Bhattacharya *et al.* (2022)	7* 35*	1.3* 3.5*	2025 2030	Net-zero transition and climate resilience (EMDEs, excluding China)	Human capital, sustainable infrastructure, agriculture, forestry, and other land use (AFOLU) and adaptation and resilience
Songwe *et al.* (2022)	20–28	2–2.8	2030	1.5ºC temperature goal (EMDEs, excluding China)	Energy system, loss and damage, adaptation and resilience, natural capital and mitigating methane emissions
International Energy Agency (2023)	22–28	2.2–2.8	Early 2030s	Lower bound: Sustainable development scenario (SDS); Higher bound: Net-zero emissions by 2050 scenario	Clean energy

**Specifically indicated as ACE requirement.*

Source: Authors' compilation.

Overall, various estimates of climate finance exhibit large variations, ranging between US$ 40 and US$ 104 trillion by 2030 (US$ 4–7 trillion per year), US$ 100–275 trillion by 2050 (US$ 3–9 trillion per year) for the global economy, and US$ 6–35 trillion for EMDEs by 2030 (US$ 1–4 trillion per year).[8] It is noteworthy that there are not many estimates of climate finance requirements for EMDEs.

Most estimates have been arrived at by following top-down approaches, and their underlying methodologies have not been adequately spelt out. They also lack the granularity and contextual specificity needed to accurately assess climate finance needs at sectoral levels.

Several Country Climate and Development Reports (CCDRs) of the World Bank undertake climate finance assessment at sectoral levels. CCDRs are available for 72 countries, but most of these are small. So, in aggregate, they cover only a small portion of global carbon emissions. Moreover, CCDRs' methodologies are focused on the interplay between climate and development and thus do not provide solely climate action-related finance requirements (World Bank, 2023). Though analysis by IEA is comprehensive in terms of sector-specific projections, it lacks country-level and sectoral requirements other than energy-related investments.

The various climate finance estimates are not strictly comparable as there are several crucial differences among them, which need to be clearly understood. First, the time horizons of the estimates vary as they are aligned with achieving different objectives such as achieving the Paris Agreement goals by 2030, meeting NDCs with varying deadlines across countries, or reaching global net-zero emissions by 2050. Since short-term projections focus on immediate mitigation and adaptation actions, these estimates are not comparable with long-term projections, which incorporate broader structural changes and innovations.

Second, global estimates are largely aligned with the climate goals of the Paris Agreement, which aspires to limit the global temperature rise to 1.5°C, and net-zero emissions by 2050. On the other hand, the scenarios considered for EMDEs' climate finance projections are diverse, ranging from the achievement of NDCs to financing for restricting the temperature rise to 1.5°C, to sustainable development scenario (SDS) which encompasses much more than climate action.

Third, depending on the objectives, some estimates focus on decarbonising specific sectors such as energy or land use systems, while others provide multi-sectoral assessments that even include adaptation measures in some cases. Unlike global estimates, most of the studies for EMDEs have also considered water supply and sanitation, flood protection, adaptation and resilience, and loss and damage. Given that the energy sector contributes to three-fourths of the global emissions, all the studies have included the transformation of the energy sector in climate finance assessments (Climate Watch, 2024). Most of the investment requirements for the clean energy sector are for electricity and heat generation since they are the highest carbon-emitting activities in the sector. Enhancing climate resilience, on the other hand, does not require as large capital flows as mitigation measures.

Fourth, several studies provide estimates for total investments that will be needed to reach a climate goal instead of assessing only the ACE required beyond the BAU. It is significant that the requirement of climate finance due to the transition from high-carbon to low-carbon technologies in some sectors represents only the cost differential between the two and not the entire expenditure on low-carbon technologies. Studies suggesting ACE requirements based purely on climate change are limited. For instance, Songwe *et al.* (2022) highlight that the total annual investment needed for energy transformations is US$ 1.3–1.7 trillion, out of which US$ 500–600 billion will be an additional annual investment required. McKinsey (2022) also points out that of the total annual finance requirement of US$ 9.2 trillion from 2021 to 2050, only US$ 0.9 trillion will be additional finance needed. Bhattacharya *et al.* (2022) also provide an estimate of the ACE of US$ 35 trillion for 2020–2030. However, in most cases, it is unclear whether the climate finance estimates represent only additional funds required purely on account of climate change.

Fifth, the baselines considered for arriving at estimates are different or not transparent. Even if some studies estimate ACE requirements based on the BAU scenario, it has not been defined as such. Our approach is outlined in Box 1.

[8] These cumulative estimates cover different numbers of years up to 2030 and 2050. To make them comparable we have given annual averages in each case.

Box 1: Estimating Climate Finance - What is our Approach?

There is no single definition of climate finance, and in many cases, it has been used rather loosely. The UNFCCC defines climate finance as:

"Climate finance aims at reducing emissions and enhancing sinks of greenhouse gases and aims at reducing vulnerability of and maintaining and increasing the resilience of human and ecological systems to negative climate change impacts" (UNFCCC, 2014).

However, despite this definition, often there is confusion as to what really constitutes climate finance. Many climate finance studies refer to the funding of public and private investments needed for mitigation of and adaptation to climate change. In some cases, climate finance has been referred to as the cumulative cost of financing nationally determined commitments (NDCs).

In the recent period, the term climate finance has also been used to track climate flows to developing economies as a part of the commitment of developed economies at Conference of Parties (COP)14 at Copenhagen in 2009, to mobilise US$ 100 billion every year by 2020 (later extended to 2025). These are not estimated requirements for climate finance for EMDEs but are negotiated between developed economies and EMDEs (Songwe *et al.,* 2022). The actual requirements of climate finance for emerging market and developing economies (EMDEs) are much larger than US$ 100 billion a year.

In this study, we are not concerned with how resources are mobilised for climate change, which could include both external and domestic, which in turn, could be private and public. Our approach in this study is to estimate climate finance or additional capital expenditure needed purely for moving to a low-carbon economy over and above the investment required in the BAU scenario, which can be defined as the regular investment planned without considering the impact of climate change.

Lastly, in some studies, it remains unclear whether the estimates are climate-related only or if they also include capex for developmental needs as well (Bhattacharya *et al.,* 2022; Songwe *et al.,* 2022). Estimates including developmental expenditure cannot be compared with those focused only on climate-related expenditure.

It is significant that analysis by some studies relies on estimates of other studies. The estimates in Bhattacharya *et al.* (2022) are based on the analysis by Kharas and McArthur (2019), Bhattacharya *et al.* (2016), and Turner *et al.* (2021). They also build on the work undertaken by Stern (2021) and IEA (2021). The analysis by Songwe *et al.* (2022) builds on the analysis conducted by Bhattacharya *et al.* (2022). McKinsey (2023) estimates are based on the study by Songwe *et al.* (2022). Turner *et al.* (2021) arrived at total climate finance requirement by triangulating various existing estimates by institutions like IEA, Bloomberg New Energy Finance and OECD. Although different studies have used different methodologies and arrived at different estimates, they all point out that climate action will cost trillions of dollars.

3. Four Major Carbon Emitting Sectors: Nine Emerging Economies

The nine economies selected for the study occupy an important position in the global economy. The combined GDP of the nine EMEs was US$ 30 trillion in 2022, constituting 30 per cent of global GDP. They accounted for 47 per cent of the world's population in 2022, and 30 per cent of the global carbon emissions (Table 2). These countries have committed to achieving various climate goals encompassing low-carbon technologies such as renewable energy (RE), increasing carbon sinks and achieving net zero, among others (Appendix 2).

Table 2: Select EMEs and the Global Economy - Key Indicators

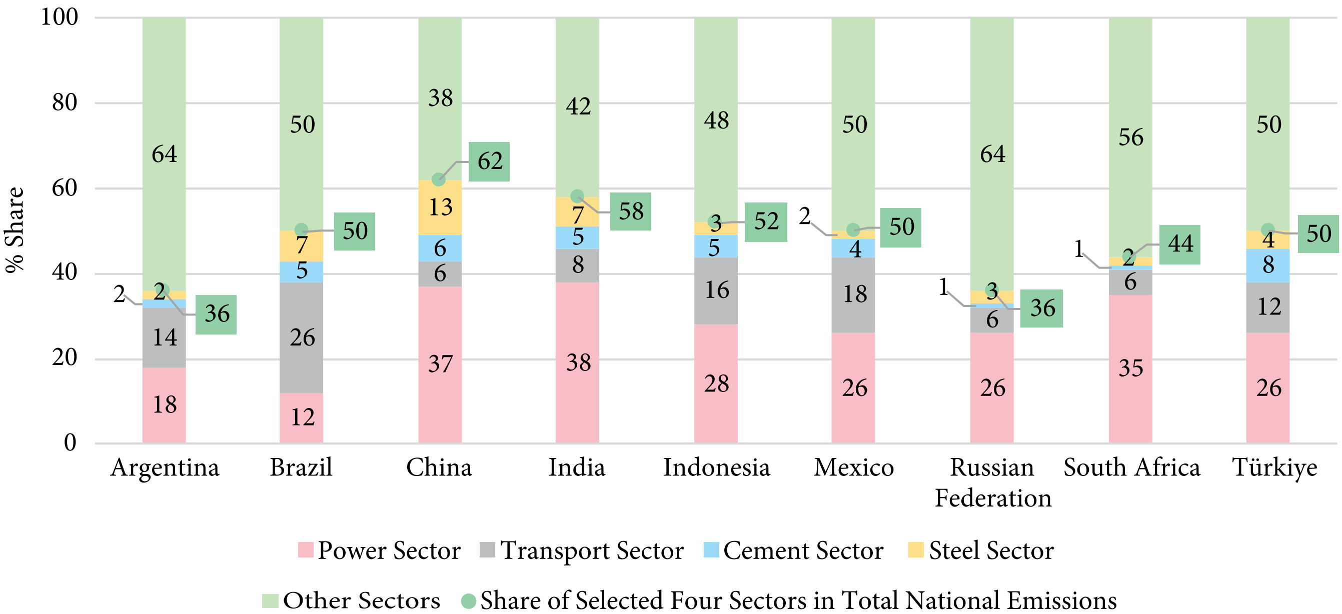
Country	GDP - 2022 (US$ Billion)	Population - 2022 (Million)	Total Carbon Emissions up to 2022 (Billion Tonnes)	Share in Global Carbon Emissions till 2022 (per cent)
Argentina	631	46	9	0.5
Brazil	1,920	215	17	1.0
China	17,960	1,410	261	14.7
India	3,420	1,410	60	3.4
Indonesia	1,320	276	16	1.0
Mexico	1,470	128	21	1.2
The Russian Federation	2,240	144	119	6.7
South Africa	405	60	22	1.2
Türkiye	907	85	12	0.7
Total EMEs (1 to 9)	**30,274 (30)**	**3,773 (47)**	**537 (30)**	**30**
Global	**100,880**	**7,950**	**1,773**	**100**

Note: 1. Figures are based on market exchange rates.

2. Figures in parentheses represent percentage shares in the global total.

Source: World Bank (2024), World Bank (2024a), and Our World in Data (2024).

Figure 1: Share of Carbon Emissions of Select Sectors in Nine EMEs - Up to 2022



Note: For absolute sectoral carbon emissions, refer to Appendix 3.

Source: Authors' calculations based on the data from Climate Watch (2024), Our World in Data (2023), Our World in Data (2023a), and World Steel Association (2024).

The power, transport, steel, and cement sectors selected for the study account for a sizeable portion of global carbon emissions. In the last three decades, carbon emissions from the steel sector in the nine economies constituted 74 per cent of the global steel sector emissions, followed by cement - 53 per cent, power - 44 per cent, transport - 21 per cent (Climate Watch, 2024; World Steel Association, 2024; Our World in Data, 2023, 2023a).

The four sectors were also major emitters of CO_2 in the nine economies, constituting, on average, 49 per cent of the overall national emissions up to 2022 (Figure 1). These four sectors accounted for a combined share of 62 per cent of carbon emissions in China, followed by 58 per cent in India and 50 per cent each in Türkiye and Brazil. In all the nine economies, the power and transport sectors are the highest carbon-emitting sectors, other than China where the steel and power sectors are the largest contributors to CO_2 emissions.

Thus, the four sectors selected for the study hold significant potential for impactful climate mitigation in the nine EMEs. Additionally, these sectors are integral to the infrastructural development and, hence, economic growth of these economies. Prioritising the decarbonisation of these sectors can help in transitioning to low-carbon development and achieving national climate goals effectively.

4. Climate Finance Estimates

4.1 Power and Road Transport Sectors: Methodology for Estimating Climate Finance

Climate finance estimated in this study is essentially the ACE[9] *required for switching over from fossil-fuel-based sources of power to renewables (power sector) and from ICEVs to EVs (road transport sector) due to climate change.* This, in turn, is the difference between (i) total capex planned for these two sectors including the capex required for climate change mitigation; and (ii) capex that would have taken place in the BAU scenario (without the investments needed specifically for climate change mitigation). The capex planned (including that for climate change mitigation) can be estimated based on the official projections of installed capacity (power sector) and vehicle sales (road transport sector),[10] data on which are readily available. However, capex in the BAU scenario has been estimated based on a methodology adopted in Box 2.

Box 2: Business-As-Usual Methodology: Power and Transport Sectors

The methodology used for arriving at capex in the BAU scenario was consistent for the power and transport sectors. For assessing the BAU capex, it was assumed that the total electricity generation (power sector) and number of vehicles (road transport sector) would not be impacted by climate change. That is, the requirement of energy and number of vehicles should not change because of climate change.

To mitigate climate change, what is required is only a change in the mix in favour of non-fossil fuel-based sources (from fossil fuel-based sources) of energy and EVs (from ICEVs). After having assumed no change in the overall energy/vehicle requirements, the challenge then was to assess the changes in the mix between installed capacity of energy sources and sales of types of vehicles (fossil fuel-based to renewables and ICEVs to EVs) in the BAU scenario. Since the focus of the study is to assess climate finance up to 2030, we needed to estimate the change in the mix between 2023 (or latest available year) and 2030. For this, the following steps were followed:

a. Estimation of the CAGR of **total** installed capacity (fossil fuel-based and non-fossil fuel-based) and total sales of vehicles (ICEVs and EVs) for the last 10 years.

b. Estimation of the CAGR of **fossil fuel**-based installed capacity and **ICEV** sales for the last 10 years.

[9] The terms climate finance and additional capital expenditure (ACE) have been used interchangeably in this study.

[10] Since data on capex for vehicles in the road transport sector were not readily available, the per unit sale price has been proxied as per unit capital cost.

c. Estimation of the CAGR of installed capacity of all sources of power and all vehicle sales based on official projections between the latest available data and 2030.

d. Normalisation of the CAGR of installed capacity of fossil fuel-based sources of energy/ICEVs sales of past 10 years with the projected growth up to 2030 to arrive at their BAU CAGR as explained below:

$$CAGR_{BAU_{installed\ capacity\ of\ fossil\ fuels\ /ICEVs\ Sales}} = CAGR_{installed\ capacity\ of\ fossil\ fuels\ /ICEVs\ sales}\ (2012\ to\ 2022) \times \frac{CAGR_{total\ installed\ capacity\ of\ power\ /vehices\ sales}\ (2022\ to\ 2030)}{CAGR_{total\ installed\ capacity\ of\ power\ /vehices\ sales}\ (2012\ to\ 2022)}$$

e. Estimation of installed capacity of fossil fuel-based sources of power/ICEVs sales in 2030 based on the normalized CAGR using the values obtained at step (d).

f. Fossil-fuel installed capacity/ICEVs sales arrived at for 2030 based at step (e) above was deducted from total projected installed capacity of sources of power/total vehicle sales for 2030 to arrive at installed capacity of non-fossil fuel-based power/EV sales for 2030 in the BAU scenario as indicated below:

   BAU installed capacity of non-fossil fuel-based sources/EV sales = Projected total installed capacity of sources of power/total vehicle sales for 2030 – Installed capacity of fossil fuel-based power/ICEV sales in the BAU scenario as arrived step (e).

Table B2.1: An Illustration: Estimation of EV Sales in the BAU Scenario

Vehicle Type	Number of Vehicle Sales - 2012	Number of Vehicles Sales - 2022	Projected Sales of Vehicles - 2030	Past CAGR of Sales Vehicles (2012–2022)	CAGR Based on Projected sales	Projections in the BAU (2022–2030)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
ICEV	179	203	243	0.01	0.02	274
EV	0	12	125	–	–	94
Total	179	215	368	0.02	0.06	368

Source: Authors' representation.

$CAGR_{total\ vehicles}\ (2022\ to\ 2030) = 0.06$

$CAGR_{total\ vehicles}\ (2012\ to\ 2022) = 0.02$

$CAGR_{ICEVs}\ (2012\ to\ 2022) = 0.01$

Apply the above formula,

$$CAGR_{BAU_{ICEVs}} = CAGR_{ICEVs}\ (2012\ to\ 2022) \times \frac{CAGR_{total\ vehicles}\ (2022\ to\ 2030)}{CAGR_{total\ vehicles}\ (2012\ to\ 2022)}$$

$$CAGR_{BAU_{ICEVs}} = 0.01 \times \frac{0.06}{0.02} = 0.038$$

$$ICEV_{2030} = 203 \times (1 + 0.038)^8 = 274$$

$$EV_{2030} = 368 - 274 = 94$$

The above methodology essentially boils down to estimating the growth of fossil fuel-based sources of power and ICEVs in the past 10 years, adjusted for future growth. As expected, this methodology gives consistently higher CAGR for installed capacity of conventional sources of power/sales of ICEVs in the BAU scenario *vis-à-vis* that based on projections (relative to the initial year) and lower CAGR for installed capacity of non-conventional sources/sales of EVs across the nine economies.

Power Sector - Climate Finance Estimates

Apart from the capital cost of power generation, renewable sources of energy (RE) also entail additional capital costs for integration and storage. Integration costs are the cost of integrating RE onto the power system. They entail improved flexibility of thermal generation, coordination between system operators, provision of ancillary services to address uncertainty and variability in renewable sources, transmission/distribution reinforcements, and demand-side flexibility with demand response and time-of-use pricing.

Renewable sources of energy, such as solar and wind, are intermittent and variable, leading to fluctuations in energy production. This variability can impact the stability and reliability of traditional grid systems. As more RE is added to the grid, storage plays an important role in ensuring that the operation of the grid remains stable. Storage also helps in easing grid congestion, and the surplus power generated by renewables can be used at non-solar and non-windy hours.

There are two primary sources of energy storage: battery storage and pumped storage. Battery energy storage systems (BESS) rely on electrochemical processes - most commonly lithium-ion technologies - to provide fast-response, short-duration energy storage suitable for grid stabilisation and ancillary services such as frequency regulation and voltage support (Box 3).

In contrast to battery storage, a pumped storage plant (PSP) utilises gravitational potential energy by transferring water between reservoirs, enabling large-scale and long-duration energy shifting, ideal for managing extended supply-demand imbalances.

PSP is the most mature and widely deployed form of energy storage, providing critical large-scale and long-duration storage that supports RE integration and grid stability. PSP systems work by using surplus electricity, often generated during periods of high solar or wind output, to pump water from a lower to an upper reservoir. During high demand or reduced renewable output, the stored water is released through turbines to generate electricity, effectively acting as a grid-scale energy buffer. With a typical round-trip efficiency of 70–85 per cent and operational lifespans that can exceed 50 years, PSP offers a highly durable and cost-effective solution for balancing seasonal or daily variability in renewable generation.

Box 3: Renewable Sources of Energy - Storage Costs

In 2023, battery storage was the fastest growing technology in the power sector with its deployment more than doubling in a single year. The globally installed battery storage capacity increased from about 1 gigawatt (GW) in 2013 to over 85 GW in 2023. Battery storage is of three types. Currently, Lithium-ion (Li-ion) batteries dominate electricity storage. Over the past 13 years, the cost of these batteries has decreased by approximately 90 per cent from US$ 1,400/kilowatt-hour (kWh) in 2010 to less than US$ 140/kWh in 2023 (IEA, 2024). The falling battery prices have been driven mainly by technological innovations, and to some extent by a fall in raw material costs. New and emerging materials have a further potential to reduce installed costs of Li-ion batteries between 50 per cent and 60 per cent by 2030 (International Renewable Energy Agency [IRENA], 2020).

Large cost reduction potential is also enabled by two other rechargeable storage technologies - vanadium redox flow and zinc bromine flow. Unlike Li-ion batteries, a flow battery system dissolves solid-state charge storage materials in electrolyte solutions and pumps these solutions through the electrodes. When compared to lead-acid and Li-ion batteries, these batteries are currently expensive to manufacture and install. The total costs including installation of the two main flow battery technologies was between US$ 315/kWh and US$ 1,680/kWh in 2016. The total installed cost of flow batteries could decrease by two-thirds by 2030, when the cost is expected to fall to between US$ 108 and US$ 576/kWh (IRENA, 2017). In 2022, the global flow battery market size was valued at US$ 328 million and is anticipated to grow at a CAGR of 22.6 per cent from 2023 to 2030. The market for global energy flow storage batteries is projected to reach over 2,500 GWh by 2030.

As the cost of storage technologies falls further, they will become increasingly competitive. Storage can also support cost reduction by reducing the need for generation and transmission capacity. If countries proceed to double the share of renewables in the world's energy system, then total electricity storage capacity will triple in energy terms by 2030 relative to 2023, as projected by IRENA's Renewable Energy Roadmap scenarios.

The capital cost of a PSP varies significantly across countries due to the complexity of physical geography, labour and material costs, regulatory frameworks, financing mechanisms, and technical characteristics of individual projects. This variation is particularly significant in the context of global energy transitions, where PSP plays a crucial role in facilitating higher shares of variable RE sources such as solar and wind, by providing long-duration, grid-scale energy storage (Box 4).

For estimating climate finance for the power sector, while we have considered battery storage and pumped storage, we have not considered the cost of integration because it would have required assessment of several alternative scenarios which are difficult to envisage at this stage.

Box 4: Pumped Storage Plant Costs - Variations Across Countries

In developing countries such as China and India, capital costs for PSP projects are significantly lower, often ranging from US$ 750 million to US$ 1,400 million per GW of installed capacity and are expected to decline significantly by 2030 or even beyond. The lower capital cost in these countries is attributed to several factors. First, both countries benefit from favourable topographic conditions, including mountainous terrain and natural elevation differentials, which reduce the amount of civil engineering work required. Second, labour and material costs are significantly lower than those in developed economies, which lower the overall construction expenditure. Third, these countries have relatively streamlined regulatory and permitting processes, reducing lead times and administrative overheads (IRENA, 2023; IEA, 2021). In China, for instance, the government has actively promoted the expansion of pumped storage hydropower (PSH), targeting over 120 GW by 2030 (Global Transmission, 2023).

Other emerging economies such as Brazil, Argentina, Indonesia, Mexico, Russia, South Africa, and Türkiye also show considerable potential for PSP deployment, albeit with varying cost structures. For instance, Brazil and Argentina possess abundant hydrological resources and suitable topography, allowing for more cost-effective open-loop systems. However, their PSP development is often constrained by regulatory bottlenecks, insufficient long-term planning, and limited financial incentives, which lead to higher costs. Despite having mountainous terrain, Indonesia and Mexico face logistical challenges and fragmented regulatory environments, which drive up the costs of PSP projects. In Russia, while technical expertise and natural topographic advantages exist, political and economic uncertainties, along with limited market liberalisation, hinder large-scale investment. South Africa and Türkiye have initiated some PSP projects, with costs largely dependent on the scale of government support and integration with national energy strategies (IEA, 2021; World Bank, 2021).

Another significant factor influencing cost variation is the type of PSP system, open-loop or closed-loop. Open-loop systems, which connect to natural water bodies, generally require lower costs when such water sources are available. However, environmental concerns often limit their feasibility in developed countries. Closed-loop systems, which rely on artificial reservoirs, are more flexible in terms of location but typically involve higher construction and operational costs. In many advanced economies, where environmental regulations are stringent and the availability of natural water sources is limited, closed-loop systems have become the preferred option despite their higher costs (IEA, 2021).

Financing mechanisms and risk allocation are other critical elements affecting PSP costs. In developing countries, state-owned enterprises often spearhead PSP development, absorbing significant financial and project execution risks. This centralised approach allows for risk pooling and reduces the cost of capital. In contrast, in liberalised electricity markets such as those in the US and parts of Europe, PSP projects are typically developed by private entities that must secure financing in competitive capital markets. The associated risk premiums result in higher required returns on investment, thereby inflating project costs (IRENA, 2023). Understanding these regional dynamics is essential for policymakers, investors, and developers as they evaluate the potential of PSP in supporting the global clean energy transition.

Power generation from the solar and wind sources has become increasingly competitive, which has fundamentally altered the energy landscape. Over the last decade, these renewable sources of energy have transitioned from expensive propositions to viable mainstream sources of energy. This remarkable transformation has been largely driven by (i) a sharp decline in the prices of solar panels/wind turbines; and (ii) an improvement in project performance of both solar and wind energy, as measured by the capacity factors of solar and wind facilities, driven mainly by technological improvements (Box 5).

Box 5: What Explains a Collapse in Solar and Wind Energy Costs Globally?

A solar panel or photovoltaic (PV) module, is an assembly of PV cells. While individual solar cells produce a limited amount of energy, solar panels contain multiple solar cells made of silicon connected in series and parallel configuration. In the case of wind energy, a wind turbine, *or* wind generator or wind turbine generator is the main device used to convert energy from the wind into electricity. Solar PV and wind turbines are significant components of the overall installation cost for solar plants and wind farms, respectively.

Globally, the total installed cost of solar PV decreased by 83 per cent from US$ 5,124/kW in 2010 to US$ 876/kW in 2022. Likewise, the total installed cost of onshore wind energy declined by 42 per cent from US$ 2,179/kW in 2010 to US$ 1,274/kW by 2022. It is significant that installation costs for setting up solar plants and onshore windmills are now the lowest amongst all the renewable sources of energy (Table B5.1).

Table B5.1: Renewable Energy - Installation Costs, Capacity Factor, and Levelised Cost

Source	Total Installation Costs (US$/kW)			Capacity Factor (per cent)			Global Levelized Cost of Electricity (LCOE)** (US$/kWh)		
	2010	2022	per cent Change	2010	2022	per cent Change	2010	2022	per cent Change
Bioenergy	2,904	2,162	-26	72	72	1	0.082	0.061	-25
Geothermal	2,904	3,478	20	87	85	-2	0.053	0.056	6
Hydropower	1,407	2,881	105	44	46	4	0.042	0.061	47
Solar PV	5,124	876	-83	14	17	23	0.445	0.049	-89
Concentrating Solar Power (CSP)*	10,082	4,274	-58	30	36	19	0.380	0.118	-69
Onshore Wind	2,179	1,274	-42	27	37	35	0.107	0.033	-69
Offshore Wind	5,217	3,461	-34	38	42	10	0.197	0.081	-59

**CSP utilises the sun's energy to produce electricity and process heat. It uses mirrors or lenses to focus sunlight onto a receiver, converting the sunlight into heat. Further, this heat generates electricity by producing steam to drive turbines.*

***LCOE is defined as the average cost of the unit of electricity generated by the system during its lifetime.*

Source: Renewable power generation costs in 2022, International Renewable Energy Agency, 2023.

A sharp global decline in the costs for solar PV and onshore wind was driven mainly by the large capacity additions in both solar PV and onshore wind by China. In 2022, global solar PV manufacturing capacity increased by 80 per cent or almost 200 GW leading to a record-low module prices. China was the largest market for new capacity additions in solar PV, with its share rising from 38 per cent in 2021 to an estimated 45 per cent in 2022. Between 2010 and 2022, the decline of wind turbine prices in China was almost two-thirds leading to cost reduction of onshore wind projects. Wind turbine prices outside of China also fell by 39–55 per cent (IRENA, 2023).

In addition to reduction in costs of solar panels and wind turbines, the capacity factor of solar PV too increased by 23 per cent between 2010 and 2022 and that of onshore wind energy by 35 per cent (Table B5.1). The capacity factor is the ratio of actual electrical energy produced by a generating unit to its maximum potential energy output over a defined period.

In 2014, Brazil was the first country where the weighted average LCOE of new utility-scale (a large-scale solar power plant that uses many solar panels to generate electricity) solar PV fell below the cost of new fossil fuel plant. In 2019, South Africa achieved a LCOE for utility scale solar PV below the weighted average cost of fossil fuel. In 2021, Indonesia and Mexico also achieved this milestone (IRENA, 2023).

Reduction in the prices of solar PV and wind turbines and the improvement in the capacity factors have resulted in a sharp decline in the global LCOE produced from solar and wind sources. The LCOE of solar fell by 89 per cent from US$ 0.4/kWh in 2010 to US$ 0.04/kWh in 2022 and that from onshore wind by 69 per cent from US$ 0.10/kWh to US$ 0.03/kWh.

In 2010, the global weighted-average LCOE of onshore wind was 95 per cent higher than the lowest fossil fuel-based cost. However, in 2022, the global weighted average LCOE of new onshore wind projects was 52 per cent lower than the cheapest fossil fuel-fired projects (IRENA, 2022). An estimated 96 per cent of newly installed solar PV and onshore wind capacity also had lower generation costs than new coal and natural gas plants in 2023.

According to the projections made by IEA for 2028, wind and solar PV systems will continue to become more cost competitive and will provide lower generation costs than coal and natural gas.

To support domestic PV equipment manufacturing, United States, the European Union, Türkiye and India have introduced direct subsidies, tax credits, local content requirements and trade measures.

Argentina: Argentina depends largely on fossil fuel-based sources of energy, which constituted 59 per cent of its total installed capacity in the power sector in 2023. Gas-based power plants are the main source of energy, constituting 57 per cent of the total installed capacity. Of non-fossil fuel-based sources of energy, hydropower constituted 26 per cent of its total installed capacity. Installed capacity of the power sector in Argentina based on official sources is projected to rise from 41 gigawatt (GW) in 2023 to 59 GW in 2030 at a CAGR of 5 per cent; the reliance on gas-fired power plants is projected to reduce to 43 per cent by 2030. Argentina has executed several projects for wind, solar, small hydro and biomass to meet its goal of increasing energy generation from renewable sources. Argentina is laying special emphasis on wind energy as its share in total installed capacity is projected to rise from 7 per cent in 2023 to 23 per cent in 2030, enabled by a sharp decline in the wind energy costs globally (Box 5). The share of hydropower is projected to decline to 22 per cent in total installed capacity in 2030 (Appendix Table A4.1).

The total projected installed capacity for the period 2024–2030 in Argentina, including renewables, is estimated to require a total capex of US$ 30.5 billion. In the BAU scenario, it is estimated that such capex cost would have been US$ 27.2 billion from 2024 to 2030, *thus requiring an additional capex of US$ 3.3 billion, which can be construed as climate finance required to mitigate the impact of climate change in power generation*. While capex for coal-fired plants is estimated to decline by US$ 6.6 billion, capex for non-fossil fuel-based power sources is estimated to increase by US$ 9.9 billion. In addition, the power sector will also require storage cost of US$ 0.5 billion for 2024–2030. Overall, the additional capex requirement or climate finance is estimated at US$ 3.8 billion. On an annual average basis, climate finance works out to US$ 0.5 billion (0.08 per cent of GDP) - Table 3.

Table 3: Argentina - Power Sector

(Installed Capacity in GW; Amount in US$ Billion)

Source	Installed Capacity - 2023 (Actual)	Projected Installed Capacity - 2030	Installed Capacity in BAU Scenario - 2030	Total Electricity Generation (TWh)		Capex Based on Projected Capacity (2024–2030)	Capex Based on BAU Scenario (2024–2030)	ACE: 2024–2030	ACE Storage: 2024–2030	Total ACE: 2024–2030	ACE: 2024–2030	ACE (per cent of GDP)
				Based on Projected Installed Capacity - 2030	Based on BAU Scenario - 2030						Annual Average	
1	2	3	4	5	6	7	8	9 = (7 - 8)	10	11 = (9 + 10)	12	13
Fossil	24	26	32	92	112	2.0	8.6	-6.6	–	-6.6	-0.9	-0.14
Non-Fossil	17	33	28	148	128	28.5	18.6	9.9	0.5	10.4	1.5	0.21
Total	**41**	**59**	**60**	**240**	**240**	**30.5**	**27.2**	**3.3**	0.5	**3.8**	**0.5**	**0.08**

ACE: Additional capital expenditure.

TWh: Terawatt-hours

Notes: 1. The capital cost for battery storage is expected to decrease by 2030. Therefore, the battery storage cost for each year from 2024 to 2030 has been based on the average cost from 2024 and 2030.

2. The capacity (plant load) factor of fossil fuel-based sources of power is much larger than that of non-fossil fuel-based sources (other than nuclear-based sources). Therefore, the installed capacity of fossil fuel-based sources of power in the BAU was adjusted to match the total power generated based on the projected installed capacity for 2030.

3. Projected installed capacity is from official sources.

4. Some totals may not add up due to rounding off of figures.

Source: IRENA, IEA, IHA, Energy Box, and authors' calculations.

Brazil: Unlike many other EMEs, non-fossil fuel sources of energy in Brazil constitute a large share of its total installed capacity (90 per cent in 2023). Hydro power dominates the energy mix with its share of 51 per cent in total installed capacity. In Brazil, installed capacity of the power sector is projected to rise from 218 GW in 2023 to 258 GW in 2030 at a CAGR of 2 per cent, which is lower than the CAGR of 5 per cent in the last nine years (2012–2021). Non-fossil sources of power from 2023–2030 are also projected to grow at a lower rate of 2 per cent as compared with growth of 6 per cent in 2012–2021.

Unlike in the past, when Brazil focused largely on hydropower, it is now expanding wind and solar power capacity. Accordingly, Brazil's reliance on hydro power is projected to reduce from 51 per cent in 2023 to 47 per cent in 2030, while the share of solar energy would increase from 17 per cent in 2023 to 18 per cent in 2030 (Appendix Table A4.2).

The total projected installed capacity between 2024 and 2030 is estimated to require a total capex of US$ 59 billion. In the BAU scenario, capex is estimated at US$ 61 billion, thus resulting in lower capex of US$ 2 billion for power generation for the period 2024–2030. This is for two reasons. First, the slower growth of installed capacity of non-fossil sources in 2023–2030 as compared with 2012–2021 will result in lower capex for the power sector. Second, within non-fossil fuel sources, the focus is now on solar and wind, as alluded to before, the unit capital cost of which is lower than that of hydro in Brazil. Because of this lower capex for power generation, it is projected that Brazil would save US$ 1 billion on storage requirement. Overall, Brazil is estimated to save capex of US$ 0.4 billion annually or 0.02 per cent of GDP for the power sector (Table 4).

Table 4: Brazil - Power Sector

(Installed Capacity in GW; Amount in US$ Billion)

Source	Installed Capacity - 2023 (Actual)	Projected Installed Capacity - 2030	Installed Capacity in BAU Scenario - 2030	Total Electricity Generation (TWh)		Capex Based on Projected Capacity (2024–2030)	Capex Based on BAU Scenario (2024–2030)	ACE: 2024–2030	ACE Storage: 2024–2030	Total ACE: 2024–2030	ACE: 2024–2030	ACE (per cent of GDP)
				Based on Projected Installed Capacity - 2030	Based on BAU Scenario - 2030						Annual Average	
1	2	3	4	5	6	7	8	9 = (7 - 8)	10	11 = (9 + 10)	12	13
Fossil	22	31	26	110	92	5	1	4	–	4	0.6	0.02
Non-Fossil	196	227	232	855	873	54	60	-6	-1	-7	-1	-0.04
Total	**218**	**258**	**258**	**965**	**965**	**59**	**61**	**-2**	**-1**	**-3**	**-0.4**	**-0.02**

ACE: Additional capital expenditure.

TWh: Terawatt-hours

Notes: 1. The capital cost for battery storage is expected to decrease by 2030. Therefore, the battery storage cost for each year from 2024 to 2030 has been based on the average cost from 2024 and 2030.

2. The capacity (plant load) factor of fossil fuel-based sources of power is much larger than that of non-fossil fuel-based sources (other than nuclear-based sources). Therefore, the installed capacity of fossil fuel-based sources of power in the BAU was adjusted to match the total power generated based on the projected installed capacity for 2030.

3. Projected installed capacity is from official sources.

4. Some totals may not add up due to rounding off of figures.

Source: IRENA, IEA, IHA, Energy Box, and authors' calculations.

China: Fossil-based sources of power constituted 45 per cent of China's total installed capacity in 2023. Within fossil-fuel sources, the bulk of power was contributed by coal-based power plants, constituting 41 per cent of its total installed capacity. Of non-fossil-based sources, solar power constituted 22 per cent of its total installed capacity. China's reliance on fossil-based power plants is projected to reduce to 35 per cent in 2030 as it is focusing on a large expansion of onshore wind energy whose share in total installed capacity is projected to rise from 14 to 23 per cent between 2023 and 2030. Off-shore wind energy is projected to increase from 1 to 2 per cent over the same period. The unit capital cost of offshore wind energy is more than twice that of onshore wind energy. The share of hydro power is projected to decline from 14 to 11 per cent in China's total installed capacity between 2023 and 2030 (Appendix Table A4.3).

The projected installed capacity during 2024–2030 is estimated to require total capex of US$ 2,017 billion. China's capex for power generation in the BAU scenario between 2024 and 2030 is estimated at US$ 1,966 billion. China is estimated to save capex of US$ 52 billion on fossil fuel-based power plants. However, it is estimated to require an additional capex of US$ 102 billion on non-fossil fuel-based sources of power for the period 2024–2030. Thus, there will be a need for an additional capital expenditure of US$ 50 billion from 2024 to 2030 for power generation. In addition, storage costs for renewables will require capex of US$ 5 billion. Thus, overall climate finance required for 2024–2030 for China for the power sector is estimated at US$ 55 billion, representing an annual average climate finance of US$ 8 billion or 0.04 per cent of GDP (Table 5).

Table 5: China - Power Sector

(Installed Capacity in GW; Amount in US$ Billion)

Source	Installed Capacity - 2023 (Actual)	Projected Installed Capacity - 2030	Installed Capacity in BAU Scenario - 2030	Total Electricity Generation (TWh)		Capex Based on Projected Capacity (2024–2030)	Capex Based on BAU Scenario (2024–2030)	ACE: 2024–2030	ACE Storage: 2024–2030	Total ACE: 2024–2030	ACE: 2024–2030	ACE (per cent of GDP)
				Based on Projected Installed Capacity - 2030	Based on BAU Scenario - 2030						Annual Average	
1	2	3	4	5	6	7	8	9 = (7 - 8)	10	11 = (9 + 10)	12	13
Fossil	1,272	1,655	1,718	6,969	7,233	331	382	-52	–	-52	-7	-0.03
Non-Fossil	1,562	3,141	3,044	8570	8305	1,686	1,584	102	5	107	15	0.07
Total	**2,834**	**4,796**	**4,762**	**15,539**	**15,539**	**2,017**	**1,966**	**50**	**5**	**55**	**8**	**0.04**

ACE: Additional capital expenditure.

TWh: Terawatt-hours

Notes: 1. The capital cost for battery storage is expected to decrease by 2030. Therefore, the battery storage cost for each year from 2024 to 2030 has been based on the average cost from 2024 and 2030.

2. The capacity (plant load) factor of fossil fuel-based sources of power is much larger than that of non-fossil fuel-based sources (other than nuclear-based sources). Therefore, the installed capacity of fossil fuel-based sources of power in the BAU was adjusted to match the total power generated based on the projected installed capacity for 2030.

3. Projected installed capacity is from official sources.

4. Some totals may not add up due to rounding off of figures.

Source: IRENA, IEA, IHA, Energy Box, and authors' calculations.

Indonesia: Indonesia depends largely on fossil fuel-based sources of power, constituting 85 per cent of its total installed capacity in 2023. Within fossil-fuel sources of power, coal-based power plants constituted 59 per cent of Indonesia's total installed capacity, and gas-based power plants 26 per cent. Of non-fossil fuel-based sources of energy, hydropower constituted 10 per cent of total installed capacity in 2023. Based on the official projections made for 2030, the share of thermal-based power plants will decline to 76 per cent, while that of non-fossil fuel-based sources will rise to 24 per cent. Of the constituents of fossil-based sources, the share of coal-based power plants will reduce to 41 per cent in 2030, while that of gas-based power plants will increase to 35 per cent. Of the constituents of non-fossil fuel-based sources, the share of hydro in total installed capacity is projected to increase from 10 per cent in 2023 to 14 per cent in 2030, while that of solar energy from 1 to 5 per cent. RE development in Indonesia faces roadblocks as electricity pricing regulations still favour fossil fuels (Appendix Table A4.4).

The total installed capacity in Indonesia is projected at 108 GW in 2030. The total capex required for projected installed capacity between 2024 and 2030 is US$ 48.5 billion. In the BAU scenario, capex is estimated at US$ 48.2 billion for the period 2024–2030. Thus, Indonesia is estimated to require only US$ 0.3 billion of additional capex for power generation. Capex for fossil fuel-based plants is expected to decrease by US$ 17.1 billion, while that for non-fossil fuel sources of power is estimated to increase by US$ 17.4 billion. In addition, storage costs for RE will entail a capex of US$ 2.5 billion. Overall, climate finance for 2024–2030 is estimated at US$ 2.8 billion, which translates to US$ 0.4 billion annually or 0.02 per cent of GDP (Table 6).

Table 6: Indonesia - Power Sector

(Installed Capacity in GW; Amount in US$ Billion)

Source	Installed Capacity - 2023 (Actual)	Projected Installed Capacity - 2030	Installed Capacity in BAU Scenario - 2030	Total Electricity Generation (TWh)		Capex Based on Projected Capacity (2024–2030)	Capex Based on BAU Scenario (2024–2030)	ACE: 2024–2030	ACE Storage: 2024–2030	Total ACE: 2024–2030	ACE: 2024–2030	ACE (per cent of GDP)
				Based on Projected Installed Capacity - 2030	Based on BAU Scenario - 2030						Annual Average	
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9 = (7 -8)**	**10**	**11 = (9 + 10)**	**12**	**13**
Fossil	59	82	94	324	371	23.2	40.3	-17.1	–	-17.1	-2	-0.12
Non-Fossil	11	26	17	99	53	25.3	7.9	17.4	2.5	19.9	3	0.14
Total	**70**	**108**	**111**	**424**	**424**	**48.5**	**48.2**	**0.3**	**2.5**	**2.8**	**0.4**	**0.02**

ACE: Additional capital expenditure.

TWh: Terawatt-hours

Notes: 1. The capital cost for battery storage is expected to decrease by 2030. Therefore, the battery storage cost for each year from 2024 to 2030 has been based on the average cost from 2024 and 2030.

2. The capacity (plant load) factor of fossil fuel-based sources of power is much larger than that of non-fossil fuel-based sources (other than nuclear-based sources). Therefore, the installed capacity of fossil fuel-based sources of power in the BAU was adjusted to match the total power generated based on the projected installed capacity for 2030.

3. Projected installed capacity is from official sources.

4. Some totals may not add up due to rounding off of figures.

Source: IRENA, IEA, IHA, Energy Box, and authors' calculations.

Mexico: Non-fossil fuel-based sources constituted 43 per cent of Mexico's total installed capacity in 2023. Mexico initiated several reforms in the 2010s to promote the use of non-fossil fuel-based sources, including the introduction of a carbon tax on fossil fuel emissions in 2014. The Energy Transition Law was enacted in 2015, which emphasised the goal of 35 per cent of clean energy by 2024. Based on official projections, Mexico's reliance on coal-fired power plants will reduce from 8 to 4 per cent between 2023 and 2030, while that of gas-based power plants will decrease from 49 per cent to 39 per cent (Appendix Table A4.5). The share of solar power in total installed capacity of Mexico is projected to rise from 12 per cent in 2023 to 22 per cent in 2030. The unit capex required for producing solar energy in Mexico is 23 per cent lower than that produced by coal-based power plants.

Total installed capacity in the power sector in Mexico is projected to rise from 75 GW in 2023 to 139 GW in 2030, which will require a total capex of US$ 74.5 billion from 2024 to 2030. In the BAU scenario, capex is estimated at US$ 65 billion. Thus, Mexico is estimated to require an additional capex of US$ 9.5 billion for transitioning from fossil fuel-based sources of power to renewables between 2024 and 2030. While capex for fossil-based power plants is estimated to decrease by US$ 6 billion, that for non-fossil fuel-based sources of power would increase by US$ 15.4 billion. The capex for battery and pumped storage requirement of the economy is estimated at US$ 5.5 billion. Overall, Mexico is estimated to require a total capex US$ 15 billion for the period 2024–2030 for the power sector, which works out to US$ 2 billion or 0.09 per cent of GDP annually up to 2030 (Table 7).

Table 7: Mexico - Power Sector

(Installed Capacity in GW; Amount in US$ Billion)

Source	Installed Capacity - 2023 (Actual)	Projected Installed Capacity - 2030	Installed Capacity in BAU Scenario - 2030	Total Electricity Generation (TWh)		Capex Based on Projected Capacity (2024–2030)	Capex Based on BAU Scenario (2024–2030)	ACE: 2024–2030	ACE Storage: 2024–2030	Total ACE: 2024–2030	ACE: 2024–2030	ACE (per cent of GDP)
				Based on Projected Installed Capacity - 2030	Based on BAU Scenario - 2030						Annual Average	
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9 = (7 - 8)**	**10**	**11 = (9 + 10)**	**12**	**13**
Fossil	43	60	68	215	244	11.8	17.7	-6.0	–	-6	-0.9	-0.04
Non-Fossil	32	79	69	230	200	62.7	47.2	15.4	5.5	21	3	0.13
Total	**75**	**139**	**137**	**445**	**445**	**74.5**	**65.0**	**9.5**	**5.5**	**15**	**2**	**0.09**

ACE: Additional capital expenditure.

TWh: Terawatt-hours

Notes: 1. The capital cost for battery storage is expected to decrease by 2030. Therefore, the battery storage cost for each year from 2024 to 2030 has been based on the average cost from 2024 and 2030.

2. The capacity (plant load) factor of fossil fuel-based sources of power is much larger than that of non-fossil fuel-based sources (other than nuclear-based sources). Therefore, the installed capacity of fossil fuel-based sources of power in the BAU was adjusted to match the total power generated based on the projected installed capacity for 2030.

3. Projected installed capacity is from official sources.

4. Some totals may not add up due to rounding off of figures.

Source: IRENA, IEA, IHA, Energy Box, and authors' calculations.

The Russian Federation: Non-fossil fuel-based sources of power in Russia constituted 51 per cent of its total installed capacity in 2023, with hydropower constituting the largest segment with a share of 31 per cent, followed by nuclear power at 16 per cent. Of fossil fuel-based sources of power, the share of gas-based plants in total installed capacity accounted for 28 per cent and that of coal-based 21 per cent. Total installed capacity in the power sector is projected to rise from 179 GW in 2023 to 232 GW in 2030 at a CAGR of 4 per cent. In 2030, nuclear power and gas-based power plants are projected to become the largest sources of energy with a share of 27 per cent each, followed by hydropower at 25 per cent (Appendix Table A4.6). The share of fossil fuel-based sources of energy will decline from 49 per cent in 2023 to 43 per cent in 2030.

The total installed power capacity of the Russian Federation for the period 2024–2030 will require a total capex of US$ 140.1 billion. Capex in the BAU scenario works out to US$ 131.9 billion, thus requiring an additional capex of US$ 8.2 billion from 2024 to 2030. While capex for fossil-based plants is estimated to decline by US$ 25.5 billion, that for non-fossil fuel-based power sources will increase by US$ 33.7 billion. Additionally, Russia will require a capex of US$ 0.6 billion for developing storage capacity. Overall, climate finance is estimated at US$ 8.8 billion. On an annual basis, climate finance requirement for 2024–2030 works out to US$ 1 billion (0.06 per cent of GDP) - Table 8.

Table 8: The Russian Federation - Power Sector

(Installed Capacity in GW; Amount in US$ Billion)

Source	Installed Capacity - 2023 (Actual)	Projected Installed Capacity - 2030	Installed Capacity in BAU Scenario - 2030	Total Electricity Generation (TWh)		Capex Based on Projected Capacity (2024–2030)	Capex Based on BAU Scenario (2024–2030)	ACE: 2024–2030	ACE-Storage: 2024–2030	Total ACE: 2024–2030	ACE: 2024–2030	ACE (per cent of GDP)
				Based on Projected Installed Capacity - 2030	Based on BAU Scenario - 2030						Annual Average	
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9 = (7 - 8)**	**10**	**11 = (9 + 10)**	**12**	**13**
Fossil	88	100	122	374	455	10.3	35.8	-25.5	–	-25.5	-4	-0.18
Non-Fossil	91	132	118	744	664	129.8	96.1	33.7	0.6	34.3	5	0.25
Total	**179**	**232**	**240**	**1,118**	**1,118**	**140.1**	**131.9**	**8.2**	**0.6**	**8.8**	**1**	**0.06**

ACE: Additional capital expenditure.

TWh: Terawatt-hours

Notes: 1. The capital cost for battery storage is expected to decrease by 2030. Therefore, the battery storage cost for each year from 2024 to 2030 has been based on the average cost from 2024 and 2030.

2. The capacity (plant load) factor of fossil fuel-based sources of power is much larger than that of non-fossil fuel-based sources (other than nuclear-based sources). Therefore, the installed capacity of fossil fuel-based sources of power in the BAU was adjusted to match the total power generated based on the projected installed capacity for 2030.

3. Projected installed capacity is from official sources.

4. Some totals may not add up due to rounding off of figures.

Source: IRENA, IEA, IHA, Energy Box, and authors' calculations.

South Africa: Fossil fuel-based sources of power in South Africa constituted 75 per cent of its total installed capacity in 2023. Of non-fossil fuel-based sources, the share of solar power was 11 per cent in its total installed capacity and that of wind energy 5 per cent. Total installed capacity in the power sector is projected to rise from 62 GW in 2023 to 75 GW in 2030. The share of fossil-based power plants is projected to decline to 58 per cent in 2030 and that of non-fossil fuel-based sources is projected to rise to 42 per cent, driven mainly by wind energy whose share will rise sharply from 5 per cent in 2023 to 23 per cent in 2030. Capex required for the power sector in South Africa, based on projected installed capacity, is estimated at US$ 24 billion from 2024 to 2030. However, in the BAU scenario, capex estimated was lower at US$ 20 billion, thus requiring an additional capex of US$ 4 billion for the period 2024–2030. In addition, South Africa is estimated to require US$ 4 billion for storage. The total additional capex for the power sector in South Africa is estimated at US$ 8 billion for the period 2024–2030, which works out to US$ 1 billion annually (0.25 per cent of GDP) - Table 9.

Table 9: South Africa - Power Sector

(Installed Capacity in GW; Amount in US$ Billion)

Source	Installed Capacity - 2023 (Actual)	Projected Installed Capacity - 2030	Installed Capacity in BAU Scenario - 2030	Total Electricity Generation (TWh)		Capex Based on Projected Capacity (2024–2030)	Capex Based on BAU Scenario (2024–2030)	ACE: 2024–2030	ACE Storage: 2024–2030	Total ACE: 2024–2030	ACE: 2024–2030	ACE (per cent of GDP)
				Based on Projected Installed Capacity - 2030	Based on BAU Scenario - 2030						Annual Average	
1	2	3	4	5	6	7	8	9 = (7 - 8)	10	11 = (9 + 10)	12	13
Fossil	47	44	50	158	182	-5	5	-10	–	-10	-1	-0.32
Non-Fossil	16	32	24	103	78	29	15	14	4	18	3	0.57
Total	**62**	**75**	**75**	**261**	**261**	**24**	**20**	**4**	**4**	**8**	1	**0.25**

ACE: Additional capital expenditure.

TWh: Terawatt-hours

Notes: 1. The capital cost for battery storage is expected to decrease by 2030. Therefore, the battery storage cost for each year from 2024 to 2030 has been based on the average cost from 2024 and 2030.

2. The capacity (plant load) factor of fossil fuel-based sources of power is much larger than that of non-fossil fuel-based sources (other than nuclear-based sources). Therefore, the installed capacity of fossil fuel-based sources of power in the BAU was adjusted to match the total power generated based on the projected installed capacity for 2030.

3. Projected installed capacity is from official sources.

4. Some totals may not add up due to rounding off of figures.

Source: IRENA, IEA, IHA, Energy Box, and authors' calculations.

Türkiye: In Türkiye, non-fossil fuel-based sources constituted the largest segment in the power sector in 2023, with their share being 56 per cent in total installed capacity. In Turkiye, installed capacity of the power sector is projected to rise from 102 GW in 2023 to 168 GW in 2030 at a CAGR of 7.5 per cent. The share of renewable sources is projected to rise to 65 per cent in 2030, driven largely by solar and wind energy whose shares are projected to rise to 18 per cent each in 2030 from 11 per cent each in 2023 (Appendix Table A4.8).

The projected installed capacity for power generation between 2024 and 2030 will entail total capex of US$ 86.7 billion in Türkiye. However, the BAU capex is estimated at US$ 86.3 billion, suggesting that transition to renewable sources will require ACE of US$0.4 billion cumulatively for 2024–2030. Capex for fossil fuel-based plants is estimated to reduce by US$ 0.1 billion, but it would increase by US$ 0.5 billion for non-fossil fuel-based sources. The storage capacity will require additional capex of US$ 0.2 billion. Overall, climate finance for Türkiye for 2024–2030 is estimated at US$ 0.6 billion, translating to US$ 0.08 billion annually (0.01 per cent of GDP) - Table 10.

Overall Assessment - Power Sector

All the nine EMEs selected for the study are focusing on RE sources to incrementally substitute for the existing fossil-based sources for power generation. The share of clean energy in the total installed electricity capacity in the nine economies is projected to rise from 54 per cent in 2023 to 65 per cent in 2030. The largest change in the pattern is observed in South Africa, in which the share of renewables will rise from 25 per cent to 42 per cent (Table 11).

Table 10: Türkiye - Power Sector

(Installed Capacity in GW; Amount in US$ Billion)

Source	Installed Capacity - 2023 (Actual)	Projected Installed Capacity - 2030	Installed Capacity in BAU - 2030	Total Electricity Generation (TWh)		Capex Based on Projected Capacity (2024–2030)	Capex Based on BAU Scenario (2024–2030)	ACE: 2024–2030	ACE Storage: 2024–2030	Total ACE: 2024–2030	ACE: 2024–2030	ACE (per cent of GDP)
				Based on projected installed capacity - 2030	Based on BAU Scenario - 2030						Annual Average	
1	2	3	4	5	6	7	8	9 = (7 - 8)	10	11 = (9 + 10)	12	13
Fossil	45	59	59	337	338	6.4	6.5	-0.1	–	-0.1	-0.02	-0.001
Non-Fossil	57	109	109	365	364	80.3	79.8	0.5	0.2	0.7	0.1	0.006
Total	**102**	**168**	**168**	**702**	**702**	**86.7**	**86.3**	**0.4**	**0.2**	**0.6**	**0.08**	**0.01**

ACE: Additional capital expenditure.

TWh: Terawatt-hours

Notes: 1. The capital cost for battery storage is expected to decrease by 2030. Therefore, the battery storage cost for each year from 2024 to 2030 has been based on the average cost from 2024 and 2030.

2. The capacity (plant load) factor of fossil fuel-based sources of power is much larger than that of non-fossil fuel-based sources (other than nuclear-based sources). Therefore, the installed capacity of fossil fuel-based sources of power in the BAU was adjusted to match the total power generated based on the projected installed capacity for 2030.

3. Projected installed capacity is from official sources.

4. Some totals may not add up due to rounding off of figures.

Source: IRENA, IEA, IHA, Energy Box, and authors' calculations.

Table 11: Fossil and Non-Fossil Fuel Sources of Power in Nine EMEs - Changing Pattern

(Installed Capacity in GW)

	Installed Capacity - 2023					Installed Capacity - 2030			
Country	Fossil Fuel	Non-Fossil Fuel	Total	Share of Non-Fossil in Total Installed Capacity (per cent)		Fossil Fuel	Non-Fossil Fuel	Total	Share of Non-Fossil in Total Installed Capacity (per cent)
(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)
1. Argentina	24	17	41	41		26	33	59	57
2. Brazil	22	196	218	90		31	227	258	88
3. China	1,272	1,562	2,834	55		1,655	3,141	4,796	65
4. India*	212	171	383	45		277	476	753	63
5. Indonesia	59	11	70	16		82	26	109	24
6. Mexico	43	32	75	43		60	79	139	57
7. Russia	88	91	179	51		100	132	232	57
8. South Africa	47	16	63	25		44	32	76	42
9. Türkiye	45	57	102	56		59	109	168	65
Total (1 to 9)	**1,812**	**2,153**	**3,965**	**54**		**2,334**	**4,255**	**6,590**	**65**
Total (Excluding China)	**540**	**591**	**1,131**	**52**		**679**	**1,114**	**1,794**	**62**

**Refer to Raj and Mohan (2025) for India's estimates.*

Note: Some totals may not add up due to rounding off of figures.

Source: Authors' calculations.

Climate finance for the nine economies (including India) for power generation for 2024–2030 is estimated at US$ 121 billion. While capex for fossil-based power plants is estimated to decline by US$ 156 billion, that for non-fossil fuel-based power is estimated to increase by US$ 277 billion. Storage (both battery storage and pump storage) for renewables are estimated to entail capex of US$ 28 billion. The overall climate finance needed for 2024–2030 for the nine economies is estimated at US$ 149 billion, which translates to US$ 21 billion annually (Table 12).

Excluding China, it is estimated that the eight other economies would require capex of US$ 71 billion for switching over from fossil fuel-based sources of power to renewables for 2024–2030. However, with the addition of storage costs, cumulative climate finance for 2024–2030 is estimated at US$ 94 billion, which works out to US$ 13 billion annually (Table 12).

At an economy level, 37 per cent of the climate finance requirement estimated for 2024–2030 is on account of China (US$ 55 billion) - Figure 2. Climate finance requirement of India for the power sector is projected to be somewhat more than that of China because the rise in the share of renewables in total installed capacity of India is projected to be more pronounced than that of China. Brazil is projected to save capex in the power sector as the share of renewable sources of energy in the total installed capacity is projected to decline in 2030 relative to 2023.

Table 12: Climate Finance Estimates - Power Sector: Nine Economies

(Installed Capacity in GW; Amount in US$ Billion)

Source	Installed Capacity - 2023 (Actual)	Projected Installed Capacity - 2030	Installed Capacity in BAU - 2030	Capex Based on Projected Installed Capacity 2024–2030	Capex Based on Installed Capacity in BAU 2024–2030	ACE: 2024–2030	ACE: Storage 2024–2030	Total ACE: 2024–2030	ACE: 2024–2030 Annual Average
(1)	(2)	(3)	(4)	(5)	(6)	(7) = (5 – 6)	(8)	(9) = (7 + 8)	(10)
Fossil-Based	1,812	2,334	2,490	423	579	-156	–	-156	-22
Non-Fossil-Based	2,153	4,224	4,000	2,317	2,040	277	28	305	44
Total	**3,965**	**6,558**	**6,490**	**2,740**	**2,619**	**121**	**28**	**149**	**21**
Excluding China									
Fossil-Based	540	679	772	93	197	-104	–	-104	-15
Non-Fossil-Based	591	1,083	956	631	456	175	23	197	28
Total	**1,131**	**1,762**	**1,728**	**724**	**653**	**71**	**23**	**94**	**13**

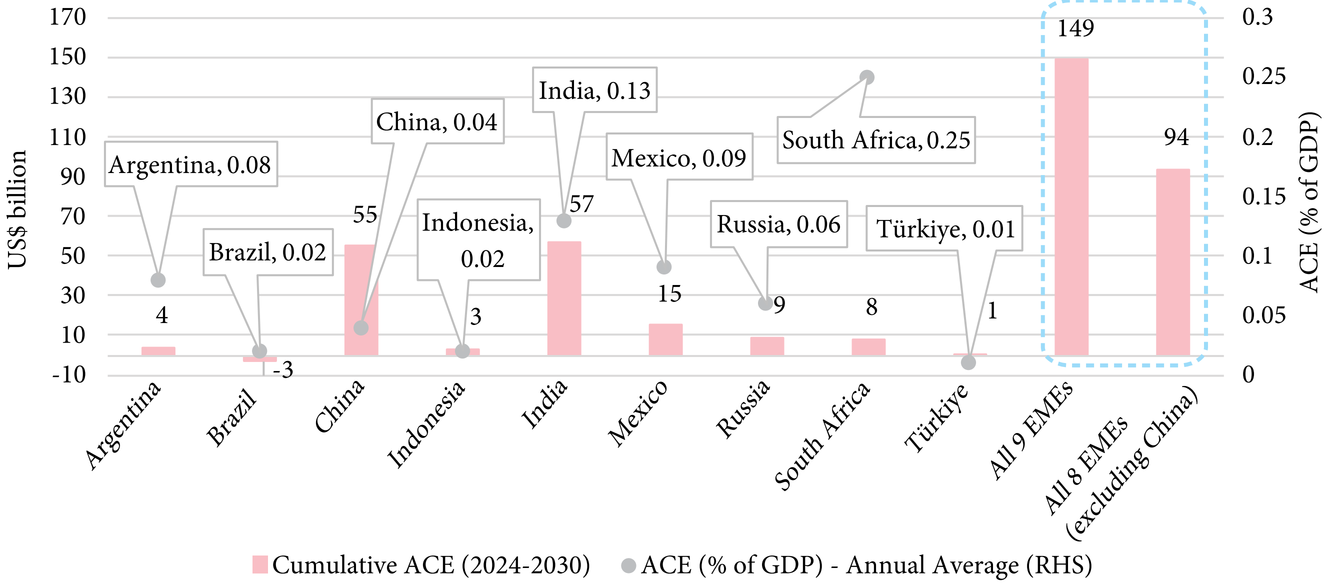
ACE: Additional capital expenditure.

Capex: Capital expenditure.

Note: Totals may not add up due to rounding off of figures.

Source: Authors' calculations.

Figure 2: Climate Finance Estimates - Power Sector: Country-wise (2024-2030)



ACE: Additional capital expenditure.

Note: Refer to Raj and Mohan (2025) for India's estimates.

Source: Authors' representation.

Why Carbon Capture and Storage not Considered for the Power Sector?

The transitioning from fossil fuel-based sources of power to renewables mitigates carbon emissions. However, so long as fossil fuel-based power plants exist, they would continue to emit CO_2. To mitigate such CO_2, the only feasible technology is CCS (Box 8). However, there is hardly any use of CCS for the power sector due to its high cost, "parasitic load" and availability of cost-effective renewable alternatives (Rubin *et al.*, 2012). Integrating CCS into power plants requires large upfront investment for installing carbon capture equipment, transportation arrangements, and storage facilities. For instance, it has been estimated that the CCS for the power sector in India could require capex of US$ 725 billion for installed capacity of 277 GW (Raj and Mohan, 2025). Integrating CCS with power plants also entails an energy penalty. The capturing and compressing of CO_2 is highly energy-intensive, which leads to a "parasitic load" that reduces the net electricity output of power plants. This loss in efficiency increases fuel consumption and may also offset some of the environmental benefits (Rubin *et al.*, 2012). Unlike hard-to-abate steel and cement sectors, cost-effective renewable alternatives such as solar and wind are available in the power sector. In recent years, the cost of non-fossil fuel sources of power in many countries has also nose-dived and is expected to decline even further in the coming years. It, therefore, makes far better sense to expand quickly the use of renewables rather than incur large capex on CCS technology for benefits over a limited number of years while fossil fuel sources of power are phased out. It is important to note that globally only 0.02 per cent of total electricity generated in 2021 was based on power plants with CCS facility (IEA, 2021). The steel and cement sectors have limited decarbonisation options available such as the prospects of achieving energy efficiency and using alternative fuels. While innovations like hydrogen steelmaking and new cement formulations are being explored, they have not yet reached commercial viability at industrial scale. Therefore, CCS remains one of the few feasible options for reducing emissions in the cement and steel sectors (IEA, 2021). For all these reasons and limited uptake of CCS in the power sector, we have not considered CCS capex for the power sector.

Road Transport Sector - Climate Finance Estimates

For the road transport sector, capex is required for transitioning from ICEVs to EVs. In addition, capex is also required to build the charging infrastructure for EVs, the cost of which varies due to a variety of reasons, especially the speed of a charging station (Box 6).

Box 6: Electric Vehicles: Charging Infrastructure

The transition from ICEVs to EVs has necessitated a robust charging infrastructure. The recommended EV-to-charger ratio was 1 charger for 10 EVs in 2021 (IEA, 2022). At the end of 2022, there were 2.7 million public charging points installed worldwide (IEA, 2023). More than 9,00,000 charging points were installed in 2022 alone, of which 6,00,000 were slow-speed public charging points and the remaining were fast-speed direct charge (DC) charging points. More than half of the world's charging points are in China, followed by Europe (IEA, 2023). Of the total public slow-speed charging points installed globally in 2022, 60 per cent were in China. With this, the total stock of slow-speed chargers reached one million in China. Of 3,30,000 fast-speed chargers installed in 2022, about 90 per cent of them were in China (IEA, 2023).

The total cost of setting up a charging station consists of charger cost, installation cost, land, and labour costs, which vary from region to region. The average cost structure of three types of chargers (slow-speed, medium-speed, and fast-speed) and their installation costs vary significantly. The slow-speed chargers are mainly used for charging at residential places. Hence, we have considered the average costs of medium and fast-speed chargers for estimating the capex for charging stations (Table B6.1).

Table B6.1: EV Charging Station - Capital Cost Estimates

Country	Average Cost of a Charging Station* (US$)
Argentina	55,000
Brazil	55,000
China	3,45,127
Indonesia	1,08,284
Mexico	77,500
The Russian Federation	33,789
South Africa	77,500
Türkiye	1,39,050

**Average cost of medium- and fast-speed chargers.*

A major reason for the relatively higher cost of charging stations in China is that it is building mainly high-speed charging stations (DC chargers), the cost of which is about seven times higher than that of slow-speed chargers. The cost of setting up charging infrastructure in Türkiye is also relatively high because of the regulatory requirement that each charging station should contain minimum 50 charges.

The capex for charging infrastructure is arrived at as follows:

$$\text{Charging Infrastructure capex} = \text{Average cost of setting up a charging station} \times \text{Number of charging stations}$$

Charging Infrastructure capex = Average cost of setting up a charging station × Number of charging stations

In this study, we have considered AC level 2 and DC fast charging stations. Data on average cost was collected from different sources for each country.

Argentina: Of the total vehicles sold in Argentina in 2022, 95 per cent (0.8 million units) were ICEVs and 5 per cent EVs. Total vehicle sales are projected to rise to 1.8 million in 2030 at a CAGR of 11 per cent. In the BAU scenario, ICEVs are estimated to grow at a CAGR of 11 per cent between 2022 and 2030, and EVs at 15 per cent. In 2030, the share of EV sales is projected to rise to 11 per cent (0.2 million units) and that of ICEVs to fall to 89 per cent (1.7 million units), while in the BAU scenario, the shares are estimated at 7 per cent and 93 per cent, respectively (Appendix Table A5.1).

From 2023 to 2030, the climate finance requirement for Argentina's road transport is estimated at US$ 4 billion for electrification of its fleet. While capex for

Table 13: Argentina - Road Transport Sector

(Amount in US$ Billion)

Vehicle Type	Vehicles Sold in 2022 ('000)	Projected Sales - 2030 ('000)	BAU Sales - 2030 ('000)	ACE: 2023–2030	Cost of Charging Infrastructure: 2023–2030	Total ACE: 2023–2030	Total ACE	Total ACE (per cent of GDP)
							Annual Average	
(1)	(2)	(3)	(4)	(5)	(6)	(7) = (5 + 6)	(8)	(9)
ICEVs	779	1,676	1,746	-4	–	-4.0	-0.5	-0.07
EVs	45	211	141	8	0.3	8.3	1.0	0.14
Total	**823**	**1,887**	**1,887**	**4**	**0.3**	**4.3**	**0.5**	**0.07**

ACE: Additional capital expenditure.
Note: Some totals may not add up due to rounding off of figures.
Source: Statista and authors' calculations.

ICEVs is estimated to decline by US$ 4 billion, that for EVs is projected to rise by US$ 8 billion. An additional capex of about US$ 0.3 billion is estimated between 2023 and 2030 to develop the charging infrastructure for EVs. Thus, Argentina is estimated to require an overall climate finance of US$ 4.3 billion from 2023 to 2030, which works out to US$ 0.5 billion or 0.07 per cent of GDP on an annual average basis (Table 13).

Brazil: In 2022, EV sales in the road transport sector in Brazil comprised only 5 per cent (0.16 million) of total vehicle sales of 3.3 million. Vehicle sales in Brazil are projected to grow at a CAGR of 5 per cent between 2022 and 2030. While ICEV sales are projected to grow at a CAGR of 3 per cent, EV sales are projected to grow at a CAGR of 20 per cent. However, in the BAU scenario, ICEVs are estimated to have grown at a faster CAGR of 4.5 per cent and EVs at a much lower rate of 6.8 per cent (Appendix Table A5.3).

On a cumulative basis from 2023 to 2030, climate finance for the road transport sector for switching from ICEVs to EVs is estimated at US$ 16 billion. In addition, Brazil would need an additional capex of US$ 3.4 billion for developing the charging infrastructure. Overall, capex for road transport in Brazil is estimated at US$ 19 billion or US$ 2.4 billion annually (0.09 per cent of GDP) - Table 14.

Table 14: Brazil - Road Transport Sector

(Amount in US$ Billion)

Vehicle Type	Vehicles Sold in 2022 ('000)	Projected Sales - 2030 ('000)	BAU Sales - 2030 ('000)	ACE: 2023–2030	Cost of Charging Infrastructure: 2023–2030	Total ACE: 2023–2030	Total ACE	Total ACE (per cent of GDP)
							Annual Average	
(1)	(2)	(3)	(4)	(5)	(6)	(7) = (5 + 6)	(8)	(9)
ICEVs	3,147	4,039	4,477	-26	–	-26	-3.3	-0.12
EVs	162	712	274	42	3.4	45	5.7	0.21
Total	**3,309**	**4,751**	**4,751**	**16**	**3.4**	**19**	**2.4**	**0.09**

ACE: Additional capital expenditure.
Note: Some totals may not add up due to rounding off of figures.
Source: Statista and authors' calculations.

Table 15: China - Road Transport Sector

(Amount in US$ Billion)

Vehicle Type	Vehicles Sold in 2022 ('000)	Projected Sales - 2030 ('000)	BAU Sales - 2030 ('000)	ACE: 2023–2030	Cost of Charging Infrastructure: 2023–2030	Total ACE: 2023–2030	Total ACE	Total ACE (per cent of GDP)
							Annual Average	
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7) = (5 + 6)**	**(8)**	**(9)**
ICEVs	33,230	27,029	31,204	-357	–	-357	-45	-0.19
EVs	51,487	45,278*	41,103	247	446	693	87	0.37
Total	**84,717**	**72,307**	**72,307**	**-110**	**446**	**336**	**42**	**0.18**

ACE: Additional capital expenditure.

**EV sales in 2030 are projected to be lower than those in 2022 due to the projected decline in sales of two-wheelers.*

Note: Some totals may not add up due to rounding off of figures.

Source: Statista and authors' calculations.

China: In China, the largest market of EVs, total EVs sold were 51.5 million units (61 per cent of total vehicles) in 2022, driven by electric two-wheelers (e2Ws). The share of EVs is projected to rise to 63 per cent (45 million units) in 2030, despite a projected decline in overall vehicle sales to 72 million units in 2030 *vis-à-vis* 85 million in 2022, largely due to a decline in the sales of e2Ws. The share of e2Ws is projected to decline to 66 per cent (30 million units) from 87 per cent in 2022, while that of electric cars is expected to increase to 29 per cent (13.3 million units) in 2030 from 11.5 per cent (5.9 million units) in 2022 (Appendix Table A5.5).

Overall, on a cumulative basis from 2023 to 2030, China is estimated to save capex on road transport fleet by US$ 110 billion. This is because ACE for electrification of the road transport fleet will be more than offset by an overall reduction in vehicle sales projected for 2030 *vis-à-vis* 2022. However, the capex for charging infrastructure is estimated at US$ 446 billion. Thus, climate finance for road transport in China is estimated at US$ 336 billion, representing US$ 42 billion annually or 0.18 per cent of GDP (Table 15).

Indonesia: Total vehicles sold in Indonesia were placed at 6.2 million units in 2022, of which 6.1 million were ICEVs (99.2 per cent) and only 48,000 were EVs (0.8 per cent). The sales of all vehicles (ICEVs and EVs) are projected to grow at a CAGR of 6.3 per cent to 10 million units by 2030. Indonesia has a very ambitious goal for electrification of its road transport fleet, with EV sales projected to grow at a rapid CAGR of 68 per cent up to 2030, while ICEV sales are projected to grow only at a modest CAGR of 1.7 per cent. Consequently, the share of EVs in all vehicles is projected at 30 per cent in 2030 and that of ICEVs at 70 per cent. In the BAU scenario, the EVs share is estimated at 1 per cent in 2030 and that of ICEV at 99.0 per cent (Appendix Table A5.7).

In Indonesia, the cumulative capex from 2023 to 2030 is estimated at US$ 34 billion for electrification of its road transport fleet. Alongside this transition, Indonesia would also need to develop the charging infrastructure, the capex for which is estimated at US$ 3.3 billion. Overall, additional capex for road transport for Indonesia is estimated at US$ 38 billion or US$ 5 billion annually (0.24 per cent of GDP) - Table 16.

Table 16: Indonesia - Road Transport Sector

(Amount in US$ Billion)

Vehicle Type	Vehicles Sold in 2022 ('000)	Projected Sales - 2030 ('000)	BAU Sales - 2030 ('000)	ACE: 2023–2030	Cost of Charging Infrastructure: 2023–2030	Total ACE: 2023–2030	Total ACE	Total ACE (per cent of GDP)
							Annual Average	
(1)	(2)	(3)	(4)	(5)	(6)	(7) = (5 + 6)	(8)	(9)
ICEVs	6,121	7,023	9,981	-99	–	-99	-12	-0.61
EVs	48	3,061	104	133	3.3	137	17	0.84
Total	**6,169**	**10,084**	**10,084**	**34**	**3.3**	**38**	**5**	**0.24**

ACE: Additional capital expenditure.

Note: Some totals may not add up due to rounding off of figures.

Source: Statista and authors' calculations.

Mexico: In 2022, total vehicles sold in Mexico were 1.4 million units, of which the share of EVs was just 3 per cent (50,000 units). The share of EVs is projected to increase to 6 per cent (0.17 million units) in 2030 and that of ICEVs to decrease to 94 per cent (2.9 million units). Thus, relative to many other EMEs, the pace of electrification of vehicles in Mexico is rather slow. In the BAU scenario, ICEV sales are estimated to have grown at a CAGR of 9.8 per cent between 2022 and 2030 (as against the projected CAGR of 9.5 per cent) and that of EVs at 11 per cent (compared with a projected CAGR of 17 per cent) - Appendix Table A5.9.

The cumulative additional capex in Mexico from 2023 to 2030 is estimated at US$ 8 billion for switching from ICEVs to EVs. Additionally, Mexico would need a capex of US$ 1.3 billion for building the charging infrastructure for EVs. Overall, capex for road transport for Mexico is estimated at US$ 9 billion or US$ 1.2 billion annually (0.05 per cent of GDP) - Table 17.

The Russian Federation: The Russian Federation is far behind in electrification of its road transport fleet. In 2022, total vehicles sold were 0.79 million, of which the share of electric vehicle sales was just 4.8 per cent (38,000 units). Total vehicle sales are projected to grow at a CAGR of 6.6 per cent to 1.3 million in 2030. The share of EV sales is projected to increase to 14.6 per cent (0.2 million units) in 2030 and that of ICEVs to decline to 85.4 per cent (1.1 million units). In the BAU scenario, ICEV sales are estimated to have grown at a CAGR of 6.8 per cent (as compared with a projected CAGR of 5.2 per cent), while EVs at a CAGR of 1.4 per cent (relative to the projected CAGR of 22.5 per cent) - Appendix Table A5.11.

Table 17: Mexico - Road Transport Sector

(Amount in US$ Billion)

Vehicle Type	Vehicles Sold in 2022 ('000)	Projected Sales - 2030 ('000)	BAU Sales - 2030 ('000)	ACE: 2023–2030	Cost of Charging Infrastructure: 2023–2030	Total ACE: 2023–2030	Total ACE	Total ACE (per cent of GDP)
							Annual Average	
(1)	(2)	(3)	(4)	(5)	(6)	(7) = (5 + 6)	(8)	(9)
ICEVs	1,408	2,921	2,981	-5	–	-5	-0.7	-0.03
EVs	50	177	117	13	1.3	15	1.8	0.08
Total	**1,458**	**3,098**	**3,098**	**8**	**1.3**	**9**	**1.2**	**0.05**

ACE: Additional capital expenditure.

Note: Some totals may not add up due to rounding off of figures.

Source: Statista and authors' calculations.

Table 18: The Russian Federation - Road Transport Sector

(Amount in US$ Billion)

Vehicle Type	Vehicles Sold in 2022 ('000)	Projected Sales - 2030 ('000)	BAU Sales - 2030 ('000)	ACE: 2023–2030	Cost of Charging Infrastructure: 2023–2030	Total ACE: 2023–2030	Total ACE	Total ACE (per cent of GDP)
							Annual Average	
(1)	(2)	(3)	(4)	(5)	(6)	(7) = (5 + 6)	(8)	(9)
ICEVs	756	1,135	1,287	-12	–	-12	-1.5	-0.08
EVs	38	195	43	37	2	39	4.9	0.24
Total	**795**	**1,330**	**1,330**	**25**	**2**	**27**	**3.3**	**0.17**

ACE: Additional capital expenditure.

Note: Some totals may not add up due to rounding off of figures.

Source: Authors' calculations.

The Russian Federation's climate finance requirement for the period 2023–2030 is estimated at US$ 25 billion for transitioning from ICEVs to EVs. Over and above this, the Russian Federation is estimated to need a capex of US$ 2 billion for developing the charging infrastructure. The total climate finance requirement for road transport of the Russian Federation is estimated at US$ 27 billion from 2023 to 2030, translating to US$ 3.3 billion (0.17 per cent of GDP) on an annual average basis (Table 18).

South Africa: In 2022, the share of EVs in total vehicle sold in South Africa was 7.6 per cent (41 thousand units). Total vehicle sales are projected to grow at a CAGR of 2.1 per cent up to 2030; sales of EVs are projected to grow at a CAGR of 8 per cent and that of ICEVs at 1.5 per cent. In the BAU scenario, EVs are estimated to grow at a CAGR of 3.5 per cent, and ICEVs at 2 per cent (Appendix Table A5.13).

From 2023 to 2030, cumulative additional capex to decarbonise road transport fleet in South Africa is estimated at US$ 3 billion. Additionally, South Africa would need US$ 0.2 billion for developing the charging infrastructure. Total climate finance requirement for road transport in South Africa is estimated at US$ 3 billion between 2023 and 2030 or US$ 0.3 billion (0.07 per cent of GDP) annually (Table 19).

Table 19: South Africa - Road Transport Sector

(Amount in US$ Billion)

Vehicle Type	Vehicles Sold in 2022 ('000)	Projected Sales - 2030 ('000)	BAU Sales - 2030 ('000)	ACE: 2023–2030	Cost of Charging Infrastructure: 2023–2030	Total ACE: 2023–2030	Total ACE	Total ACE (per cent of GDP)
							Annual Average	
(1)	(2)	(3)	(4)	(5)	(6)	(7) = (5 + 6)	(8)	(9)
ICEVs	497	563	585	-4	–	-4	-0.5	-0.11
EVs	41	75	54	6	0.2	7	0.8	0.18
Total	**538**	**638**	**638**	**3**	**0.2**	**3**	**0.3**	**0.07**

ACE: Additional capital expenditure.

Note: Some totals may not add up due to rounding off of figures.

Source: Statista and Authors' calculations.

Table 20: Türkiye - Road Transport Sector

(Amount in US$ Billion)

Vehicle Type	Vehicles Sold in 2022 ('000)	Projected Sales - 2030 ('000)	BAU Sales - 2030 ('000)	ACE: 2023–2030	Cost of Charging Infrastructure: 2023–2030	Total ACE: 2023–2030	Total ACE	Total ACE (per cent of GDP)
							Annual Average	
(1)	(2)	(3)	(4)	(5)	(6)	(7) = (5 + 6)	(8)	(9)
ICEVs	727	1,098	1,144	-5	–	-5	-0.6	-0.04
EVs	26	107	61	11	0.5	11.5	1.4	0.09
Total	**753**	**1,205**	**1,205**	**6**	**0.5**	**6.5**	**0.8**	**0.05**

ACE: Additional capital expenditure.

Note: Some totals may not add up due to rounding off of figures.

Source: Statista and authors' calculations.

Türkiye: Of the total vehicles sold in Türkiye in 2022, the share of ICEVs was 96 per cent (0.7 million units), and that of EVs 4 per cent (26,000 units). Total vehicle sales are projected to grow at a CAGR of 6.1 per cent to 1.2 million units up to 2030; ICEV sales are projected to grow at a CAGR of 5.3 per cent and EVs at 19.1 per cent. In the BAU scenario, ICEVs are estimated to have grown at a CAGR of 5.8 per cent and EVs at 11.1 per cent (Appendix Table A5.15).

From 2023 to 2030, the cumulative capex for switching over from ICEVs to EVs is estimated at US$ 6 billion. Apart from this, it is estimated that Türkiye would need an additional capex of US$ 0.5 billion from 2023 to 2030 to develop the charging infrastructure. Total climate finance requirement for Türkiye is estimated at US$ 6.5 billion from 2023 to 2030 or US$ 0.8 billion (0.05 per cent of GDP) annually (Table 20).

Overall Assessment - Road Transport Sector

Economy-wise data suggest that the share of EVs is projected to rise in all the nine economies in 2030 relative to 2022. In China, the share of EVs would rise marginally from 61 per cent in 2022 to 63 per cent in 2030. Though e2W sales are projected to decline sharply, the sales of EVs in all other categories in China are projected to rise significantly. The high cost of e2Ws without subsidies has reduced their demand in China, while affordable small cars now offer a viable alternative. Many urban regions in China have also banned two-wheelers to reduce crime, traffic, and pollution. Environmental concerns are also leading to the phase-out of two-stroke motorcycles, which emit more carbon.

The share of EVs is expected to increase from 1 per cent in 2022 to 30 per cent in 2030 in Indonesia, followed by India from 6 per cent to 34 per cent - the two economies with the largest increases in the share of EVs. Significant changes were also observed in other countries, though not as large as in Indonesia and India. Overall, the share of EVs in the nine EMEs is projected to rise from 44 per cent in 2022 to 47 per cent in 2030. However, excluding China, the share of EVs in the eight other EMEs will rise from 5 per cent in 2022 to 28 per cent in 2030 (Table 21).

Of all EVs sold in nine emerging economies in 2022, about 97 per cent were in China. By 2030, the share of EVs in China will decline to 73 per cent and that of India will rise to 20 per cent (from 2 per cent in 2022). The share of EVs in Indonesia is also set to rise to 5 per cent (from 0.1 per cent in 2022). The share of EVs in most other economies in total EVs sold in the nine economies are projected to remain small, i.e., 1 per cent or lower (Table 21).

Table 21: ICEV and EV Sales in Nine EMEs - Changing Pattern

(Sales in '000)

EME	ICEV Sales		EV Sales		Total Vehicle Sales		Share of EVs (per cent) Country-Wise		Share of EVs in Total Nine Economies (per cent)	
	2022	2030	2022	2030	2022	2030	2022	2030	2022	2030
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1.Argentina	779	1,676	45	211	823	1,887	5	11	0.1	0.3
2. Brazil	3,147	4,039	162	712	3,309	4,751	5	15	0.3	1.1
3. China	33,230	27,029	51,487	45,278	84,717	72,307	61	63	97.0	72.7
4. India*	20,314	24,303	1,200	12,492	21,525	36,794	6	34	2.2	20
5. Indonesia	6,121	7,023	48	3,061	6,169	10,084	1	30	0.1	4.9
6. Mexico	1,408	2,921	50	177	1,458	3,098	3	6	0.1	0.3
7. Russia	756	1,135	38	195	795	1,330	5	15	0.1	0.3
8. South Africa	497	563	41	75	538	638	8	12	0.1	0.1
9. Türkiye	727	1098	26	107	753	1,205	4	9	0.1	0.2
Total (1 to 9)	**66,978**	**69,787**	**53,098**	**62,308**	**120,076**	**132,095**	**44**	**47**	**100.0**	**100.0**
Total (Excluding China)	**33,748**	**42,758**	**1,611**	**17,029**	**35,359**	**59,787**	**5**	**28**	**–**	**–**

**Refer to Raj and Mohan (2025) for details of India's figures.*
Source: Authors' calculations.

All the nine economies combined are estimated to save capex of US$ 5 billion for the road transport sector for 2023–2030 as the additional capex required for transitioning from ICEVs to EVs is more than offset by a decline in vehicle sales (both ICEVs and EVs) in China in 2030 relative to 2022, as alluded to before. Therefore, capex in China for road transport is estimated to decline by US$ 110 billion. Excluding China, climate finance for the eight other economies from 2023 to 2030 due to the switchover from ICEVs to EVs is estimated at US$ 105 billion. However, China is building large charging infrastructure. Including an additional capex for building the charging infrastructure of US$ 465 billion, aggregate capex for the road transport sector for the nine economies is estimated at US$ 459 billion from 2023 to 2030 (Table 22). Excluding China, climate finance for the eight other economies from 2023 to 2030 due to the switchover from ICEVs to EVs and building the charging infrastructure works out to US$ 123 billion or US$ 16 billion annually.

Of all the nine EMEs, China needs the largest amount of climate finance (US$ 336 billion or 0.18 per cent of GDP) for the road transport sector (electrification and for building the charging infrastructure), followed by Indonesia (US$ 38 billion or 0.24 per cent of GDP) and Russia (US$ 27 billion or 0.17 per cent of GDP). India's climate finance requirement for road transport is relatively small at US$ 18 billion (0.05 per cent of GDP) *vis-à-vis* some other countries (such as China, Indonesia, Brazil and the Russian Federation) mainly because electrification of road transport fleet in India involves largely two-wheelers and there is not much difference in the capital cost of electric two-wheelers *vis-à-vis* ICE two-wheelers (Figure 3).

Table 22: Climate Finance Estimates - Road Transport Sector: Nine EMEs

(Sales are in Million; Amount in US$ Billion)

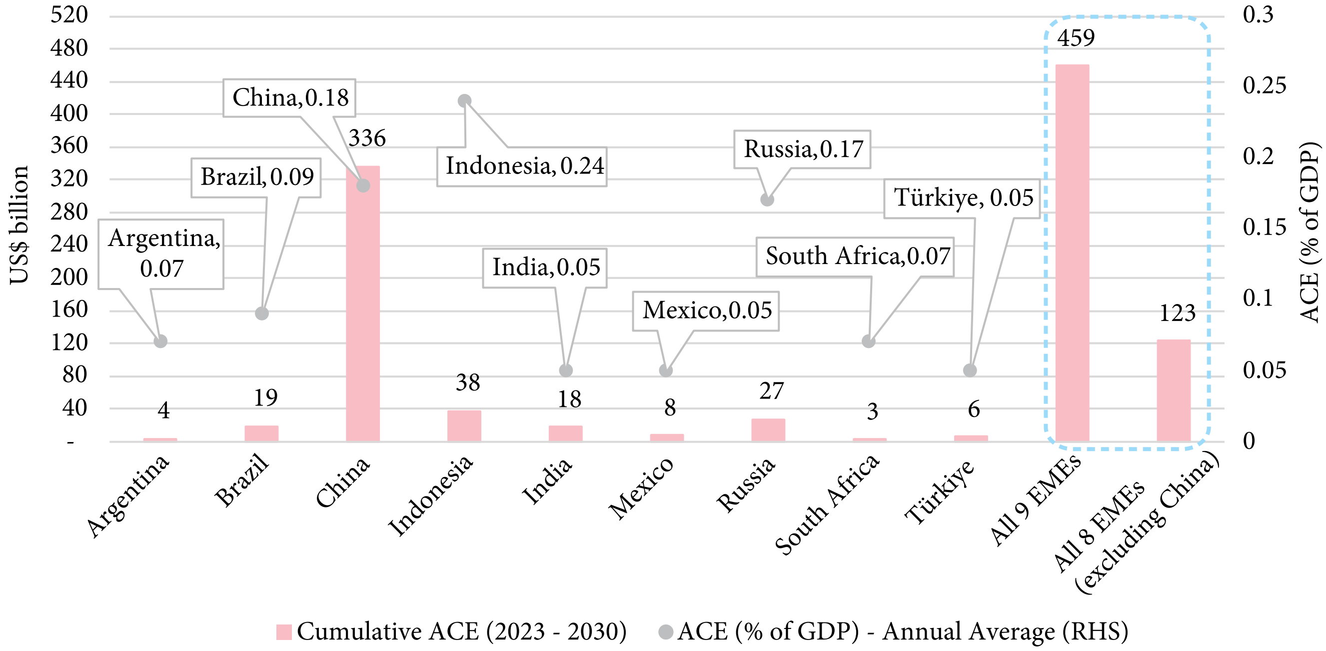
Vehicle Type	Vehicles Sold in 2022	Projected Sales - 2030	BAU Sales - 2030	ACE: 2023–2030	Cost of Charging Infrastructure: 2023–2030	Total ACE: 2023–2030	Total ACE Annual Average
(1)	(2)	(3)	(4)	(5)	(6)	(7) = (5 + 6)	(8)
ICEVs	67	70	79	-543	–	-543	-68
EVs	53	62	53	538	465	1,003	125
Total	**120**	**132**	**132**	**-5**	**465**	**459**	**58**
Excluding China							
ICEVs	34	43	48	-186	–	-186	-23
EVs	2	17	12	291	19	310	39
Total	**35**	**60**	**60**	**105**	**19**	**123**	**16**

ACE: Additional capital expenditure.

Note: Some totals may not add up due to rounding off of figures.

Source: Authors' calculations.

Figure 3: Climate Finance Estimates - Road Transport Sector: Country-wise (2023-2030)



ACE: Additional capital expenditure.

Note: Refer to Raj and Mohan (2025) for details of India's figures.

Source: Authors' representation.

4.2 Steel and Cement Sectors: Methodology for Estimating Climate Finance

Cement and steel are hard-to-abate sectors as their production processes are highly energy and emission-intensive. Therefore, decarbonising the steel and cement industries requires a diverse mix of low-carbon solutions. Deep systemic changes are needed in the way materials are produced, used and recycled.

There are multiple decarbonisation solutions available, which aim at reducing either of the two types of emissions - process emissions and energy emissions. Various decarbonisation options can be classified into five broad categories: (i) energy efficiency; (ii) renewable energy (RE); (iii) alternative fuels; (iv) carbon management; and (v) clinker substitution in the case of cement (Box 7).

Box 7: Different Decarbonising Pathways - Cement Sector

Energy efficiency methods aim at reducing energy consumption (thermal and electrical) of the final output and increasing the waste heat recovered in the manufacturing process of cement (Nitturu *et al.,* 2023). This method reduces emission intensity without requiring significant changes in the process or inputs. As a result, improvements in energy efficiency have resulted in a 60 per cent reduction in the amount of energy required to make one tonne of crude steel since 1960 (World Steel Association, 2021). In addition, energy efficiency also results in a marked reduction in the production cost as energy forms a significant portion of the total cost. However, because of the notable increase in energy efficiency that has already taken place, it is estimated that there is only limited room for additional improvement with current technology.

Switching to alternative fuels includes use of biomass, waste fuel and green hydrogen which have less carbon intensities than the traditional fuels like coal. However, in the cement industry, the reduction potential ranges from only 1–18 per cent and depends on the source of biogenic emissions (Hasanbeigi & Bhadbhade, 2023). Kiln electrification refers to switching to RE sources like solar, wind, hydro or nuclear instead of fossil fuels like coal. It can reduce the emission from the use of captive or grid electricity. It also has the potential to reduce about 40 per cent of the thermal emissions resulting from fossil fuel combustion in cement production (Aggarwal, 2024).

Clinker is a crucial component of cement, but its chemical process is the most energy-intensive, causing 60–65 per cent of cement manufacturing emissions - process emissions (Cembureau, n.d.). Therefore, it is imperative to reduce clinker production by using substitute agents such as steel slag and fly ash to create more blended cement mixes. However, the ability to replace clinker depends heavily on the local availability of substitutes and the desired properties of the final concrete, which are governed by local standards and intended applications (Oki *et al.,* 2021).

Transitioning to alternative energy sources and energy-efficient systems alone is insufficient to mitigate climate change impacts caused by existing level of CO_2 in the atmosphere. Actively removing and storing CO_2 through carbon management: carbon capture, utilisation, and storage (CCUS) technology is essential to achieve significant reductions in carbon emissions of the steel and cement sectors, complementing above mentioned clean energy solutions (Box 8).

Box 8: Carbon Capture, Utilisation and Storage

Conventional methods like energy efficiency and the use of renewables are popular approaches for carbon reduction adopted significantly by many countries. However, they are not sufficient to mitigate the large cumulative carbon emissions in the atmosphere (IEA, 2021a). Furthermore, only energy-related emissions are reduced by energy efficiency measures, but process-related emissions, which make up most emissions in the industrial sector, remain unaffected (Bhardwaj, 2021). If the goal is to achieve carbon neutrality, the use of CCUS at a large scale must be supported by a significant reduction in the production and use of fossil fuels, as well as other decarbonisation measures to address carbon emissions (Lebling *et al.*, 2023).

The IEA defines CCUS as a suite of technologies capable of mitigating CO_2 emissions. It is a three-step process involving capture, transport, and storage or utilisation of CO_2, for which existing emission sources can be retrofitted. CCUS technologies capture CO_2 emissions from large point sources like industrial facilities which are heavily dependent on fossil fuels or biomass for fuel (IEA, 2021b). These technologies separate CO_2 from other gases generated during the production process, capturing the carbon emissions before they enter the atmosphere (Lebling *et al.*, 2023).

After capture, the CO_2 is typically compressed into a liquid state for ease of transport. The transportation stage involves moving the captured CO_2 through underground pipelines, ships, trains or trucks, depending upon the quantity and distance to storage or utilisation sites. Pipelines and ships are the most common mode of transport for large volumes of CO_2 over long distances (IEA, 2021b).

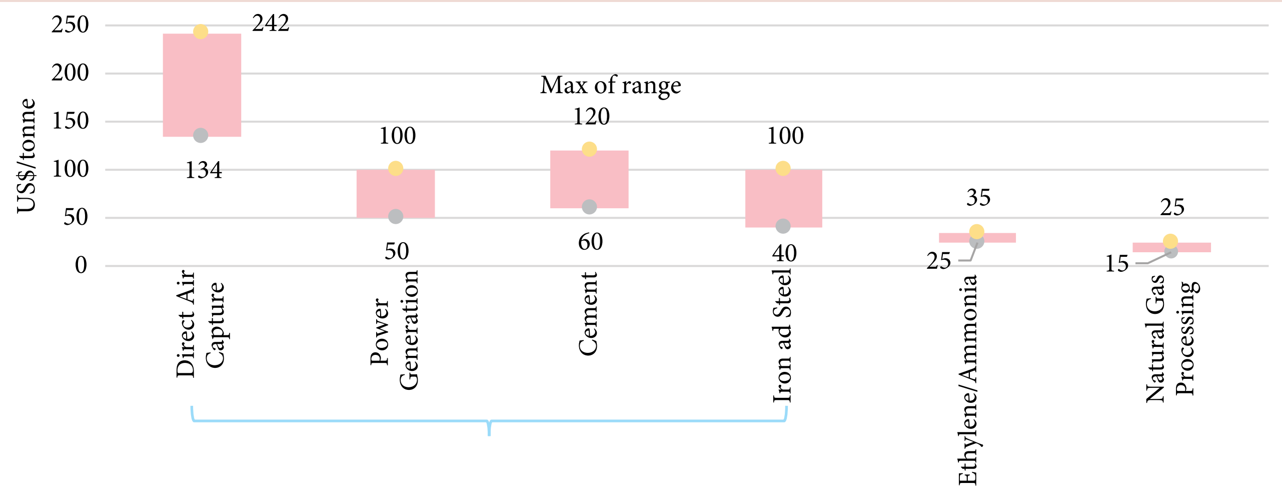
The final stage is either storage or utilisation of the captured CO_2. For storage, the liquefied CO_2 is injected into deep geological formations in either onshore or offshore sites like depleted oil/gas reservoirs or saline aquifers where it is permanently trapped and isolated from the atmosphere. Alternatively, the captured CO_2 can be utilised as an input in a range of products like construction materials and synthetic fuel, turning a potential waste product into a valuable resource. Alternatively, it can be directly used in the process like enhanced oil recovery (EOR). However, utilisation pathways typically have a limited capacity compared to geological storage since they are not expected to reduce emissions to the same extent as permanent geological storage (IEA, 2019). The captured CO_2 can also be directly stored in pressurised tanks or other containment systems on-site, either for later transport or direct utilisation.

CCUS technologies play a vital role in reducing carbon emissions from numerous industries, particularly steel and cement, that are challenging to decarbonise using conventional methods. CCUS is currently the only known feasible technological option for achieving deep emissions cuts in cement and steel production and is also considered one of the most feasible with the current technology (DNV, n.d.; LSE, 2023). Dominant methods of production in both the cement and steel sectors include chemical reactions that inherently emit CO_2, resulting in "process emissions," and fuel combustion at high temperatures, which creates "thermal emissions," making the production process highly carbon intensive. CCUS has the potential to reduce both process and thermal emissions, making it a highly effective decarbonisation solution for industry if scaled (Lebling *et al.*, 2023). IPCC (2022), in its latest report, emphasised that the deployment of carbon dioxide removal (CDR) technologies such as CCUS "counterbalance hard-to-abate residual emissions is unavoidable if net-zero CO_2 or GHG emissions are to be achieved."

CCUS facilities are capital-intensive to deploy and energy-intensive to operate (LSE, 2023). The cost of carbon capture varies significantly depending on the CO_2source. For industrial processes that generate highly concentrated or "pure" CO_2 streams such as ethanol production or natural gas processing, the cost ranges from US$ 15 to US$ 25 per tonne of CO_2. In contrast, processes with "dilute" gas streams, such as cement production and power generation, have higher capture costs, ranging from US$ 40 to US$ 120 per tonne of CO_2 - Figure B8.1 (IEA, 2021a). This cost variation is significant because it affects the economic viability of implementing carbon capture technologies in different industries.

However, experts in many regions regard it as the most cost-effective option to decarbonise industry at scale, even though the cost varies significantly among economies, depending upon geography. The cost of implementing CCUS is expected to decrease, given rapid technological development (LSE, 2023; Evans, 2021). With a capture rate of 90 per cent,[11] CCUS currently captures about 50 million tonnes of CO_2 annually, about 0.1 per cent of the global emissions (Lebling *et al.,* 2023). In 2022, 61 new CCUS facilities were added to the global project pipeline, increasing the overall number of CCUS projects to 30 in operation, 11 under construction, and 153 in development stage (LSE, 2023). However, almost all projects are concentrated in developed economies such as the US, Europe, and Australia. The global capacity for carbon capture in 2030 is anticipated to increase six-fold from today's level to 279 million tonnes of CO_2 captured annually (Bloomberg NEF, 2022). This presents a significant opportunity for developing countries to leverage CCUS technologies and accelerate their decarbonisation efforts in hard-to-abate sectors like cement and steel.

Figure B8.1: Cost of Carbon Capture by Sector and Initial Carbon Concentration



Note: The graph shows the cost range of carbon capture across industries.
Source: IEA.

Direct Air Capture (DAC) technology can also capture existing CO_2 from the atmosphere directly. However, this technology is still in its nascent stage, with only 27 DAC plants currently operational worldwide, capturing just 0.01 million tonnes CO_2/year. Despite its potential, DAC technology remains in the early stages of deployment and requires further development and scaling to enable it to make a significant impact on atmospheric CO_2 levels.

Another decarbonisation option for energy-intensive sectors like steel and cement production is the use of green hydrogen either as an alternative fuel or in carbon management through CCUS. However, both these uses have their own challenges (Box 9).

Although CCS is a relatively costly decarbonisation pathway, its adoption is crucial for addressing the hard-to-abate emissions from sectors like cement and steel, which are essential for economic development and infrastructure. In this study, the focus is on the costs of CCS, not on utilisation. This choice was made because the cost of mitigation with CCUS is significantly higher than CCS today (Nitturu *et al.,* 2023). Additionally, utilisation costs of CO_2 are highly dependent on the specific product or applications, which need to be assessed in advance, thus making it challenging to provide a comprehensive cost estimate. As a result, this study focuses on the more basic and well-documented costs associated with storage.

[11] Capture 90 per cent of the CO_2 present in the flue gas.

Box 9: Green Hydrogen for CO_2 Mitigation and Challenges

Transitioning from traditional fuels like petcoke to hydrogen in cement and steel industries involves significant technical challenges (Nitturu *et al.,* 2023). Both sectors require extensive modifications in their production processes, including changes in metallurgical techniques and combustion technologies, to effectively integrate hydrogen as an alternative fuel source. Alternatively, in carbon management, the CO_2 produced during the production process can be strategically integrated with green hydrogen to generate synthetic fuels through methanation processes, fundamentally utilising the captured CO_2 into various industrial applications. However, there are economic challenges.

For instance, the cost of producing green hydrogen in developing countries such as India ranges from US$ 3.6 to US$ 5.8 per kg at present, but by 2040, it is expected to be US$ 2 per kg (Tirtha *et al.,* 2020). Even with this projected price reduction, the technology would remain relatively unviable for widespread adoption in carbon mitigation strategies, compared to storage technologies. In addition, the development of hydrogen infrastructure is slow, which is holding back its widespread adoption across the globe (IEA, 2019).

The study aims at estimating the capex required during 2022–2030 for mitigating carbon emissions in the steel and cement sectors through CCS technology, while also considering other emission reduction pathways such as energy efficiency, RE, and using alternative fuels. In the case of cement, reduction in clinker factor is also considered. The approach adopted in the report is consistent for both the cement and steel sectors, and across all EMEs included in the study. The methodology for estimating climate finance essentially involved estimating the capex needed to mitigate per unit of CO_2 both through CCS and other pathways (Box 10).

Box 10: Estimating Per Unit Capex for CCS - Methodology

This study aims at estimating the capex required between 2022 and 2030 to reduce carbon emissions in India's steel and cement sectors. The methodology is applied uniformly across both the sectors. Following steps were undertaken to arrive at the required capex:

- The per-unit emission capture and storage (CCS) cost for the cement and steel sectors was taken from different reliable published sources as no single source provided comprehensive cost estimates (Appendix Table A6.1.) For countries where specific cost data were not available, the average global cost was taken (IEA, 2021).
- The CCS costs obtained from various sources did not consistently include transportation and storage components. Where these components were missing, appropriate estimates were added to the CCS costs, using the transportation and storage costs for different countries available from the study by Smith *et al.* (2021).
- The following formula based on a study by Qiao *et al.* (2023) was used to calculate the capex required to mitigate one unit of CO_2 through the CCS pathway:

  Per unit capital cost of CCS =

  $$\frac{(Capture\ Cost\ 2022 + Storage\ Cost\ in\ 2022 + Transport\ Cost\ in\ 2022)}{(CRF + OPEX\%)}$$

  where: capture cost, storage cost and transport cost are the annualised cost per unit of emission; CRF: Capital Recovery Factor; OPEX = 5 per cent of Total Capex.

- The CRF has been arrived at using the following assumptions:
  - Average plant life (for steel and cement): 25 years
  - Interest rate: 10 per cent
  - Operational Expenditure (OPEX): 5 per cent of total capex

CRF which is used to annualise the total capex over the lifetime of a project and taking prevailing interest rate was calculated using the formula $\frac{i(1+i)^n}{(1+i)^n-1}$. This is because CCS costs are often reported on an annual basis, while capex is a one-time investment. The CRF allows us to convert a series of future cash flows (annual costs) into an equivalent present value (initial capex). That is, the CRF is crucial for translating the total annual costs (which includes both capital and operational components) into the initial capex required. The CRF worked out in this study was based on a 25-year plant life and 10 per cent interest rate.

Where:

i = interest rate: 10 per cent

n = number of years (plant life): 25 years

For instance, in the case of Argentina:

$$CRF = \frac{(0.10)(1+0.10)^{25}}{(1+0.10)^{25}-1} = 0.1102 \textit{ or 11 per cent}$$

Thus, for the steel sector:

$$\text{Per unit cost of CCS} = \frac{(70 + 1.19 + 8.44)}{(0.1102 + 0.05)} = \text{US\$ 502 per tonne of } CO_2$$

and for the cement sector:

$$\text{Per unit cost of CCS} = \frac{(90 + 1.19 + 8.44)}{(0.1102 + 0.05)} = \text{US\$ 627 per tonne of } CO_2$$

Table B10.1: CCS Capex per Unit of Emission

(US\$ per tCO_2)

Country	Cement				Steel			
	Annualised							
	Capture Cost	Transport Cost	Storage Cost	CCS Capex	Capture Cost	Transport Cost	Storage Cost	CCS Capex
Argentina	90#	1.94	8.44	627	70#	1.94	8.44	502
Brazil	102**	–	8.44	690	114*	–	–	712
China	71	1.94	8.44	506	74*	–	–	462
India	90#	1.19	6.24	608	70#	1.19	6.24	483
Indonesia	125	–	–	780	76*	–	–	475
Mexico	113	–	–	706	71*	–	–	443
The Russian Federation	80	–	–	499	70#	1.19	6.24	483
South Africa	90#	1.19	6.24	608	70#	1.19	6.24	483
Türkiye	90#	1.19	6.24	608	70#	1.19	6.24	483

#Global average as data on capture cost were not readily available.

**Includes transport and storage costs.*

***Includes transport cost.*

Source: Authors' calculations.

Both the steel and cement sectors have existing capacities that need to be decarbonised. In addition, the incremental capacities that would be added up to 2030 will also have to be decarbonised. Investment requirements would be lower, if only incremental capacity was considered for decarbonisation.

The methodology adopted for assessing capex to reduce carbon emissions through alternative pathways (improving energy efficiency, increasing the use of RE sources, utilising alternative fuels for both the cement and steel sectors, and reducing the clinker factor in cement production) is set out in Box 11.

Box 11: Estimating Capex for Pathways other than CCS - Methodology

- It is estimated that about one-third of carbon emissions in the cement and steel sectors can be removed through alternative pathways (Table B11.1). These estimates are based on a study by Nitturu *et al.* (2023) and Elango *et al.* (2023). The percentage contributions presented in Table 1 were utilised to calculate the emission reductions achievable through each pathway.

Table B11.1: Sources of Reduction of Carbon Emissions

Pathway	Cement (per cent)	Steel (per cent)
Energy Efficiency	9	9
RE	3	19
Alternative Fuels	10	6
Reduction in Clinker Factor	11	–
CCS	67	66

RE - Renewable energy.
Source: Nitturu et al. (2023) and Elango et al. (2023).

- Based on the total capex required for each pathway and the associated emission reduction obtained from the study Nitturu *et al.* (2023) and Elango *et al.* (2023), we compute the capex per unit of emission reduction for each pathway by dividing the total capex by the emission reduction (Table B11.2).

Table B11.2: Capex per Unit of Emission - Other Pathways

Pathway	Cement (US$)	Steel (US$)
Energy Efficiency	147	437
RE	806	239
Alternative fuels	27	1,119
Reduction in clinker factor	227	–

RE - Renewable energy.
Source: Nitturu et al. (2023) and Elango et al. (2023).

- The percentage reduction of emission and the capex per unit of emission of each pathway (except CCS) were assumed to be consistent across all countries and years, in the absence of readily available data for all economies included in the study.

Steel Sector: Climate Finance Estimates

Steel production primarily uses two methods: basic oxygen steelmaking (BOS) and electric arc furnace (EAF). BOS uses molten pig iron,[12] steel scrap, and oxygen to produce steel, whilst EAF mainly relies on recycled steel scrap melted using electric arcs. EAF is considered more environmentally friendly due to its use of recycled materials and lower emissions. However, BOS remains the dominant method globally, accounting for about 70 per cent of steel production as of 2021. This is largely due to existing infrastructure, raw material availability, and suitability for large-scale production in many countries. Nevertheless, EAF is gaining traction with its share increasing from 25 per cent in 2012 to 30 per cent in 2021, producing around 560 million tonnes of steel (Kumar, 2024). This growth reflects a gradual shift towards more sustainable steelmaking processes, driven by environmental concerns and the increasing availability of steel scrap.

[12] Iron ore is first processed in a blast furnace to create a pig iron.

Table 23: Argentina - Steel Sector

Year	Production	Total Emissions	Required Capex: CCS	Required Capex: Other Pathways				Total Required Capex	Total Capex Average (2022–2030)	Total Capex (% of GDP)
				Energy Efficiency	RE	Alternative Fuels	Total			
	Million Tonnes		US$ Billion							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
2022	5	6	2.04	0.242	0.279	0.413	0.934	3.0	–	0.5
2030	5	6	-0.002	-0.0002	-0.0003	-0.0004	-0.001	-0.003	–	*
Cumulative (2022–2030)	**46**	**55**	**2.02**	**0.240**	**0.277**	**0.410**	**0.927**	**2.9**	**0.3**	**0.1**

**Negligible*

RE: Renewable energy.

Capex: Capital expenditure.

Note: Some totals may not add up due to rounding off of figures.

Source: Net-Zero Industry and authors' calculations.

Argentina: Argentina's steel sector, while significant for its economy, is relatively small compared to major global producers. In 2022, its output was only 5 million tonnes, and it is expected to remain at a similar level even in 2030. The continuously falling demand from industry and construction due to the country's economic slowdown has been the primary reason for such low output (MercoPress, 2024). With a carbon emission intensity of 1.2, emissions in 2022 and 2030 remain broadly at 6 million tonnes.

Argentina would require capex of US$ 2.9 billion (US$ 2 billion for CCS and US$ 0.9 billion for other pathways) for 2022–2030 for decarbonising its steel sector. This translates to US$ 0.3 billion (0.1 per cent of GDP) annually (Table 23).

Brazil: Brazil's steel industry is the largest in Latin America and ninth in the world, producing 34 million tonnes in 2022 (2 per cent of global production). The industry's expectations for the Brazilian steel sector are quite pessimistic, with the Brazilian Iron and Steel Association projecting a decline in steel consumption due to poor performance and uncertain recovery in key downstream sectors (Glory Rail, 2023). As a result, no significant increase in production level is expected by 2030 (37 million tonnes compared with 34 million tonnes in 2022).

Approximately 75 per cent of Brazil's crude steel production is through the basic oxygen furnace (BOF) method. However, it only uses 67 per cent of its present carbon-intensive blast furnace-basic oxygen furnace (BF-BOF) steelmaking capacity, which is significantly lower than the global average of approximately 80 per cent (World Economic Forum, 2024). Furthermore, Brazil's steel industry utilises charcoal as an energy source in some of its BF-BOF production rather than coal, and benefits from a substantial share of renewables in the energy mix powering its EAFs (WEF, 2024). Consequently, the country has managed to keep its carbon emission factor at 1.6 in 2022, which is lower than the global average of 1.85.

In line with the trajectory of steel production, the sector's carbon emissions are projected to rise from 54 million tonnes in 2022 to 58 million tonnes in 2030. The steel sector in Brazil is a relatively small driver of national emissions, accounting for only 3 per cent of the country's total emissions.

To mitigate a significant portion of carbon emissions through pathways other than CCS, Brazil's capex is estimated to rise from US$ 8 billion in 2022 to US$ 9 billion by 2030. However, capex for CCS is estimated to be three times higher at US$ 27 billion *vis-à-vis* other pathways. Cumulatively, capex for all the pathways for 2022–2030 is estimated at US$ 36 billion or US$ 4 billion annually (0.2 per cent of GDP) - Table 24.

Table 24: Brazil - Steel Sector

Year	Production	Total Emissions	Required Capex: CCS	Required Capex: Other Pathways				Total Required Capex	Total Capex Average (2022–2030)	Total Capex (% of GDP)
				Energy Efficiency	RE	Alternative Fuels	Total			
	Million Tonnes		US$ Billion							
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**
2022	34	54	26	2.1	2.5	3.7	8	34	–	1.8
2030	37	58	0.2	0.02	0.02	0.03	0.1	0.3	–	0.01
Cumulative (2022–2030)	**318**	**507**	**27**	**2.3**	**3**	**4**	**9**	**36**	**4**	**0.2**

RE: Renewable energy.

Capex: Capital expenditure.

Note: Some totals may not add up due to rounding off of figures.

Source: Net-Zero Industry and authors' calculations.

China: China currently produces over a billion tonnes of steel annually, constituting around 54 per cent of global output. It is attempting to adjust its crude steel production levels to align with its decarbonisation goals and steel demand. The country's steel output decreased by 4.5 per cent from 1,065 million tonnes in 2020 to 1,018 million tonnes in 2022. The Chinese steel industry is a major source of carbon emissions in the country, emitting approximately 1,800 million tonnes of CO_2, which accounts for around 17 per cent of China's total carbon emissions. The steel-making process in the country is dominated by the long process method, which uses coal-based BF–BOFs (Jingna, 2024). This method generates high carbon emissions, thereby contributing to the high carbon emission intensity of the sector (1.8 in 2022).

China's steel production is estimated to decline due to output control by the government, slow progress of infrastructure projects, and a decline in downstream demand and consumption (Shen & Myllyvirta, 2023; Zong *et al.*, 2024) following the slowdown of the economy. By 2030, China's steel production is projected to reduce by 11 per cent to 909 million tonnes. With the same high emission intensity, emissions will also reduce to 1,605 million tonnes of CO_2 in 2030. Given the large size of the sector and high carbon intensity, substantial investment would be needed to deep decarbonise the Chinese steel industry.

Even though China is making efforts to decarbonise its steel industry by introducing new EAFs that contribute to a 30–40 per cent share of the newly announced steel-making capacity since 2022, it is still investing a substantial amount of over US$ 100 billion in coal-based steel plants (CREA, 2024; Shen and Myllyvirta, 2023). This massive investment in traditional carbon-intensive technology seems to be misaligned with China's ambitious "dual carbon goals" of achieving peak carbon emissions by 2030 and carbon neutrality by 2060.

China would need to adopt CCS technology on a large scale to decarbonise its steel sector. The capex is estimated at about US$ 548 billion through CCS in 2022 and US$ 273 billion through other pathways, aggregating total capex of US$ 822 billion in 2022. The capex up to 2030 is estimated at US$ 733 billion consisting of US$ 490 billion through CCS and US$ 244 billion through other pathways. The lower estimated capex in 2030 *vis-à-vis* 2022 is due to the reduced steel production levels. China's capex for the steel sector on an annual basis works out to US$ 81 billion. In relative terms, the total capex required is estimated at 0.5 per cent of its GDP, second only to India (Raj and Mohan, 2025) - Table 25.

Table 25: China - Steel Sector

Year	Production	Total Emissions	Required Capex: CCS	Required Capex: Other Pathways				Total Required Capex	Total Capex Average (2022–2030)	Total Capex (% of GDP)
				Energy Efficiency	RE	Alternative Fuels	Total			
	Million Tonnes		US$ Billion							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
2022	1,018	1,799	548	71	82	121	273	822	–	4.6
2030	909	1,605	-7	-0.9	-1	-1.5	-3.5	-10	–	-0.04
Cumulative (2022–2030)	**8,662**	**15,304**	**490**	**63**	**73**	**108**	**244**	**733**	**81**	**0.5**

RE: Renewable energy.

Capex: Capital expenditure.

Note: Some totals may not add up due to rounding off of figures.

Source: Net-Zero Industry and authors' calculations.

Indonesia: Indonesia is one of the largest steel-producing countries in Southeast Asia. In 2022, Indonesia's crude steel production reached 16 million tonnes, growing at a high CAGR of 15 per cent over the past decade. Continuing this exceptional growth rate, it is projected to grow at a CAGR of 11 per cent to reach production level of approximately 36 million tonnes by 2030. The remarkable growth in Indonesia's steel production can be attributed to substantial investments in the sector responding to the growing demand. Currently, the country's steel consumption significantly exceeds its domestic production, necessitating imports to meet the demand. By increasing investments and production capacities, Indonesia aims at bridging this gap and reducing its dependence on imported steel.

Like most other countries, Indonesia uses conventional technology in the production process, including a blast furnace process that uses coal and coke as fuel (Peterson, 2018). Given the growth rate, emissions are expected to increase by 128 per cent from 12 million tonnes in 2022 to 28 million tonnes in 2030.

The capex for CCS is estimated at US$ 4 billion in 2022 and US$ 2 billion through other pathways, aggregating total capex of US$ 6 billion. To mitigate emissions by using all pathways, the cumulative capex for 2022–2030 is estimated to be US$ 13 billion or US$ 1.5 billion annually (0.1 per cent of GDP) - Table 26. Indonesia's significant low-cost storage potential for CCS is primarily due to its abundant suitable geological formations, particularly depleted oil and gas fields and deep saline aquifers, as well as its extensive offshore sedimentary basins (Agarwal *et al.*, 2023).

Table 26: Indonesia - Steel Sector

Year	Production	Total Emissions	Required Capex: CCS	Required Capex: Other Pathways				Total Required Capex	Total Capex Average (2022–2030)	Total Capex (% of GDP)
				Energy Efficiency	RE	Alternative Fuels	Total			
	Million Tonnes		US$ Billion							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
2022	16	12	4	0.5	0.6	0.8	2	6	–	0.4
2030	36	28	0.9	0.1	0.1	0.2	0.4	1	–	0.05
Cumulative (2022–2030)	**220**	**176**	**9**	**1**	**1**	**2**	**4**	**13**	**1.5**	**0.1**

RE: Renewable energy.

Capex: Capital expenditure.

Note: Some totals may not add up due to rounding off of figures.

Source: Net-Zero Industry and authors' calculations.

Table 27: Mexico - Steel Sector

Year	Production	Total Emissions	Required Capex: CCS	Required Capex: Other Pathways				Total Required Capex	Total Capex Average (2022–2030)	Total Capex (% of GDP)
				Energy Efficiency	RE	Alternative Fuels	Total			
	Million Tonnes		US$ Billion							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
2022	18	15	4	0.6	0.7	1.0	2.3	7	–	0.4
2030	21	17	0.1	0.01	0.01	0.02	0.04	0.1	–	0.005
Cumulative (2022–2030)	**174**	**143**	**5**	**1**	**1**	**1**	**3**	**8**	**0.8**	**0.1**

RE: Renewable energy, Capex: Capital expenditure.
Note: Some totals may not add up due to rounding off of figures.
Source: Net-Zero Industry and authors' calculations.

Mexico: Mexico is the second-largest steel producer in Latin America and ranks 14th among global producers, contributing about 1 per cent to global production. Despite its modest share in global terms, the steel industry is crucial for Mexico's domestic economy, contributing 1.4 per cent to its national GDP and 8.7 per cent to its manufacturing GDP. In 2022, Mexico produced 18 million tonnes of crude steel. Although the production level has remained steady at this level for the past decade, it is expected to increase to 21 million tonnes in 2030, at a CAGR of 2 per cent.

Mexican steel is one of the cleanest in the world as 54 per cent of its production is based on recycling, which generates 38 per cent lower emissions per tonne of steel produced than the global average (Canacero, 2024). Consequently, it has one of the lowest carbon intensities of 0.8, producing about 15 million tonnes of CO_2 in 2022. Carbon emissions are projected to increase to 17 million tonnes in 2030, if the same carbon intensity is maintained.

In recent years, Mexico's steel industry has achieved notable success in energy efficiency and environmental sustainability, establishing the country as a leader in responsible and eco-friendly steel production. However, to further reduce carbon emissions, the country still needs significant capex through different pathways. Capex for the CCS and other pathways is estimated at US$ 8 billion from 2022 to 2030. On an annual average basis, it works out US$ 0.8 billion (0.1 per cent of GDP) - Table 27.

The Russian Federation: The Russian Federation is the 5th largest crude steel producer in the world. In 2022, it produced 72 million tonnes of crude steel, accounting for about 4 per cent of the global output. It is projected to grow at a CAGR of 3.4 per cent annually till 2030 to reach output at 93 million tonnes in 2030. Similar to other large steel producing countries, the Russian Federation is also heavily dependent on the emissions-intensive coal-based BF-BOF steel-making technology. Nearly two-thirds of the Russian Federation's steel industry uses the coal-based BF-BOF steel-making route (Swalec *et al.*, 2024). Consequently, it had a high emission intensity of 1.66 in 2022. Emissions are expected to increase from 119 million tonnes in 2022 to 155 million tonnes in 2030.

Many steel companies have investment plans to build new blast furnaces, refurbish old ones, and associated infrastructure, including new units equipped with CCS projects (Swalec *et al.*, 2024). To decarbonise the sector's emissions, the country's capex is estimated at US$ 56 billion (US$ 38 billion for CCS and US$ 18 billion for other pathways) in 2022. Cumulatively, the country would need a significant capex of US$ 73 billion to decarbonise its steel sector for the period 2022–2030, which works out to be US$ 8 billion or 0.4 per cent of their GDP, annually, on an average (Table 28).

Table 28: The Russian Federation - Steel Sector

Year	Production	Total Emissions	Required Capex: CCS	Required Capex: Other Pathways				Total Required Capex	Total Capex Average (2022–2030)	Total Capex (% of GDP)
				Energy Efficiency	RE	Alternative Fuels	Total			
	Million Tonnes		US$ Billion							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
2022	72	119	38	5	5	8	18	56	–	2.5
2030	93	155	2	0.2	0.2	0.3	0.8	2.4	–	0.1
Cumulative (2022–2030)	**738**	**1,277**	**49**	**6**	**7**	**10**	**24**	**73**	**8**	**0.4**

RE: Renewable energy.

Capex: Capital expenditure.

Note: Some totals may not add up due to rounding off of figures.

Source: Net-Zero Industry and authors' calculations.

South Africa: South Africa is a relatively small player in global steel production, ranking 27th in crude steel output in 2022 with a production of only 4 million tonnes. However, despite its modest size on the global stage, the South African steel industry is of great importance to both the nation and the African continent. The country produces around 60 per cent of its steel through the BF-BOF process, while 40 per cent of the country's steel is produced using EAF technology (South African Iron and Steel Institute, 2023). Consequently, it has a relatively lower carbon emission intensity of 1.06 in 2022. Based on the same emission intensity, carbon emissions are estimated at 6 million tonnes in 2030.

To decarbonise the steel sector, the country is estimated to require cumulative capex of US$ 3 billion for 2022–2030 (US$ 2 billion for CCS and US$ 1 billion for other pathways) or US$ 0.3 billion annually on average (0.1 per cent of GDP) - Table 29.

Türkiye: Türkiye's steel industry is one of its most developed sectors, accounting for 1.9 per cent of global steel production. In 2022, Türkiye produced 35 million tonnes of crude steel, ranking eighth worldwide and the highest in Europe. However, this production level is similar to that of 2012 at 36 million tonnes. Following this pattern, it is expected to grow at a modest pace of 1 per cent CAGR to reach 38 million tonnes by 2030. Unlike most other EMEs, the country produces the most (71.5 per cent) of its crude steel through EAF mill plants, while the global average for the EAF route is 28 per cent (Grigorenko, 2024; Turkish Steel Exporters' Association, n.d).

Table 29: South Africa - Steel Sector

Year	Production	Total Emissions	Required Capex: CCS	Required Capex: Other Pathways				Total Required Capex	Total Capex Average (2022–2030)	Total Capex (% of GDP)
				Energy Efficiency	RE	Alternative fuels	Total			
	Million Tonnes		US$ Billion							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
2022	4	5	1	0.18	0.2	0.3	0.7	2	–	0.5
2030	6	6	0.1	0.01	0.01	0.01	0.03	0.1	–	0.02
Cumulative (2022–2030)	**45**	**48**	**2**	**0.24**	**0.3**	**0.4**	**1**	**3**	**0.3**	**0.1**

RE: Renewable energy.

Capex: Capital expenditure.

Note: Some totals may not add up due to rounding off of figures.

Source: Net-Zero Industry and authors' calculations.

Table 30: Türkiye - Steel Sector

Year	Production	Total Emissions	Required Capex: CCS	Required Capex: Other Pathways				Total Required Capex	Total Capex Average (2022–2030)	Total Capex (% of GDP)
				Energy Efficiency	RE	Alternative Fuels	Total			
	Million Tonnes		US$ Billion							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
2022	35	28	9	1.1	1.3	1.9	4	13	–	1.4
2030	38	30	0.1	0.01	0.01	0.02	0.05	0.2	–	0.01
Cumulative (2022–2030)	**330**	**261**	**10**	**1.2**	**1.4**	**2**	**5**	**14**	**1.6**	**0.2**

RE: Renewable energy.

Capex: Capital expenditure.

Note: Some totals may not add up due to rounding off of figures.

Source: Net-Zero Industry and authors' calculations.

Currently, Türkiye has 3 basic oxygen furnace (BOF) plants, 27 EAF plants, and 11 induction furnace plants. Consequently, at 0.8, it has one of the lowest carbon emission intensities among EMEs. Current emissions of 28 million tonnes are expected to rise to 30 million tonnes in 2030.

Cumulatively, the total capex required to decarbonise the steel sector in Türkiye through all pathways for 2022–2030 is estimated at US$ 14 billion or US$ 1.6 billion (0.2 per cent per cent of GDP) annually on an average. Since Türkiye has already adopted the more environmentally friendly EAF route on a large scale, producing lower carbon emissions, the required capex estimated is relatively lower, despite the significant production level (Table 30).

Overall Assessment - Steel Sector

Steel production in the nine EMEs is expected to increase by 42 million tonnes during 2022–2030, as a result of which carbon emissions are also estimated to increase by about 105 million tonnes. China, India, Russia, and Brazil together constitute 97 per cent of carbon emissions in the steel sector as they all have high carbon emission intensities. China is expected to reduce its steel production in 2030 relative to 2022, resulting in a decrease of approximately 194 million tonnes in carbon emissions. Consequently, the share of China in total carbon emissions of the nine economies in the sector is likely to decline from 77 per cent in 2022 to 66 per cent in 2030 (Table 31).

Carbon emissions in the nine economies, however, are estimated to increase from 2,335 million tonnes in 2022 to 2,440 million tonnes in 2030. This is because steel production in India will almost double from 125 million tonnes in 2022 to 225 million tonnes in 2030, leading to an increase in carbon emissions from 297 million tonnes in 2022 to 533 million tonnes in 2030. India's steel industry has high carbon intensity due to its heavy reliance on coal-based processes. While 54 per cent of crude steel is produced through EAFs, about half of the feedstock for these furnaces is direct reduced iron (DRI), which is highly energy-intensive and produces significant CO_2 emissions. Unlike other major steel-producing countries that primarily use steel scrap in EAFs, India's large and expanding steel production scale, coupled with limited scrap availability, forces it to depend more on DRI. This combination of factors makes India's crude steel production process particularly carbon-intensive compared to other economies (Raj and Mohan, 2025).

Table 31: Production and Carbon Emissions: Steel Sector in Nine EMEs - Changing Pattern

(Million Tonnes)

EME	Carbon Emission Factor#	Production		Carbon Emissions	Share of Carbon Emissions in Total (per cent)	Carbon Emissions	Share of Carbon Emissions in Total (per cent)
		2022	2030	2022		2030	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1. Argentina	1.2	5	5	6	0.3	6	0.2
2. Brazil	1.6	34	37	54	2.4	58	2.4
3. China	1.8	1,018	909	1,799	77.0	1,605	65.8
4. India*	2.4	125	225	297	12.7	533	21.9
5. Indonesia	0.8	16	36	12	0.5	28	1.2
6. Mexico	0.8	18	21	15	0.6	17	0.7
7. Russia	1.7	72	93	119	5.0	155	6.4
8. South Africa	1.1	4	6	5	0.3	6	0.2
9. Türkiye	0.8	35	38	28	1.2	30	1.2
Total (1 to 9)	–	**1,327**	**1,369**	**2,335**	**100.0**	**2,440**	**100.0**
Total (Excluding China)	–	**309**	**460**	**536**	**23.0**	**835**	**34.2**

**Estimates based on a study by Raj and Mohan (2025).*
#Global emissions factor for the steel sector was 1.85.
Source: Net-Zero Industry and authors' calculations.

The total capex required to decarbonise the steel sector in the nine EMEs was estimated at US$ 1,134 billion for 2022–2030 or US$ 126 billion on an annual average basis. However, China alone needs 65 per cent of this estimated capex to decarbonise its steel sector. Excluding China, the other eight economies would need US$ 401 billion to mitigate carbon emissions for 2022–2030 or US$ 45 billion annually (Table 32).

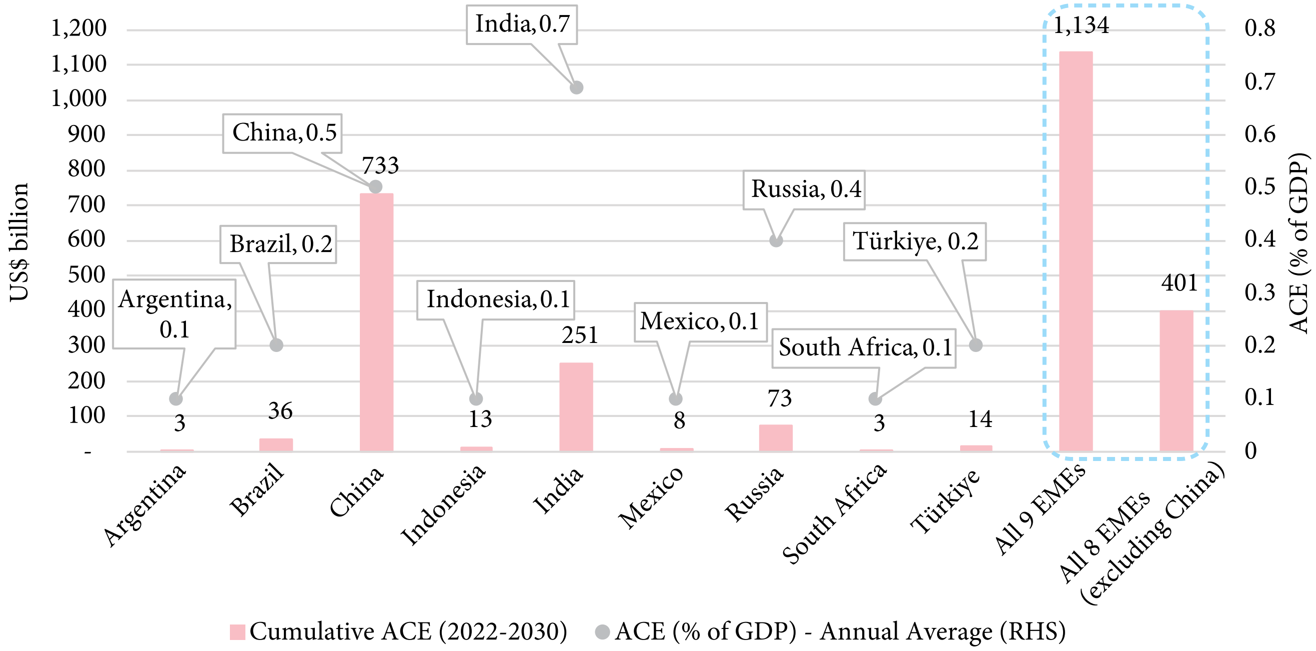
Economy-wise analysis suggests that China has the highest capex requirement for decarbonising the steel sector at US$ 733 billion (annual average of US$ 81 billion or 0.5 per cent of GDP), followed by India at US$ 251 billion (annual average of US$ 28 billion or 0.7 per cent of GDP) - Figure 4.

Table 32: Climate Finance Estimates - Steel Sector: Nine EMEs

	Production	Carbon Emission	CCS Capex	Total Capex	Annual Average: Capex
Year	**Million Tonnes**		**US$ Billion**		
		Emerging Economies			
2022	1,327	2,335	727	1,082	–
2030	1,369	2,440	8	12	–
Cumulative (2022–2030)	**1,369**	**21,363**	**764**	**1,134**	**126**
		Excluding China			
2022	309	536	179	260	–
2030	460	834	15	22	–
Cumulative (2022–2030)	**460**	**6,059**	**274**	**401**	**45**

Capex: Capital expenditure.
Source: Net-Zero Industry and authors' calculations.

Figure 4: Climate Finance Estimates - Steel Sector: Country-Wise (2022-2030)



ACE: Additional capital expenditure.

Note: Refer to Raj and Mohan (2025) for details of India's figures.

Source: Authors' representation.

Cement Sector - Climate Finance Estimates

Cement production primarily uses two methods: the dry process and the wet process. In the dry process, raw materials are ground and mixed in a dry state before being fed into the kiln, while the wet process mixes materials with water to form a slurry. The dry process is significantly more energy-efficient, requiring 56–66 per cent less energy than the wet process. This efficiency translates to lower fuel consumption and reduced CO_2 emissions. Consequently, the dry process has become the dominant method globally, accounting for about 80 per cent of clinker production. Its widespread adoption is driven by energy cost savings, lower environmental impact, and improved production efficiency (Rutkowski *et al.,* 2024). The wet process, while less common, is still used in some regions where raw materials have high moisture content or where older plants haven't been upgraded. However, the trend in the cement industry is clearly moving towards the more efficient and environmentally friendly dry process.

Argentina: Cement production in Argentina, which doubled between 2001 and 2022, is projected to further rise from 12 million tonnes in 2022 to 15 million tonnes in 2030 at a CAGR of 3.5 per cent. Emissions from the cement industry also doubled to 5 million tonnes between 2001–2022. Argentina has a higher carbon emission factor of 0.44 relative to other countries in 2022; consequently, carbon emissions are expected to increase to 7 million tonnes in 2030.

While the government is focused on alternative pathways like RE, CCS remains crucial to mitigate a significant portion of emissions from the cement sector. Capex to decarbonise the cement sector was estimated at US$ 2.5 billion in 2022. The cumulative capex till 2030 is estimated at US$ 3.2 billion or US$ 0.4 billion on an annual average basis (0.1 per cent of Argentina's GDP) - Table 33. Argentina has planned to invest approximately US$ 452 billion by 2040 in infrastructure projects (Jones, 2024), which will lead to an increase in demand and, consequently, the production of cement. As a result, actual carbon emissions of the cement sector, and for that matter even for the steel sector, could increase further.

Table 33: Argentina - Cement Sector

Year	Production	Total Emissions	Required Capex: CCS	Required Capex: Other Pathways					Total Required Capex	Total Capex Average (2022–2030)	Total Capex (% of GDP)
				Energy Efficiency	RE	Alternative Fuels	Clinker Factor Reduction	Total			
	Million Tonnes		US$ Billion								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
2022	12	5	2	0.07	0.12	0.01	0.13	0.3	2.5	–	0.4
2030	15	7	0.1	0.003	0.005	0.001	0.01	0.01	0.1	–	0.01
Cumulative (2022–2030)	**120**	**53**	**3**	**0.09**	**0.16**	**0.02**	**0.17**	**0.4**	**3.2**	**0.4**	**0.1**

RE: Renewable energy.

Capex: Capital expenditure.

Note: Some totals may not add up due to rounding off of figures.

Source: Cembureau, Our World in Data, World Cement Association, and authors' calculations.

Brazil: Brazil is a significant player in the global cement industry, producing around 65 million tonnes of cement in 2022 (1.6 per cent of global cement production). The country's cement production is expected to reach 74 million tonnes in 2030, growing at a CAGR of 1.7 per cent, driven by Brazil's sustainable infrastructure development programme (Da *et al.*, 2023). Despite its sizable cement production, Brazil stood out as one of the countries with the lowest carbon emission intensity (0.36 tonnes of CO_2 per tonne of cement) in 2022. This could be attributed to the country's energy mix, where renewable sources currently account for 74 per cent of the electric power capacity (Da *et al.*, 2023). Capex required to mitigate cement industry emissions through CCS in 2022 was estimated at US$ 11 billion. An additional US$ 1.5 billion was estimated to mitigate the emissions through other pathways. The cumulative capex required for decarbonising Brazil's cement sector is estimated at US$ 14 billion from 2022 to 2030. On average, this works out to US$ 1.6 billion per year or 0.1 per cent of its GDP (Table 34).

China: As the world's largest producer of cement, China's cement production surged by 218 per cent from 661 million tonnes in 2001 to 2,100 million tonnes in 2022, driven by the nation's rapid economic expansion, infrastructure building and urbanisation.

Table 34: Brazil - Cement Sector

Year	Production	Total Emissions	Required Capex: CCS	Required Capex: Other Pathways					Total Required Capex	Total Capex Average (2022–2030)	Total Capex (% of GDP)
				Energy Efficiency	RE	Alternative Fuels	Clinker Factor Reduction	Total			
	Million Tonnes		US$ Billion								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
2022	65	24	11	0.3	0.6	0.06	0.6	1.5	12	–	0.6
2030	74	27	0.2	0.01	0.01	0.001	0.01	0.03	0.2	–	0.01
Cumulative (2022–2030)	**626**	**228**	**12**	**0.4**	**0.7**	**0.07**	**0.7**	**1.8**	**14**	**1.6**	**0.1**

RE: Renewable energy.

Capex: Capital expenditure.

Note: Some totals may not add up due to rounding off of figures.

Source: Cembureau, Our World in Data, World Cement Association, and authors' calculations.

Table 35: China - Cement Sector

Year	Production	Total Emissions	Required Capex: CCS	Required Capex: Other Pathways					Total Required Capex	Total Capex Average (2022–2030)	Total Capex (% of GDP)
				Energy Efficiency	RE	Alternative Fuels	Clinker Factor Reduction	Total			
	Million Tonnes		US$ Billion								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
2022	2,100	763	259	10	18	2	19	50	308	–	1.7
2030	1,475	536	-8.2	-0.3	-0.6	-0.06	-0.6	-1.6	-10	–	-0.04
Cumulative (2022–2030)	**15,944**	**5,796**	**182**	**7**	**13**	**1**	**13**	**35**	**217**	**24**	**0.1**

RE: Renewable energy.

Capex: Capital expenditure.

Note: Some totals may not add up due to rounding off of figures.

Source: Cembureau, Our World in Data, World Cement Association, and authors' calculations.

Production peaked at 2,400 million tonnes in 2016, before moderating by 2022. China's share in the world production of cement is expected to drop from a predominantly large share of 51 per cent in 2022 to 35 per cent in 2030, reflecting a potential slowdown in construction activities or a shift towards more sustainable building materials (World Cement Association, n.d.).

It is also the third-largest emitting sector in the country, after the power and steel industries, contributing a significant share of 13 per cent to the country's total carbon emissions. Carbon emissions from the sector followed the same trajectory as production, peaking at 858 million tonnes in 2020, before gradually decreasing to 763 million tonnes by 2022. With carbon intensity of 0.4, the emissions for 2030 for cement are projected to decline to 536 million tonnes, indicating a continued downward trend, mostly due to reduced production by 30 per cent by 2030.

The total capex to mitigate carbon emissions in China for the cement sector is estimated at US$ 308 billion in 2022. It is the largest capex required for any of the nine emerging market economies in 2022 covered in the study. However, the capex is projected to decrease over the years due to a decline in production and consequently low-carbon emissions. The cumulative capex required by China to mitigate emissions for 2022–2030 is estimated at US$ 217 billion, translating to US$ 24 billion on an annual average basis, or 0.1 per cent of its GDP (Table 35).

It is not known at this stage when the CCS facilities will be set up in China. If CCS plants are installed in 2025, then the capex requirement will be US$ 270 billion and it could possibly stay unchanged thereafter till 2030 even if the production as well as associated carbon emission decline thereafter. However, if CCS plants are set up in any of the subsequent years, capex for CCS will decline due to a decline in production and concomitant lower CO_2 emissions which will require CCS facilities with lower capacity. Since the year of installation of CCS facilities is unknown, the estimates factor in the decline in production and lower carbon emissions up to 2030. Hence the estimate for 2030 is lower *vis-à-vis* 2022.

Indonesia: Indonesia is the largest producer of cement in the Southeast Asia region. In 2022, its production volume was 64 million tonnes, which was the world's eighth largest. Between 2001 and 2022, Indonesia's cement production increased by 106 per cent. After reaching a record high of over 71 million tonnes in 2018, cement production in Indonesia has steadily declined since then. The current production level is similar to that of 2015, with the last four years witnessing stagnant volumes around 64–65 million tonnes (Cembureau, 2022). This decline in production is primarily due to significant overcapacity in the cement industry (Indonesia Investments, 2016). However, cement production is now projected to rise by 98 per cent to reach 126 million tonnes in 2030. Consequently, emissions would also rise to 53 million tonnes in 2030, intensifying the industry's carbon footprint in future.

Table 36: Indonesia - Cement Sector

Year	Production	Total Emissions	Required Capex: CCS	Required Capex: Other Pathways					Total Required Capex	Total Capex Average (2022–2030)	Total Capex (% of GDP)
				Energy Efficiency	RE	Alternative Fuels	Clinker Factor Reduction	Total			
	Million Tonnes		US$ Billion								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
2022	64	27	14	0.4	0.6	0.07	0.7	2	16	–	1.2
2030	126	53	2	0.1	0.1	0.01	0.1	0.3	3	–	0.1
Cumulative (2022–2030)	**829**	**348**	**28**	**0.7**	**1.3**	**0.14**	**1.3**	**3**	**31**	**3.5**	**0.2**

RE: Renewable energy.

Capex: Capital expenditure.

Note: Some totals may not add up due to rounding off of figures.

Source: Cembureau, Our World in Data, World Cement Association, and authors' calculations.

It is estimated that Indonesia would need capex of US$ 16 billion to decarbonise its cement sector capacity till 2022. During 2022–2030, the cumulative capex is estimated to rise to US$ 31 billion, which on average works out US$ 3.5 billion per year or 0.2 per cent of the country's GDP (Table 36).

Mexico: Mexico's cement industry, with an output of 50 million tonnes in 2022, ranks as the 11th largest in the world. The industry is expected to grow at a modest CAGR of 2 per cent between 2022 and 2030, reaching an output of 57 million tonnes in 2030.

Mexico's cement production is characterised by the dominance of fossil fuels in the energy mix. About 87 per cent of the energy consumed is derived from fossil fuel sources, primarily petroleum coke, natural gas, and coal. Consequently, emissions from the cement sector are projected to increase from 22 million tonnes in 2022 to 25 million tonnes in 2030.

To mitigate carbon emissions from the cement sector, the required capex for Mexico is estimated at US$ 12 billion for 2022. Over the period from 2022 to 2030, the cumulative capex required for all decarbonisation pathways is estimated at US$ 13 billion or US$ 1.5 billion per year on average (0.1 per cent of the GDP) - Table 37.

Table 37: Mexico - Cement Sector

Year	Production	Total Emissions	Required Capex: CCS	Required Capex: Other Pathways					Total Required Capex	Total Capex Average (2022–2030)	Total Capex (% of GDP)
				Energy Efficiency	RE	Alternative Fuels	Clinker Factor Reduction	Total			
	Million Tonnes		US$ Billion								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
2022	50	22	10	0.28	0.5	0.06	0.5	1.4	12	–	0.8
2030	57	25	0.2	0.01	0.01	0.001	0.01	0.03	0.2	–	0.01
Cumulative (2022–2030)	**482**	**207**	**12**	**0.32**	**0.6**	**0.07**	**0.6**	**1.6**	**13**	**1.5**	**0.1**

RE: Renewable energy.

Capex: Capital expenditure.

Note: Some totals may not add up due to rounding off of figures.

Source: Cembureau, Our World in Data, World Cement Association, and authors' calculations.

Table 38: The Russian Federation - Cement Sector

Year	Production	Total Emissions	Required Capex: CCS	Required Capex: Other Pathways					Total Required Capex	Total Capex Average (2022–2030)	Total Capex (% of GDP)
				Energy Efficiency	RE	Alternative Fuels	Clinker Factor Reduction	Total			
	Million Tonnes		US$ Billion								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
2022	62	22	8	0.3	0.5	0.06	0.6	1.5	9	–	0.4
2030	84	31	0.4	0.02	0.03	0.003	0.03	0.07	0.5	–	0.02
Cumulative (2022–2030)	**654**	**237**	**10**	**0.4**	**0.7**	**0.08**	**0.8**	**2**	**12**	**1.4**	**0.1**

RE: Renewable energy.

Capex: Capital expenditure.

Note: Some totals may not add up due to rounding off of figures.

Source: Cembureau, Our World in Data, World Cement Association, and authors' calculations.

The Russian Federation: In 2022, the Russian Federation's cement production was 62 million tonnes, a 116 per cent increase from the 2001 level. Cement production is projected to grow to 84 million tonnes by 2030 - an increase of 36 per cent from 2022. A study by Bazhenov *et al.* (2022) suggests that transportation *via* pipelines is the most readily available option for CCS technology in the Russian Federation. This is due to the country's highly developed pipeline infrastructure, which would reduce the costs associated with the transportation stage of CCS implementation. The total estimated capex to decarbonise the cement sector in 2022 was US$ 9 billion, of which US$ 8 billion (89 per cent) was for the CCS pathway. Over the period from 2022 to 2030, the cumulative capex required for the CCS pathway by the Russian Federation is estimated at US$ 10 billion and a total capex of US$ 12 billion, including all other pathways. Thus, on an annual average, it works out to US$ 1.4 billion or 0.1 per cent of GDP (Table 38).

South Africa: Cement production in South Africa increased from 12.5 million tonnes in 2018 to 13.9 million tonnes in 2022. With a carbon intensity of 0.38, the cement sector produced 5 million tonnes of CO_2 emissions. The carbon emissions from the sector have increased by 45 per cent since 2001. The cement sector is expected to grow at a CAGR of 2.1 per cent to reach a production level of 16 million tonnes and carbon emissions of 6 million tonnes in 2030.

The cumulative climate finance required for 2022–2030 to decarbonise the cement sector in South Africa is estimated at US$ 3 billion, which is about US$ 0.3 billion per year or 0.1 per cent of GDP on an annual average basis (Table 39).

Table 39: South Africa - Cement Sector

Year	Production	Total Emissions	Required Capex: CCS	Required Capex: Other Pathways					Total Required Capex	Total Capex Average (2022–2030)	Total Capex (% of GDP)
				Energy Efficiency	RE	Alternative Fuels	Clinker Factor Reduction	Total			
	Million Tonnes		US$ Billion								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
2022	14	5	2	0.07	0.1	0.01	0.1	0.3	2	–	0.6
2030	16	6	0.1	0.002	0.003	0.0003	0.003	0.01	0.1	–	0.01
Cumulative (2022–2030)	**136**	**52**	**3**	**0.08**	**0.2**	**0.02**	**0.2**	**0.4**	**3**	**0.3**	**0.1**

RE: Renewable energy.

Capex: Capital expenditure.

Note: Some totals may not add up due to rounding off of figures.

Source: Cembureau, Our World in Data, World Cement Association, and authors' calculations.

Türkiye: Türkiye's cement sector grew remarkably in the last two decades, securing its place as the largest producer in Europe. The nation's cement output increased by 154 per cent from 30 million tonnes in 2001 to an all-time high of about 85 million tonnes in 2022. There is no expected increase in the country's cement production capacity in the upcoming years after 2023.

The Turkish cement sector has performed well as the CO_2 emissions level in 2022 remained similar to 2016 at 38 million tonnes, despite a 13 per cent increase in output (by about 10 million tonnes).

Considering the current production of cement in the country, the capex to mitigate the emissions for Türkiye was estimated at US$ 18 billion in 2022. The cumulative capex required to mitigate the emissions for the period 2022–2030 is estimated slightly lower at US$ 17.9 billion or US$ 2 billion per year on average (0.2 per cent of GDP) - Table 40. However, the country is facing high energy cost and inflation rate, which could impact the estimated capex requirements going forward.

Table 40: Türkiye - Cement Sector

Year	Production	Total Emissions	Required Capex: CCS	Required Capex: Other Pathways					Total Required Capex	Total Capex Average (2022–2030)	Total Capex (% of GDP)
				Energy Efficiency	RE	Alternative Fuels	Clinker Factor Reduction	Total			
	Million Tonnes		US$ Billion								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
2022	85	38	16	0.505	0.925	0.102	1.0	2.49	18.1	–	2.0
2030	84	38	-0.02	-0.001	-0.001	-0.0001	-0.001	-0.003	-0.02	–	-0.001
Cumulative (2022–2030)	**762**	**343**	**15**	**0.501**	**0.917**	**0.101**	**0.9**	**2.47**	**17.9**	**2**	**0.2**

RE: Renewable energy.

Capex: Capital expenditure.

Note: Some totals may not add up due to rounding off of figures.

Source: Cembureau, Our World in Data, World Cement Association, and authors' calculations.

Overall Assessment - Cement Sector

Total cement production in the nine economies is set to decline significantly by 214 million tonnes (7.6 per cent) between 2022 and 2030, mainly due to a decline in cement production in China (by 30 per cent), which will result in an overall reduction of 49 million tonnes of carbon emissions from the sector. China and India are the two largest contributors to the sector's emissions, accounting for 87 per cent of nine EMEs' cement-related emissions due to their large production volumes and high carbon emission intensities. Notably, a significant shift is occurring in the distribution of these emissions. China's share of global cement-related carbon emissions is projected to decrease from 71 per cent in 2022 to 52 per cent in 2030, while that of India is expected to double during the same period from 15 per cent to 29 per cent (Table 41).

The capex required to decarbonise the cement sector across the nine EMEs is estimated at US$ 458 billion in 2022. The cumulative capex required to mitigate CO_2 from the cement sector across the nine EMEs from 2022 to 2030 is estimated somewhat lower at US$ 453 billion or US$ 50 billion on an annual average basis. This decline could be attributed to a significant reduction in China's share of cement production, even as production increases in other economies. Excluding China, capex for the cement sector is estimated at US$ 149 billion till 2022 and US$ 236 billion for 2022–2030 or US$ 26 billion annually on an average basis (Table 42).

Table 41: Production and Carbon Emissions: Cement Sector in Nine EMEs - Changing Pattern

(Million Tonnes)

EME	Carbon Emission Factor#	Production		Carbon Emissions	Share in Total (per cent)	Carbon Emissions	Share in Total (per cent)
		2022	2030	2022		2030	
1. Argentina	0.44	12	15	5	0.5	7	0.7
2. Brazil	0.36	65	74	24	2.2	27	2.6
3. China	0.36	2,100	1,475	763	71.2	536	52.4
4. India*	0.44	370	674	164	15.3	300	29.4
5. Indonesia	0.42	64	126	27	2.5	53	5.2
6. Mexico	0.43	50	57	22	2.1	25	2.4
7. Russia	0.36	62	84	22	2.1	31	3.0
8. South Africa	0.38	14	16	5	0.5	6	0.6
9. Türkiye	0.45	85	84	38	3.6	38	3.7
Total (1 to 9)	–	**2,822**	**2,608**	**1,071**	**100.0**	**1,022**	**100.0**
Total (Excluding China)	–	**722**	**1,133**	**308**	**28.8**	**486**	**47.6**

**Estimates based on a study by Raj and Mohan, 2024.*

#Global emissions factor in the cement sector was 0.68.

Source: Cembureau, Our World in Data, World Cement Association and authors' calculations.

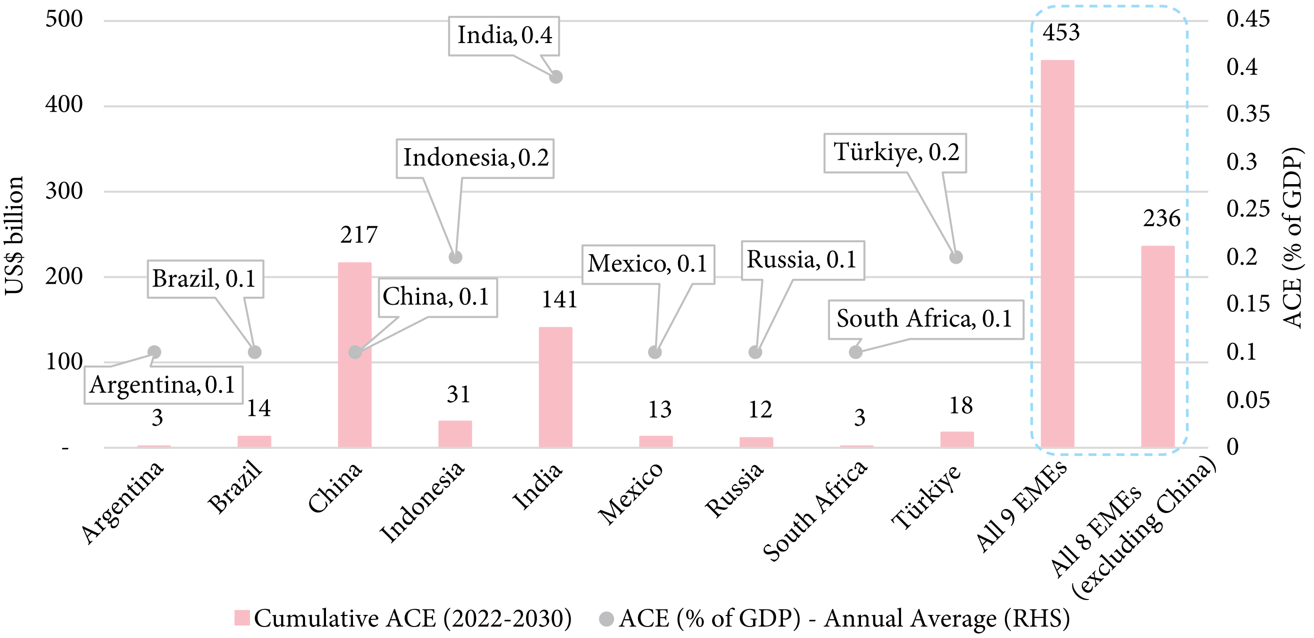
Table 42: Climate Finance Estimates - Cement Sector: Nine EMEs

Year	Production	Carbon Emission	CCS Capex	Total Capex	Annual Average: Capex
	Million Tonnes		US$ Billion		
Emerging Economies					
2022	2,822	1,071	388	458	–
2030	2,608	1,022	4	4	–
Cumulative (2022–2030)	**2,608**	**9,272**	**387**	**453**	**50**
Excluding China					
2022	722	307	129	149	–
2030	1,066	486	12	14	–
Cumulative (2022–2030)	**1,133**	**3,501**	**205**	**236**	**26**

Source: Cembureau, Our World in Data, World Cement Association, and authors' calculations.

As in the steel sector, climate finance requirement for the cement sector is the largest by China at US$ 217 billion (annual average US$ 24 billion or 0.1 per cent of GDP), followed by India at US$ 141 billion (US$ 16 billion or 0.4 per cent of GDP) - Figure 5.

Figure 5: Climate Finance Estimates - Cement Sector: Country-Wise (2022-2030)



ACE: Additional capital expenditure.

Note: Refer to Raj and Mohan (2025) for details of India's figures.

Source: Authors' representation.

5. Overall Estimates

Climate finance requirements for the nine economies are estimated at US$ 2.2 trillion for the four sectors (power, transport, steel, and cement) from 2022 to 2030.[13] This translates to an annual climate finance requirement of US$ 255 billion or 0.6 per cent of GDP. Steel and cement are hard-to-abate sectors, and their decarbonisation requires the use of CCS, which is expensive to deploy, but the only effective technology option at present. These two sectors account for 72 per cent (steel – 51 per cent and cement – 21 per cent). of climate finance requirement of all the four sectors in the nine economies. Climate finance for the steel sector is estimated at US$ 1.2 trillion. The cement sector's needs, on the other hand, are estimated at US$ 453 billion - about 40 per cent of the steel sector. This is mainly due to a significantly lower carbon intensity of cement relative to steel even as projected cement production is almost twice that of steel and the unit cost of CCS for cement is also somewhat higher than that of steel.

Climate finance for the road transport sector is estimated at US$ 459 billion. It is significant to note that the climate finance required for road transport is largely for developing the charging infrastructure, the cost of which varies widely depending on the speed of the charging instrument. The nine economies are estimated to save US$ 5 billion capex for road transport during 2023–2030, entirely because of a projected decline in vehicle sales (both ICEVs and EVs) in China in 2030 relative to 2022. Excluding China, climate finance for electrification of vehicle fleet has been estimated at US$ 105 billion for the eight other economies. The cost of developing charging infrastructure in the nine economies is estimated at US$ 460 billion, of which China alone accounts for US$ 446 billion (97 per cent). This is because China is mainly developing the high-speed charging infrastructure, the cost of developing which is seven times more than that of the slow-speed charging infrastructure.

Lastly, of all the four sectors, contrary to all other estimates, the power sector is estimated to require the least amount of additional capital investment of US$ 149 billion because the low-carbon alternatives in this sector are now well advanced and in commercial phases, thus making it cheaper to decarbonise the power sector. This is even though the capacity (plant load) factor of renewables is far lower (almost one-third) than that of fossil fuel-based power plants and also that the renewables require additional costs of storage (pumped storage and battery storage).[14] The power sector has often been singled out for requiring large climate finance requirements. *However, this common narrative is clearly disapproved by the findings of this study.*

At the economy level, total climate finance for the four sectors in China is estimated at US$ 1.3 trillion (US$ 155 billion annually or 0.7 per cent of GDP), which constitutes 61 per cent of total climate finance estimated of all the nine economies. More than half of China's climate finance requirement is estimated for the steel sector (US$ 733 billion), followed by road transport (US$ 336 billion), cement (US$ 217 billion) and power (US$ 55 billion).

Of all the nine economies, China is on a different footing because of (i) its sheer size in that the next largest economy (India) is one-fifth of the Chinese economy at present; and (ii) some idiosyncratic factors such as (a) the focus on developing high-speed charging infrastructure for EVs, unlike other EMEs which are developing slow/medium-speed chargers; and (b) slowdown in steel and cement production and vehicle sales in China going forward, while they are projected to rise in other EMEs.

Excluding China, climate finance required for the four sectors for the eight other economies is estimated at US$ 854 billion, which works out to US$ 100 billion annually (0.5 per cent of GDP).

Climate finance required by India is estimated at US$ 467 billion (US$ 54 billion per year or 1.3 per cent of GDP), of which US$ 251 billion is on account of climate related capex for the steel sector and US$ 141 billion for the cement sector (Raj and Mohan, 2025). Climate finance estimated for road transport for India is small at US$ 18 billion. India is estimated to require climate finance of US$ 57 billion for the power sector transition.

The Russian Federation is another economy whose climate finance requirement estimated at US$121 billion (US$14 billion annually or 0.7 per cent of

[13] The period covered is 2022–2030 for the steel and cement sectors, 2024–2030 for the power sector, and 2023–2030 for road transport.
[14] The renewable sources of energy also entail integration costs. However, they have not been considered in the study.

GDP) is relatively large, next only to China and India, mainly because it is also a major producer of steel. Overall, excluding the three large economies (China, India and the Russian Federation), climate finance requirement for the six other economies is estimated at US$ 265 billion for 2022–2030 or US$ 31 billion per year (in the range of 0.3–0.6 per cent of GDP) - Table 43. It is significant that investment needs for climate action across 24 countries covered under the CCDR by the World Bank averaged 1.4 per cent of GDP in 2030, but large differences were found across country income classes.

Table 43: Total Climate Finance: All Sectors and Nine EMEs

(US$ Billion)

Country	Power	Transport	Steel	Cement	Total Capex	Total Capex (2022–2030)#	Total Capex as per cent of GDP (2022–2030)
	2024–2030	**2023–2030**	**2022–2030**	**2022–2030**	**2022–2030**	**Annual Average#**	
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
1. China	55	336	733	217	1,341	155	0.7
2. India*	57	18	251	141	467	54	1.3
3. The Russian Federation	9	27	73	12	121	14	0.7
4. Brazil	-3	19	36	14	67	8	0.3
5. Indonesia	3	38	13	31	85	10	0.6
6. Türkiye	0.6	6	14	18	39	4	0.3
7. Mexico	15	8	8	13	44	5	0.3
8. Argentina	4	4	3	3	14	2	0.3
9. South Africa	8	3	3	3	17	2	0.5
Total (1 to 9)	**149 (6.8)**	**459 (20.9)**	**1,134 (51.7)**	**453 (20.6)**	**2,195**	**255**	**0.6**
Total (Excluding China)	**94 (11.0)**	**123 (14.4)**	**401 (47.0)**	**236 (27.6)**	**854**	**100**	**0.5**

**Refer to Raj and Mohan (2025) for details of India's figures.*

Capex: Capital expenditure

#Values are based on the years 2022–2030 for the cement and steel sectors, 2023 to 2030 for the road transport sector and 2024–2030 for the power sector.

Note: Figures in parentheses represent the percentage shares in total climate finance requirement.

Source: Authors' calculations.

Based on the estimated capital investments for climate action, it is expected that the nine economies included in this study will be able to mitigate 33 billion tonnes of CO_2 in the power, steel, and cement sectors combined[15] (Table 44). Most of the emission mitigation potential is in the steel sector (65 per cent), followed by cement (28 per cent), and power (7 per cent).

[15] CO_2 emissions for the road transport sector could not be estimated in the absence of readily available data.

Table 44: Carbon Emission Mitigation Potential in Nine EMEs: 2022–2030

(Million tonnes)

Country	Power	Steel	Cement	Total Carbon Emissions Mitigation Potential*
	2024–2030	2022–2030	2022–2030	2022–2030#
(1)	(2)	(3)	(4)	5 = (2 +3 + 4)
1. China	682	15,304	5,796	21,782
2. India***	1,230	3,642	2,033	6,905
3. The Russian Federation	193	1,227	237	1,657
4. Brazil	**	507	228	735
5. Türkiye	**	261	343	604
6. Indonesia	67	176	348	591
7. Mexico	**	143	207	350
8. South Africa	51	48	52	151
9. Argentina	19	55	53	127
All EMEs (1 to 9)	**2,242 (7)**	**21,363 (65)**	**9,297 (28)**	**32,902 (100)**

Note: Figures in parentheses are percentages to total.

**Total emissions mitigation potential does not include the road transport sector due to lack of data.*

#Values are based on the years 2022–2030 for the cement and steel sectors and 2024–2030 for the power sector.

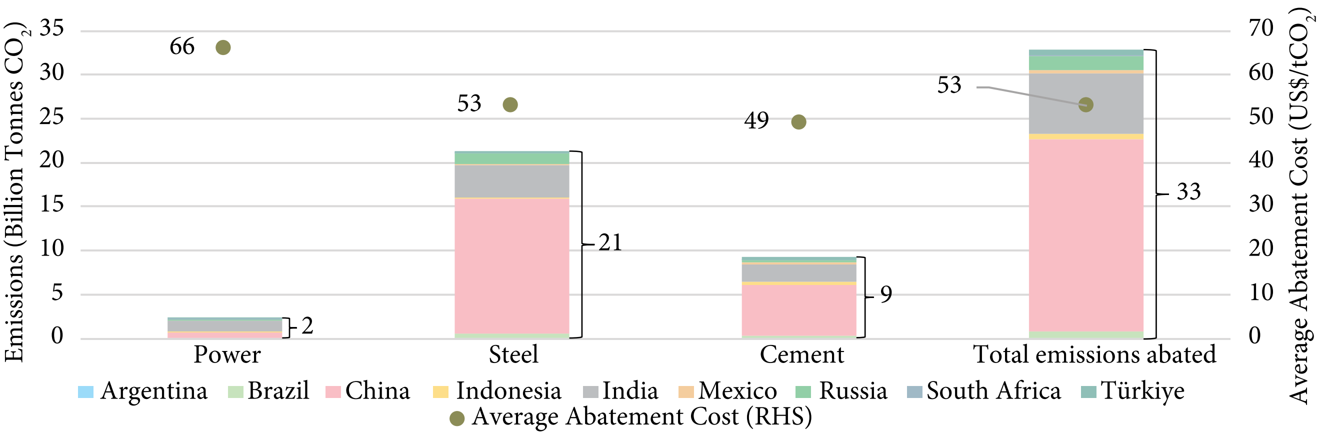
***Carbon emissions mitigation potential in the power sector of Brazil, Mexico, and Türkiye could not be worked out due to lack of readily available reliable data.*

****Refer to Raj and Mohan (2025) for India's estimates.*

Source: Authors' calculations.

The average capex for mitigating CO_2 for all the three sectors works out to US$ 53 per tCO_2 for all the nine EMEs. Of the three sectors, power is the most expensive to decarbonise on a per tCO_2 basis (US$ 66 per tCO_2), followed by the steel (US$ 53 per tCO_2) and the cement (US$ 49 per tCO_2) - Figure 6.

Figure 6: Expected Carbon Emissions Mitigation Potential and its Cost in Nine EMEs (2022-2030)



Notes: 1. Average cost is for the nine EMEs.

2. Total emissions mitigated do not include emissions mitigated from the road transport sector due to lack of data.

3. Carbon emissions mitigation potential in the power sector of Brazil, Mexico, and Türkiye could not be worked out due to lack of readily available reliable data.

Source: Authors' representation.

The CO_2 mitigation cost in different sectors is different in the nine EMEs.[16] The average cost of decarbonising the power sector is the least in Indonesia (US$ 45 per tonne of CO_2), steel and cement sectors in China (US$ 48 per tonne of CO_2 and US$ 37 per tonne of CO_2 respectively). Relative to other sectors, the power sector entails the least cost of decarbonisation in two economies - Indonesia (US$ 47 per tonne of CO_2) and India (US$ 46 per tonne of CO_2) - Table 45. The cement and steel sectors in these economies will be more expensive to decarbonise. In Argentina and Mexico, the steel sector requires the least amount of per unit capex for decarbonisation (US$ 53 per tonne CO_2 and US$ 52 per tonne CO_2, respectively). In four countries, the cement sector has the least cost of mitigation - China (US$ 37 per tonne of CO_2), Türkiye (US$ 52 per tonne of CO_2), South Africa (US$ 56 per tonne of CO_2) and Brazil (US$ 62 per tonne of CO_2).

Table 45: Average Carbon Mitigation Cost for Four Sectors - Economy-Wise

Countries	Power	Steel	Cement	Average Cost of Mitigation
	US$ per tCO_2			
1. Argentina	211	53	60	80
2. Brazil	*	72	62	65
3. China	81	48	37	46
4. India	46	69	70	65
5. Indonesia	45	75	90	80
6. Mexico	*	52	64	102
7. The Russian Federation	47	59	51	57
8. South Africa	157	58	56	91
9. Türkiye	*	55	52	54

**Expected carbon emissions mitigation cost in the power sector of Brazil, Mexico, and Türkiye could not be worked out due to lack of readily available data.*

The climate finance estimate of US$ 2.2 trillion between 2022–2030 for the nine EMEs arrived at in this study is much lower than that of US$ 35 trillion estimated by Bhattacharya *et al.* (2022). However, it is important to underline the significant differences between the two. First, this study's estimates are based on only the nine EMEs, whereas estimates by Bhattacharya *et al.* (2022) supposedly covered all EMDEs. Second, our estimates are based on the four sectors (power, road transport, steel, and cement), while those by Bhattacharya *et al.* (2022) do not cover road transport, cement and steel sectors, but cover other sectors such as human capital, sustainable infrastructure, agriculture, food, land use, nature, and adaptation and resilience. Third, the period covered in this study is 2022-2030, while that in Bhattacharya *et al.* (2022) is 2020-2030.

6. MDBs and Climate Finance

MDBs[17] are expected to play an important role in meeting climate finance requirements of low- and middle-income countries (LMICs). Annual climate finance extended by MDBs to all countries increased from US$ 61 billion in 2019 to US$ 125 billion in 2023. The share of LMICs in total climate finance by MDBs has remained roughly constant at 60 per cent since 2020, but lower than it was in 2019 (Table 46).

In 2023, total climate finance extended by MDBs for mitigation measures to LMICs was broadly of the same order as that of HICs (Table 47).

[16] The three sectors considered are power, cement, and steel as the cost of mitigation in the road transport sector could not be estimated in the absence of reliable data.

[17] MDBs include (i) International Bank for Reconstruction and Development (IBRD); (ii) International Development Association (IDA); (iii) Asian Development Bank (ADB), New Development Bank (NDB); (iv) African Development Bank (AfDB); (v)European Investment Bank (EIB); (vi) Inter-American Development Bank (IDB); and (vii) European Bank of Reconstruction and Development (EBRD).

Table 46: Climate Finance from MDBs: 2019–2023

Year	Climate Finance to High-Income Countries (HICs)	Climate Finance to Low-and Middle-Income Countries (LMICs)	Total	Share of LMICs in Total Climate Finance
	US$ Billion			per cent
2019	20	41	61	67
2020	28	38	66	58
2021	31	51	82	62
2022	39	61	100	61
2023	50	75	125	60

Source: Joint Report on Multilateral Banks' Climate Finance (2024).

Table 47: Climate Finance from MDBs - 2023

Region	Adaptation	Mitigation	Total
	US$ Billion		
LMICs	25	50	75
HICs	3	47	50
Total	**28**	**97**	**125**

LMICs - Low- and middle-income countries.

HICs - High income countries.

Source: Joint Report on Multilateral Banks' Climate Finance (2022).

From 2018 to 2023, annual average lending by MDBs amounted to US$ 207 billion across all sectors and countries. MDBs lent, on an annual average basis, US$ 36 billion to the nine EMEs covered in this study during the same period, with peak lending of US$ 45 billion in 2020 due to pandemic-related response measures. The share of climate finance (for mitigation) in annual loans extended to all countries increased from 24 per cent in 2018 to 42 per cent in 2023. The share of the nine economies constituted 16–22 per cent in total annual climate finance extended by MDBs to all economies.

We have made projections of overall loans and climate finance by MDBs based on the CAGR from 2018 to 2022. MDB annual loans are projected to rise from US$ 230 billion in 2023 to US$ 334 billion in 2030. Based on recent trends in climate finance, it is projected that the share of climate finance in total loans extended by MDBs will rise from 42 per cent in 2023 to 65 per cent in 2030. The share of the nine economies in total climate finance extended by MDBs is projected to remain broadly unchanged at 15–16 per cent, even as their share in total loans extended to all countries by MDBs is projected to rise from 37 per cent in 2022 to 51 per cent in 2030.

Table 48: MDBs - Overall Loan Portfolio and Climate Finance - Mitigation

	Year	Loans Extended by MDBs* to All Countries	Loans Extended by MDBs to Nine EMEs	Climate Finance Provided by MDBs to All Economies	Climate Finance Provided by MDBs to Nine EMEs	Share of Climate Finance: Loans Extended by MDBs to All Economies	Share of Climate Finance: Nine EMEs in Total Climate Finance Provided by MDBs to All Economies	Share of Climate Finance: Nine EMEs in Loans Extended by MDBs to Nine EMEs
	(1)	(2)	(3)	(4)	(5)	(6) = (Col 4 as % of Col 2)	(7) = (Col 5 as % of Col 4)	(8) = (Col 5 as % of Col 3)
		US$ Billion				per cent		
Actual	2018	183	32	43	9	24	22	29
	2019	184	34	46	9	25	20	27
	2020	224	45	49	8	22	17	19
	2021	215	36	61	11	28	18	31
	2022	205	33	74	12	36	16	37
	2023	230	39	97	20	42	21	52
Projection	2024	242	46	97	15	40	16	33
	2025	254	48	110	17	43	15	35
	2026	268	51	126	19	47	15	37
	2027	282	55	144	22	51	15	40
	2028	298	58	165	25	55	15	43
	2029	315	63	188	29	60	16	47
	2030	334	68	215	34	65	16	51

**Lending portfolio of MDBs excludes three banks (Asian Infrastructure Investment Bank, Council of Europe Development Bank, and Islamic Development Bank) due to lack of data, while these banks are included in climate finance flows from MDBs.*

Note: Projections are based on CAGR from 2018 to 2022 as this analysis was conducted before 2022–2023 data became available.

Source: Annual reports of relevant MDBs, Joint Report on Multilateral Banks' Climate Finance (2022), and Climate Policy Initiative (2023).

In our estimates, climate finance requirement estimated for the nine economies rises progressively every year - from US$ 171 billion in 2022 to US$ 375 billion by 2030.[18] However, climate finance provided by MDBs for these nine economies was US$ 20 billion in 2023 (11.3 per cent of the total climate finance requirement estimated in the study for the nine EMEs). Even though climate finance by MDBs is projected to rise gradually, it will still constitute a small share (9.1 per cent) of the total climate finance requirement of the nine EMEs in 2030. China is a large economy, with savings typically greater than investment, and it no longer avails of large loans from MDBs. However, even after excluding China, the share of MDBs in meeting the climate finance requirement of the eight other EMEs in 2030 is projected to remain broadly the same (in percentage terms) as in 2022.

[18] Given the large initial capex requirement estimated for 2022 - US$ 1,082 billion for the steel sector and US$ 458 billion for the cement sector - it is assumed that the initial estimated capex would be evenly distributed in the remaining years up to 2030. This results in an annual capex of US$ 120 billion for the steel sector and US$ 51 billion for the cement sector, which is added to capex required for mitigating incremental carbon emissions per year from 2022 to 2030.

Table 49: Climate Finance from MDBs and Climate Finance Estimates - Nine EMEs

		ACE Estimates		Climate Finance by MDBs		Share of Climate Finance by MDBs	
	Year	Nine EMEs	Eight EMEs (Excluding China)	Nine EMEs	Eight EMEs (Excluding China)	ACE for Nine EMEs	ACE for Eight EMEs (Excluding China)
	(1)	(2)	(3)	(4)	(5)	(6) = (Col 4 as % of Col 2)	(7) = (Col 5 as % of Col 3)
		US$ Billion				per cent	
Actual	2017–2018	–	–	9	8	–	–
	2018–2019	–	–	9	7	–	–
	2019–2020	–	–	8	7	–	–
	2020–2021	–	–	11	10	–	–
Projection	2021–2022	171	46	12#	10#	7.1	22.4
	2022–2023	177	70	20#	18#	11.3	25.7
	2023–2024	197	82	15	13	7.6	15.7
	2024–2025	209	87	17	14	8.1	16.6
	2025–2026	225	94	19	17	8.5	17.7
	2026–2027	247	102	22	19	8.9	18.8
	2027–2028	277	111	25	22	9.1	20.1
	2028–2029	318	123	29	26	9.2	21.3
	2029–2030	375	140	34	31	9.1	22.0

ACE: Additional capital expenditure.

Note: This analysis was conducted before actual 2022–2023 data became available.

#Actual.

Source: Joint Report on Multilateral Banks' Climate Finance (2022) and authors' calculations.

MDBs finance various activities such as health, education, transport, agriculture, water and waste management and urban infrastructure, among others, but they do not finance the cement and steel sectors. These sectors in the nine economies, other than China and Indonesia[19], are largely in the private sector. Although MDBs largely finance the public sector, in view of their large carbon emissions, there is a need for all MDBs to treat decarbonisation of the cement and steel sectors as a public good for financing purposes. International Finance Corporation, a part of the World Bank group, in any case finances the private sector like other private financiers. Thus, policies and programmes for leveraging the public funds available from MDBs to incentivise the private sector to decarbonise the steel and cement sector should receive the highest priority.

7. Macroeconomic Consistency of Climate Finance Estimates

The report of the Independent High-Level Expert Group on Climate Finance estimated that there would be a need to mobilise US$ 1 trillion per year in external finance for EMDEs, other than China, up to 2030 (Songwe *et al.*, 2022). Various other estimates are also broadly in this range. Estimates of climate finance in this study as explained above are also large, though not as large as estimated by other studies. In this section, we evaluate the macroeconomic consistency of climate finance estimated.

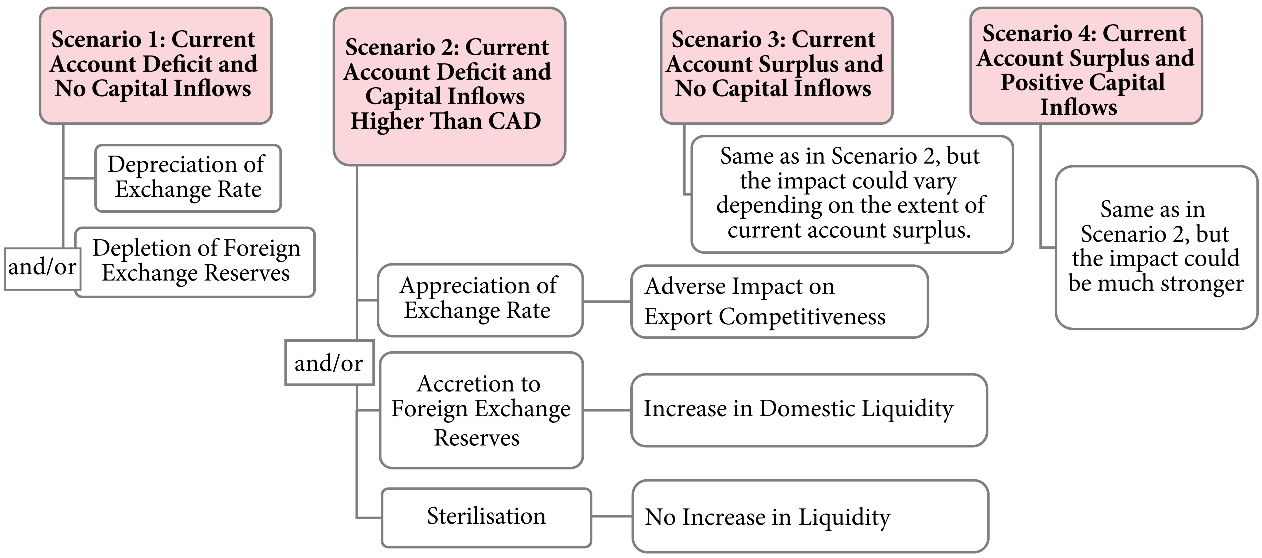
Capital flows into an economy can be absorbed only to the extent the country runs its CAD, which needs financing through capital inflows. In the absence of capital inflows, the CAD can be financed only by depleting foreign exchange reserves and/or

[19] While steel sector in China is largely in the private sector, the cement sector is owned both by the public and private sectors. In Indonesia, the cement and steel sector are majorly in the public sector.

depreciation of the exchange rate, which could then promote exports and reduce the CAD. Capital inflows exceeding the CAD and current account surplus have significant implications for the domestic economy. In both cases (capital flows greater than the CAD and current account surplus), if a country decides not to intervene in the forex market the exchange rate will tend to appreciate causing an adverse impact on export competitiveness. If a country does intervene in the forex market, foreign exchange reserves will rise, resulting in an equivalent rise in domestic liquidity. This should be consistent with the required expansion in monetary base (also referred to as reserve money or high-powered money or base money or as M0 in the US) for a growing economy.[20] If an increase in domestic liquidity corresponds to the growth in monetary base, there may not be any impact, except that the entire increase in monetary base will take place through an increase in net foreign assets (NFAs), which raises other concerns.[21] However, if an expansion in liquidity exceeds the required increase in monetary base, sterilisation becomes necessary. Unsterilised intervention on a large scale can result in excessive liquidity, leading to domestic inflation, an increase in domestic interest rates, a widening of the interest rate differential *vis-à-vis* other countries, and the risk of further capital inflows, thereby defeating the very purpose of the intervention (Raj *et al.*, 2018). Therefore, to mitigate these effects, central banks undertake sterilised intervention through open market operations (Figure 7).

In actual practice, however, emerging economy central banks follow an eclectic approach. Deft management should allow some impact on the exchange rate and absorption of some capital inflows into their reserves. The corresponding rise in domestic liquidity must be managed through appropriate sterilisation so that it is consistent with the monetary base requirement of the economy. These are the issues that need to be kept in mind while considering the magnitude of external climate finance.

Figure 7: External Financial Flows - Macroeconomic Impact



CAD - Current Account Deficit.
Source: Authors' representation.

[20] In economies where central banks target interest rate, the factors affecting the monetary base are exogenous for the central bank. As such, those central banks may not exert direct influence on the size of the monetary base, which depends on the portfolio decisions of the private sector. Nevertheless, monetary base remains relevant as its unbridled growth may have a significant bearing on nominal interest rates and the macroeconomy.

[21] A larger share of NFAs also implies a corresponding decline in NDAs, which can constrain market-based liquidity absorption operations. In the face of persistently large liquidity, this constraint could become binding (Raj *et al.,* 2018).

The response of each economy may have to be different to deal with large climate finance flows required to mitigate the impact of climate change and may have different implications and macroeconomic costs to the economy. In this section, we assess external financial flows, *i.e.,* capital and financial flows net of current account balance in the nine EMEs in the BAU scenario. As it is, external financial flows in the BAU scenario need to be managed. However, climate finance flows from external sources over and above external financial flows in the BAU scenario could pose additional challenges and would need to be managed deftly.

External financial flows (capital and financial flows net of current account balance) for the nine economies in the BAU scenario for the period from 2023–2030 are estimated at US$ 2,690 billion, ranging from US$ 17 billion (South Africa) to US$ 1,545 billion (China). Excluding China, such flows are estimated at US$ 1,145 billion (Table 50). External financial flows estimated here are broadly in line with those projected by the International Monetary Fund (IMF).

Table 50: Projection of External Financial Flows of Nine EMEs - BAU: 2023–2030

Country	External Financial Flows (US$ Billion)		Percentage of GDP
	2023–2030	Annual Average	Annual Average
1. Argentina	137	20	2.8
2. Brazil	166	24	0.9
3. China	1,545	221	0.9
4. India*	530	76	1.4
5. Indonesia	103	15	0.8
6. Mexico	97	14	0.7
7. Russia	75	11	0.5
8. South Africa	17	2	0.6
9. Türkiye	19	3	0.2
Total (1 to 9)	**2,690**	**384**	**0.96**
Total (Excluding China)	**1,145**	**164**	**0.99**

External flows = Current account balance + capital inflows + financial flows.
**Refer to Raj and Mohan (2025) for details of India's figures.*
Source: Authors' calculations and IMF Article IV Report for Argentina, 2023.

The following other points emerge from the analysis:

(i) Argentina is projected to receive external financial flows of US$ 137 billion during 2023–2030 in the BAU scenario, an annual average of US$ 20 billion or 2.8 per cent of its GDP annually. Argentina's historical economic volatility suggests challenges in managing these inflows without impinging on domestic macroeconomic stability.

(ii) External financial flows of Brazil are estimated at US$ 166 billion during 2023–2030, an annual average of US$ 24 billion or 0.9 per cent of its GDP.

(iii) China stands out as it is estimated to receive US$ 1.5 trillion overall external financial flows for the period 2023–2030 or an annual average of US$ 221 billion in the BAU scenario (0.9 per cent of GDP). China has a consistent large current account surplus, though it is gradually reducing as percentage of GDP, leading to a decline in overall external financial flows as percentage of GDP. However, it may not need any external financing for climate mitigation.

(iv) External financial flows of India are estimated at US$ 530 billion during 2023–2030, or US$ 76 billion on an annual average basis (1.4 per cent of its GDP annually).

(v) Indonesia is projected to cumulatively receive external financial flows of US$ 103 billion up to 2030. On an annual average basis, these flows work out to US$ 15 billion, constituting about 0.8 per cent of GDP.

(vi) It is estimated that Mexico could receive US$ 97 billion of external financial flows (annual average of US$ 14 billion, or 0.7 per cent of GDP).

(vii) External financial flows for the Russian Federation are projected at US$ 75 billion cumulatively during 2023–2030 or US$ 11 billion dollar on an annual average basis or 0.1 per cent of its GDP.

(viii) External financial flows of South Africa are estimated US$ 17 billion during 2023–2030, an annual average of US$ 11 billion, or 0.5 per cent of GDP.

(ix) Türkiye is projected to receive external financial flows of US$ 19 billion during 2023–2030 (US$ 3 billion on an annual average basis, or 0.2 per cent of GDP). The high inflation in Türkiye could possibly be a major reason for low external financial flows into the economy.

The above country-wise variability of external flows highlights the differing levels of economic activity and the size of the external sector. Comprehensive country-wise and year-wise projections for all the economies (other than India) are set out in Appendix 7. Details for India are included in a separate study by Raj and Mohan (2025).

A critical question is the extent to which external financial flows estimated in this study can be managed by each of the nine economies without having much adverse impact on their key macroeconomic fundamentals. This can be examined by juxtaposing external financial flows with monetary base. External financial flows that can be managed in the BAU scenario consistent with an expected increase in monetary base, vary from country to country - ranging from US$ 9 billion in the case of South Africa (from 2023–2030) to US$1.9 trillion for China. All the nine economies can manage external financial flows of about US$ 3.1 trillion from 2023 to 2030 consistent with the expansion in monetary base, which works out to US$ 445 billion a year (Table 51).

External financial flows (capital and financial flows net of current account balance) are estimated at US$ 2.7 trillion (US$ 1.1 trillion excluding China) from 2023–2030 in the BAU scenario. Thus, the projected external financial flows in the nine economies are expected to accommodate about 86 per cent (97 per cent excluding China) of the projected expansion in monetary base, leaving a small room of only US$ 423 billion (US$ 37 billion, excluding China) for absorbing climate finance from external sources. To the extent monetary base expansion takes place by an increase in net domestic assets (NDAs), it will further circumscribe the management of external financial flows, unless the authorities decide to manage them through sterilised intervention.

A country may allow its exchange rate to appreciate in response to external financial flows. For the purpose of analysis, we ignore capital flows which can be managed by allowing appreciation of the exchange rate as this will depend on exchange rate policy of each bank and several other factors, which may not be easy to predict. It is assumed that an entire increase in monetary base takes place by an increase in NFAs.

Country-wise external financial flows and expansion in monetary base for 2023–2030 are set out in Appendix 7.

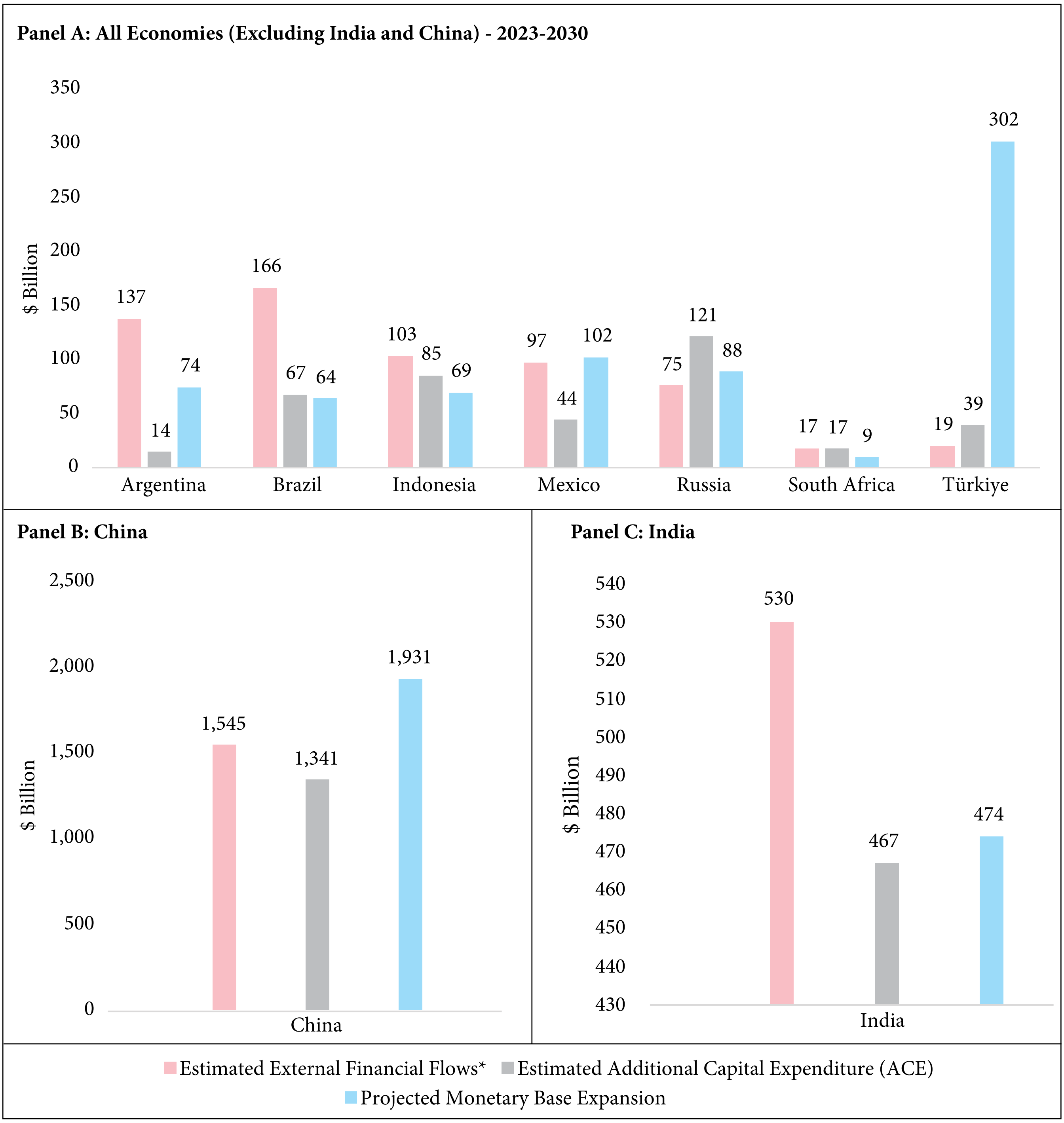
Table 51: Monetary Base Projections - Country-wise: 2023–2030

Country	Expansion in Monetary Base - Projections		
	US$ Billion		Percentage of GDP
	2023–2030	Annual Average	Annual Average
1. Argentina	74	11	1.6
2. Brazil	64	9	0.3
3. China	1,931	276	1.2
4. India*	474	68	1.2
5. Indonesia	69	10	0.5
6. Mexico	102	15	0.7
7. Russia	88	13	0.6
8. South Africa	9	1	0.3
9. Türkiye	302	43	3.6
A. Total (1 to 9)	**3,113**	**445**	**1.1**
B.Total (excluding China)	**1,182**	**169**	**1.0**

**Refer to Raj and Mohan (2025) for details of India's figures.*
Note: Refer to Appendix 8 for projected nominal GDP growth rates.
Source: Authors' calculations.

The ability to manage both (i) external financial flows in the BAU scenario and (ii) climate finance from external sources consistent with an increase in monetary base is constrained for most of the EMEs under study. Türkiye is the only economy which can comfortably manage both external financial flows and estimated climate finance (should it flow from external sources). This is mainly because Türkiye is projected to receive small external financial flows. All other economies will be constrained to manage both external financial flows in the BAU scenario and estimated climate finance requirements from external sources. Expansion in monetary base in some economies such as China, Mexico and Russia is projected to be more than the external financial flows. Therefore, these economies can manage climate finance flows from external sources to some extent alongside BAU external financial flows. All other economies would need to skilfully manage both external financial flows in the BAU scenario and climate finance from external sources (Figure 8).

Figure 8: Monetary Base, Estimated Climate Finance and External Financial Flows - Country-Wise



Note: Refer to Raj and Mohan (2025) for details of India's figures.

**External Financial Flows = Current Account Balance + Capital Inflows + Financial Inflows.*

Source: Authors' representation.

Table 52: Monetary Base, Climate Finance Estimates and External Financial Flows - Year-Wise

(Percentage of GDP)

Year	Expansion in Monetary Base		ACE[22]		External financial flows#	
	Nine EMEs	EMEs, Excluding China	Nine EMEs	EMEs, Excluding China	Nine EMEs	EMEs, Excluding China
(1)	(2)	(3)	(4)	(5)	(6)	(7)
2022	1.1	1.5	0.5	0.3	0.6*	0.2*
2023	2.2	2.1	0.5	0.4	0.2*	0.4*
2024	1.7	1.0	0.5	0.4	1.1	1.0
2025	1.1	1.1	0.5	0.4	0.9	0.9
2026	1.1	1.1	0.5	0.5	0.9	0.9
2027	1.1	1.0	0.6	0.5	1.0	1.0
2028	1.0	1.0	0.6	0.5	1.0	0.9
2029	1.0	1.0	0.6	0.5	1.0	1.0
2030	1.0	1.0	0.7	0.5	1.0	0.9

Note: Refer to Raj and Mohan (2025) for details of India.
ACE: Additional capital expenditure; CAB: Current Account Balance.
#External financial flows = CAB + Capital Inflows + Financial Inflows.
**Actual figures.*
Source: Authors' calculations.

Year-wise, climate finance requirements in the four sectors of the nine economies move in a range of 0.5 and 0.7 per cent of GDP, barring India (Table 52).

External financial flows, on an annual average, are expected to be less than 1 per cent of GDP up to 2030 for all the nine economies covered in the study. However, should these economies reduce current account surpluses or widen CADs, they should be able to absorb even larger external financial flows, including climate finance. It is, however, significant to note that some of the economies - Indonesia and Argentina - are estimated to have a small positive current account balance during 2023–2030. Some other economies also run large current account surpluses (China and the Russian Federation), which means they export savings, reducing their domestic consumption. While China may not need climate finance from external sources, the Russian Federation could strategically reduce its current account surplus, which would increase its domestic absorption, thereby improving its capacity to absorb external climate finance flows. Thus, there is room for higher capital flows than the BAU by expanding CAD/reducing current account surpluses.

All sources – external, public and private – would need to be combined to finance climate change, though the bulk of the burden is likely to fall on the domestic private sector. Governments and MDBs can complement private sector financing of climate action through multiple strategic approaches. It would be imperative to step up the savings rate in almost all countries (other than China, the Russian Federation and Mexico), which will help them boost their domestic investment rate without exacerbating their debt burden. This is particularly crucial for emerging economies already struggling with high debt-to-GDP ratios. Second, governments can induce private investment in green activities by introducing carbon pricing mechanisms such as carbon tax and emissions trading schemes to mobilise necessary resources. In addition, they may have to provide monetary incentives to private players to decarbonise their activities. However, these may lead to higher energy costs for the public, and hence there may be a need to protect vulnerable sections of society.

[22] Given the large initial capital expenditure requirement estimated for 2022, it is assumed that the initial estimated capital expenditure would be evenly distributed in the remaining years up to 2030.

8. Summing up and Final Reflections

In view of the increasing impact of climate change, climate action has become imperative. This is reflected in the pledges and enhanced climate goals of countries. The nine EMEs selected in this study have also formulated and enhanced their climate goals in their respective updated NDCs and LT-LEDS. However, large capital investment is needed to mitigate carbon emissions and enhance adaptability and resilience against climate change. While there is a consensus that the capital requirement for these actions is in trillions of US dollars, the exact amount of climate finance needed is not clear. The global estimates for climate finance requirements up to 2030 range between US$ 40 trillion and US$ 104 trillion (US$ 4–7 trillion annually), and that till 2050 range between US$ 100 trillion and US$ 275 trillion (US$ 3.4–9.2 trillion annually). For EMDEs, the estimates vary between US$ 6 trillion and US$ 35 trillion (US$ 0.6–4 trillion per year) to achieve climate goals by 2030.

The methodologies used by most of the existing studies are not very transparent. On climate finance, most of the studies, except the World Bank's CCDRs, have used top-down approaches which lack local geographical and sectoral granularities. Moreover, different studies have estimated the requirements aligned with different objectives, baselines, time horizons and scope of sectors. These differences render the estimates incomparable. Lastly, most of the studies have arrived at total climate finance including capital investment which may not be solely related to climate change. Unlike other studies, this study has assessed the climate finance requirement, in a transparent way, for the power, transport, cement and steel sectors, solely for climate action over and above the capital requirement for these sectors in the BAU. It is significant to note that most studies do not include the steel, cement and transport sectors for assessing climate finance requirement.

Climate finance requirements for the nine economies in this study are estimated at US$2.2 trillion for the period 2022–2030[23] or US$ 255 billion annually (0.6 per cent of GDP), the bulk of which are on account of China. Excluding China, climate finance requirements are assessed at US$ 854 billion (US$ 100 billion or 0.5 per cent of GDP, annually). Our estimates of additional capital expenditure (ACE) needed amounts to less than 1 per cent of GDP annually, except India which requires 1.3 per cent of GDP. The climate finance requirement for India is estimated to be large at US$ 467 billion (US$ 54 billion annually). In India, the steel and cement sectors account for the largest shares of estimated climate finance requirement. China and India account for 82 per cent of climate finance requirement of all the nine economies combined.

The climate finance estimates for the steel and cement sectors include capital investments in CCS and other pathways such as energy efficiency, RE, alternative fuels and clinker substitution (in the case of cement). *The climate finance requirement to decarbonise the steel sector in the nine economies is estimated at US$ 1.2 trillion for 2022–2030 or US$ 126 billion annually, more than half of the total climate finance requirement estimated.* Of this, three economies, *viz.*, China, India and the Russian Federation account for 93 per cent (China – 65 per cent, India – 22 per cent and the Russian Federation – 6 per cent).

To decarbonise the cement sector, the nine economies are estimated to require US$ 453 billion (21 per cent of total climate finance estimate) for 2022–2030 as climate finance, translating to US$ 50 billion annually. China constitutes 48 per cent of the total climate finance requirement (US$ 217 billion) in the cement sector because of its large share in global production, followed by India which accounts for 31 per cent (US$ 141 billion) of the total requirement in the cement sector. While production of cement in China is projected to decline going forward, that of India is expected to rise. The remaining seven economies are estimated to require US$ 95 billion to decarbonise the cement sector up to 2030.

The cement and steel sectors are among the most challenging to decarbonise due to their inherent processes and high emission intensities. Significantly, this is the case even with the advanced economies because of high carbon intensity associated especially with the steel sector. Though various options are available such as energy efficiency, RE integration, and the use of alternative fuels, their scope to reduce emissions is limited. A promising pathway for decarbonising these sectors is CCS, which aims at capturing and storing a large portion of the carbon emissions released during the production process, but it is expensive to deploy.

[23] The period covered is 2022–2030 for the steel and cement sectors, 2024–2030 for the power sector and 2023–2030 for road transport.

As most EMEs are expected to maintain robust growth trajectories in the foreseeable future, the demand for cement and steel as inputs for infrastructure development is expected to remain large, underscoring the importance of climate finance for decarbonising the cement and steel sectors. As EMEs grow, there will be more steel scrap available, enabling increased use of EAF which is more energy efficient. This could lead to lower climate finance requirement.

To encourage private investment for decarbonising the cement and steel sectors, governments would need to provide an appropriate incentive structure that leverages available public funds, including those from the MDBs. This could include well-designed targeted subsidies/incentives such as loan guarantees. This might also require actions on several other fronts, including the introduction of carbon pricing mechanisms in economies where they do not exist, and clear regulatory frameworks that include carbon reduction targets and green taxonomy. EMEs, especially China and India, would need to pay attention to research and development (R&D) efforts for making CCS more cost-effective or developing alternative technologies to make decarbonising of the hard-to-abate sectors more affordable. Advanced economies may not have adequate incentives to promote such R&D since steel and cement production in those countries is not expected to rise substantially.

The road transport sector (including two-wheelers, three-wheelers, passenger cars and taxis, trucks/goods vehicles and buses) in the nine economies is estimated to require additional capital investment of US$ 459 billion for 2023–2030, which translates to US$ 59 billion annually. However, climate finance for road transport is entirely on account of charging infrastructure for EVs, the cost of which varies significantly, depending on the charger type; the high-speed charger costs almost seven times more than the slow-speed chargers. The capex for road transport (for switching from ICEVs to EVs) is estimated to decline by US$ 5 billion, mainly because vehicle sales (both ICEVs and EVs) in China are projected to decline in 2030 compared with 2022. With the falling costs of EVs, particularly in China, replacement of ICEVs with EVs is not expected to pose a problem. China, however, plans to set up an extensive high-speed charging infrastructure, which will require a large amount of capex. Of US$ 459 billion capex estimated for the road transport for all nine economies, US$ 346 billion is required by China alone. Excluding China, climate finance for the road sector for the eight other economies was estimated at US$ 124 billion, of which the capital cost of switching from ICEVs to EVs was estimated at US$ 105 billion and that of developing charging infrastructure was at US$ 19 billion. The cost of developing the charging infrastructure other than in China is low as these economies are not planning to develop fast-speed charging infrastructure. However, the need to build the fast-speed charging infrastructure even in other economies could become imperative if the volume of EVs increases significantly going forward.

The climate finance requirement for power through renewables as well as setting up storage capacity (battery storage and pump storage) is estimated at US$ 149 billion for 2024–2030, which corresponds to roughly US$ 21 billion annually. A major requirement of climate finance in the power sector arises on account of India (38 per cent) and China (37 per cent). Climate finance requirement by the eight economies, excluding China, is estimated merely at US$ 94 billion for 2024–2030.

The power sector is the most discussed for achieving decarbonisation goals and also for requiring large climate finance. However, this study finds that of the four sectors, the power sector requires the least amount of climate finance because of a sharp reduction in the cost of renewables over the last ten years. RE has reached a commercial stage and it is now cost effective to implement.

The estimated climate finance in this study has the potential to mitigate 33 billion tCO_2 in three sectors[24] (power, steel and cement) in the nine EMEs. The average cost of mitigating one tonne of CO_2 is estimated at US$ 53 for the nine EMEs, with power sector requiring the highest per unit mitigation cost (US$ 66 per tCO_2), followed by the steel sector (US$ 53 per tCO_2) and cement sector (US$ 49 per tCO_2).

It was also assessed as to what extent MDBs can finance climate action in the nine economies considered in this study. MDBs' contribution to the climate finance requirement is expected to be small at 7–9 per cent for 2022–2030 for all the nine economies, and 15–25 per cent, excluding China. The range of

[24] Mitigation of CO_2 for the transport sector could not be estimated for lack of data.

15–25 per cent can be regarded for these eight economies as quite substantial, especially if these resources are used to leverage private sector funds in the steel and cement sectors through appropriate incentive frameworks. But MDBs are constrained in financing climate action on a larger scale, unless their capital base expands significantly.

MDBs finance various sectors but exclude the cement and steel sectors. The cement and steel sectors in the nine economies, other than China and Indonesia, are largely in the private sector. While MDBs traditionally focus on public sector financing, significant carbon emissions from cement and steel production require them to treat their decarbonisation as a public good, fund technology development in these sectors, and set up incentive frameworks to leverage private sector financing in these sectors. In addition, the International Finance Corporation (IFC), the private financing arm of World Bank group, and corresponding institutions in other MDBs, can also be utilised for funding private players in the cement and steel sectors.

Several studies have assessed that the EMDEs may need large financial assistance from external sources. Therefore, capacity to absorb/manage climate finance flows from external sources was also assessed in this study by estimating the external financial flows (capital and financial flows net of current account balance) and projected expansion in monetary base up to 2030. This is the first study to focus on macroeconomic consistency of climate finance estimates.

External financial flows (capital and financial flows net of current account balance) to the nine economies are estimated at US$ 2.7 trillion during 2023–2030 (US$ 1.1 trillion excluding China) in the BAU scenario. Monetary base in the nine economies is projected to expand by US$ 3.1 trillion (US$ 1.2 trillion excluding China) in the BAU scenario during 2023–2030. Thus, external financial flows in the BAU will accommodate about 86 per cent (97 per cent, excluding China) of the projected expansion in monetary base in the nine economies, leaving a small room of US$ 423 billion (US$ 37 billion, excluding China) to absorb climate finance flows from external sources. At a country level, only Türkiye can manage comfortably both (i) external financial flows; and (ii) estimated climate finance flows from external sources. China, Mexico and Russia can manage climate finance flows to some extent over and above the external financial flows in the BAU. All other economies would need to skilfully manage both external financial flows in the BAU scenario and climate finance from external sources.

It may also be possible for the countries to strategically adjust their current account balances to enhance their absorptive capacity. For instance, the expected current account surplus lies in the range of 1.2–1.9 per cent of GDP during 2023–2030 for China, 0.9–5.8 per cent of GDP for Russia and 0.8–1.5 per cent of GDP for Argentina. While China may not need climate finance from external sources, other economies could strategically reduce the surpluses, if required, to facilitate management of higher climate finance inflows. On the other hand, countries with CAD could also strategically expand their deficits to allow for greater absorption of external financing. The average CAD for the countries under study - Brazil, India, Mexico, South Africa and Türkiye - is 2 per cent of GDP during 2023–2024. This could perhaps be widened further to some extent to absorb large climate finance flows from external sources. The management of external financial flows could become less challenging for some economies to the extent countries can import decarbonisation technology, especially CCS, EAF and EV charging infrastructure, thereby leading to widening of their CAD.

Climate change is posing a huge challenge to the global economy and even threatening humanity. Even though the threat of climate change has been well recognised, efforts to mitigate its impact have been lacking and we have reached a tipping point where the cost of inaction could be heavy. Various climate finance estimates available at the global level, though useful for assessing the global efforts required to combat climate change, do not help much for assessing sector-specific requirements at the country level. In the absence of robust climate finance estimates rooted in local conditions and at the sectoral level, it has become challenging to prioritise climate mitigation efforts. This study is an attempt to fill this gap. The findings of the study suggest that climate finance requirements vary significantly across the nine economies and across the four sectors. While some countries and sectors need huge climate finance, some other economies and sectors do not. Thus, the country-wise and sector-wise requirement of climate finance should serve as an important policy guide. The findings of the study suggest that climate mitigation strategies need to be country-specific and sector-specific so as to achieve the best possible outcomes with the limited resources that are available to finance the climate action. The average cost of reducing carbon emissions in the three sectors (other than road transport) assessed in this study should help map the climate finance requirement and its potential to reduce carbon emissions.

It is also important to be cognizant of certain limitations of this study. This study has incorporated a sectoral approach to estimate additional capital requirements of only four sectors (power, transport, steel and cement). Thus, the country-level estimates reflect only partial climate finance requirements as there are other sources of carbon emissions. Second, it includes capital needs for only mitigation measures and excludes investment required for adaptation actions. Third, the climate finance estimate is assessed only for the nine EMEs and cannot be termed as global climate finance requirements. Fourth, for making estimates for the cement and steel sectors, the study has considered global average as the cost of CCS for some countries where such data were not available. Fifth, all climate finance estimates are based on capex and exclude operational costs. Sixth, CCS estimates have been worked out in steel and cement from 2022 to 2030. Actual capex could turn out to be lower than estimated if CCS facility is installed before 2030 as it may not be feasible to install CCS facility for small incremental capacity of cement and steel production added subsequently (after the installation of CCS facility) up to 2030. Seventh, the estimates are based on current technologies and their prevalent costs. Since the technologies are fast evolving, it is difficult to envisage the kind of technological advancements that may occur, going forward. Should there be technological breakthroughs in the sectors covered, the decarbonisation measures may entail lower climate finance than that estimated in this study. Eighth, while carbon capture has several potential applications, most current uses are more expensive than storage. Consequently, this study does not consider uses of carbon capture. However, should the cost of uses of carbon captured fall significantly below the storage costs in the future due to technological advances, it will be economically more feasible to put carbon captured to uses than to store it. In this scenario, the estimates for decarbonising the cement and steel sectors could be lower than those estimated in this study. Finally, the projections of external financial flows based on the historical data may not fully capture the evolving dynamics in trade, capital and financial flows, going forward. Should there be structural or significant changes in trade, capital and financial flows for any reason in future, the actual outcomes may deviate from the projections made in this study.

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Appendix

Appendix 1: Climate Finance Requirement

Table A1.1: Climate Finance Estimates - Global

S. No.	Source	Annual Climate Finance Requirements (US$ Trillion)	Cumulative Climate Finance Requirements (US$ Trillion)	Time Period by Which the Target to be Achieved	Objective/Scenario	Sectors Included
1.	Bhattacharya *et al.* (2016)	5.4	80	2030	Paris Agreement goals	Infrastructure investments across power, transport, water and waste and telecommunications
2.	New Climate Economy (2016)	6	90	2030	Paris Agreement goals	Infrastructure investments in urban, transport, water, telecommunications and energy systems
3.	Organization for Economic Co-operation and Development (2018)	6.9	104	2030	Paris Agreement goals	Infrastructure investments across energy, transport, building and water
4.	Intergovernmental Panel on Climate Change (2018)	2.4 (2.5)	48	2035	1.5°C temperature goal	Energy related investments
5.	Green Climate Fund (2020): Bayat-Renoux *et al.*	0.75–1.5*	15–30*	2040	Paris Agreement goals	Infrastructure investments
6.	Glasgow Financial Alliance for Net Zero (2021)	3.4	100	2050	Net-zero emissions by 2050 scenario	–
7.	Climate Policy Initiative (2021): Buchner *et al.*	4.5–5	135–150	2050	1.5°C pathway	–
8.	International Energy Agency (2021): Bouckaert *et al.*	5	50	2030	Net zero emissions by 2050 scenario	Energy investments
9.	Grantham Research Institute (2021): Turner *et al.*	7.4–7.9	74–79	2030	–	Energy, transport, water and sanitation and telecom
10.	Vivid Economics (2021)	2.6 4.5	13 23	2021–2025 2026–2030	Net zero by 2050 scenario	–
11.	United Nations Environment Programme (2022)	4–6	40–60	2030	–	Transformations required in electricity supply, industry, transport, buildings, food systems and the financial system
12.	McKinsey (2022): Krishnan *et al.*	9.2 (7.5)	275	2050	Net-zero emissions by 2050 scenario	Capital spending on physical assets for energy and land-use systems
13.	International Renewable Energy Agency (2023)	5	150	2050	1.5°C scenario	Energy investments

Note: Figures in parentheses represent climate finance as percentage of world GDP.

**Specifically indicated as climate finance requirement.*

Source: Authors' compilation.

Table A1.2: Climate Finance Estimates - EMDEs

S. No.	Source	Annual Climate Finance Requirements (US$ Trillion)	Cumulative Climate Finance Requirements (US$ Trillion)	Time Period by Which the Target to be Achieved	Objective/Scenario	Sectors Included
1.	World Bank (2019)	1.5 (4.5)	23	2030	Preferred scenario: ambitious goals, high efficiency	Power, transport, water supply and sanitation, flood protection and irrigation
2.	Standing Committee of Finance (2021)	0.58–0.59 (1.1–1.49)	6	2030	To meet NDCs of developing countries	–
3.	Bhattacharya *et al.* (2022)	1.3* (15.1*) 3.5* (18.2*)	7* 35*	2025 2030	Net-zero transition and climate resilience - EMDCs excluding China	Human capital, sustainable infrastructure, AFOLU (agriculture, food, land use, nature) and adaptation and resilience
4.	Independent High-Level Expert Group (2022): Songwe *et al.*	2–2.8 (6.5)	20–28	2030	1.5°C temperature goal - EMDCs excluding China	Transforming the energy system, loss and damage, adaptation and resilience, natural capital and mitigating methane emissions
5.	International Energy Agency (2023)	2.2–2.8	22–28	Early 2030s	Lower bound is estimated for the sustainable development scenario (SDS); Higher bound is estimated for the net-zero emissions by 2050 scenario	Clean energy
6.	McKinsey (2023): Daharwal *et al.*	2*	20*	2030	To meet the Paris Agreement goals and cap warming at 1.5°C above pre-industrial levels	Transformation of energy system, respond to growing climate change vulnerability, scale sustainable agriculture and restore natural capital and biodiversity
7.	World Bank (2023)	0.8*	8*	2030	Current Policy Scenario with aim to reduce emissions by70 per cent - LMICs excluding China	Resilience, adaptation and low-carbon development

Note: Figures in parentheses represent climate finance as percentage of EMDEs GDP.

**Specifically indicated as climate finance requirement.*

EMDEs - Emerging Market and Developing Economies

Source: Authors' compilation.

Appendix 2: Climate Goals - Nine Emerging Economies

The climate goals, particularly mitigation objectives, of the select EMEs under study are as follows:

1. **Argentina**
   i. Economy-wide net emissions not to exceed 349 million tonnes of CO_2 in 2030.
   ii. Achieve net zero by 2050.
   iii. Cut methane emissions by at least 30 per cent from 2020 levels by 2100.
   iv. End and reverse deforestation by 2030.

2. **Brazil**
   i. Reduce net GHG emissions by 48.4 per cent from 2005 levels by 2025.
   ii. Reduce GHG emissions by 53.1 per cent from 2005 levels by 2030.
   iii. Achieve climate neutrality by 2050.

3. **China**
   i. Achieve carbon neutrality before 2060.
   ii. Reduce emissions intensity by 65 per cent from 2005 levels.
   iii. Increase non-fossil fuel-based primary energy consumption to 25 per cent.
   iv. Increase forest stock volume by 6 million cubic meters from 2005 levels.
   v. Achieve total installed capacity of 1.2 billion kW from solar and wind power by 2030.
   vi. Improve the proportion of non-fossil fuels in energy consumption up to over 80 per cent.
   vii. By 2025, 100 per cent of new buildings in cities and towns will implement green building standards. Fossil fuel replacement rate by renewable energies in urban buildings will reach 8 per cent. The rooftop PV coverage of new public buildings and new factory buildings will strive to reach 50 per cent.
   viii. By 2030, the proportion of new energy and clean energy-powered vehicles will reach about 40 per cent of all the vehicles sold in that year.
   ix. By 2030, the carbon emission intensity of converted turnover of commercial vehicles will decrease about 9.5 per cent from 2020 level.
   x. The comprehensive energy consumption per unit of converted turnover of railways will drop by 10 per cent from 2020 level by 2030, and oil consumption by land transportation strives to peak.

4. **Indonesia**
   i. Emission reduction target of 31.9 per cent conditionally[25] and 43.2 per cent unconditionally[26] from BAU.
   ii. Achieve national GHG emissions peak in 2030 and net zero by 2060 or sooner.

5. **Mexico**
   i. Reduce GHG emissions by 35 per cent by 2030.
   ii. Conditional target is to reduce emissions to 40 per cent by 2030.
   iii. The unconditional and conditional targets for reduction of black carbon emissions are 51 per cent and 70 per cent, respectively.
   iv. Implement country's National Strategy for the Reduction of Emissions from Deforestation and Forest Degradation.
   v. Increase clean energy production to 40 GW.
   vi. Reduce 50 per cent of national GHGs by 2050 from 2000 levels.
   vii. Generate at least 50 per cent energy from clean sources.

6. **The Russian Federation**
   i. Reduce 70 per cent emissions by 2030 from 1990 levels.
   ii. Achieve net zero before 2060.
   iii. Reduce emissions by 60 per cent by 2050 from 2019 levels and 80 per cent from 1990 levels.

7. **South Africa**
   i. A fixed target for GHG emissions levels of 398–510 $MtCO_2e$ by 2025, and 350–420 $MtCO_2e$ by 2030.
   ii. Achieve net zero by 2050.

8. **Türkiye**
   i. Achieve net zero by 2053.
   ii. Reduce emissions by 41 per cent by 2030 compared to BAU.
   iii. Achieve peak emissions in 2038.

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[25] Conditional targets refer to climate targets which are dependent on external financial support.
[26] Unconditional targets refer to climate targets which the country can achieve without external financial support.

Appendix 3: Country-Wise Sectoral Carbon Emissions

EME	Power (Billion Tonnes) till 2021	Cement (Billion Tonnes) till 2022	Transport (Billion Tonnes) till 2020	Steel (Billion Tonnes) till 2022
1. Argentina	1.6	0.2	1.2	0.2
2. Brazil	2.1	0.8	4.5	1.2
3. China	95.8	16.4	13.8	33.6
4. India*	22.6	2.8	4.8	4.2
5. Indonesia	4.4	0.7	2.6	0.5
6. Mexico	5.4	0.7	3.8	0.4
7. The Russian Federation	30.9	1.7	7.1	3.3
8. South Africa	7.7	0.3	1.3	0.4
9. Türkiye	3.1	1.0	1.4	0.5
Total (1 to 9)	**173.7**	**24.5**	**40.6**	**44.2**
Global	**393.5**	**46.6**	**197.3**	**59.9**
Share of Nine EMEs in Global Sectoral Emissions (per cent)	**44**	**53**	**21**	**74**

**Refer to Raj and Mohan (2025)for details of India's figures.*

Source: Authors' calculations based on the data from Climate Watch (2024), Our World in Data (2023), Our World in Data (2023a), and World Steel Association (2024).

Appendix 4: Climate Finance Requirements - Power Sector

Table A4.1: Argentina—Power Sector

(Installed Capacity in GW; Amount in US$ Billion)

		Installed Capacity (GW)			Total Electricity Generation (TWh)			Capex (US$ Billion)		
Source	**Capacity Factor* (per cent)**	**Installed Capacity - 2023 (Actual)**	**Projected - 2030**	**BAU Scenario - 2030**	**Based on Projected Installed Capacity - 2030**	**Based on BAU Scenario - 2030**	**Unit Capital Cost (US$ Million per MW of Installed Capacity)**	**Based on Projected Installed Capacity (2024–2030)**	**Based on BAU Scenario (2024–2030)**	**ACE 2024-2030**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11) = (9 - 10)**
1. Fossil-Based	–	**24**	**26**	**32**	**92**	**112**	–	**2**	**9**	**-6.6**
Coal-Based	40	24	25	31	89	108	1.16	2	8	-6.4
Gas-Based	50	1	1	1	3	4	1.4	0	0	-0.2
2. Non-Fossil Fuel-Based	–	**17**	**33**	**28**	**148**	**128**	–	**28**	**19**	**9.9**
Hydro	46	11	13	11	53	46	2.5	6	2	4.5
Solar PV	25.8	1	3	2	6	5	1.4	2	1	0.5
Wind	55	3	14	12	67	58	1.4	15	13	2.7
Biomass	72	0	1	0	3	3	2.8	1	0	0.2
Nuclear	88	2	2	2	18	16	6.6	5	3	2.1
3. Total (1 + 2)	–	**41**	**59**	**60**	**240**	**240**	–	**3**	**6**	**3.3**
4. Storage	–	1.32	2.58	2.23	–	–	–	1	1	0.5
Battery Storage	–	0.35	1.84	1.59	–	–	1,141[#]	1.57	1.32	0.3
Pump Storage	–	0.97	0.75	0.65	–	–	2,500[#]	-0.6	-0.8	0.3
Grand Total (3 + 4)	–	–	–	–	**240**	**240**	–	–	–	**3.8**

ACE: Additional capital expenditure.

TWh: Terawatt-hours

**The capacity (plant load) factor of fossil fuel-based sources of power is much larger than that of non-fossil fuel-based sources (other than nuclear-based sources). Therefore, the installed capacity of fossil fuel-based sources of power in the BAU was adjusted to match the power generated based on the projected installed capacity for 2030.*

[#]US$ million per GW of storage installed capacity.

Note: 1. The capital cost for battery storage is expected to decrease by 2030. Therefore, the battery storage cost for each year from 2024 to 2030 has been based on the average cost for 2024 and 2030.

2. Since the estimates of battery storage and pumped storage were not available for Argentina, we used the global estimates of battery storage for Argentina and the average of four countries (India, China, Indonesia, and South Africa) for pumped storage.

3. Some totals may not add up due to rounding off of figures.

Source: IRENA, IEA, IHA, Energy Box, and authors' calculations.

Table A4.2: Brazil - Power Sector

(Installed Capacity in GW; Amount in US$ Billion)

		Installed Capacity (GW)			Total Electricity Generation (TWh)			Capex (US$ Billion)		
Source	**Capacity Factor* (per cent)**	**Installed Capacity - 2023 (Actual)**	**Projected - 2030**	**BAU Scenario - 2030**	**Based on Projected Installed Capacity - 2030**	**Based on BAU Scenario - 2030**	**Unit Capital Cost (US$ Million per MW of Installed Capacity)**	**Based on Projected Installed Capacity (2024–2030)**	**Based on BAU Scenario (2024–2030)**	**ACE 2024-2030**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11) = (9 -10)**
1. Fossil-Based	–	**22**	**31**	**26**	**110**	**92**	–	**5**	**1**	**4**
Coal-Based	50	3	4	3	16	13	2.9	0	-1	2
Gas-Based	40	18	27	23	95	79	0.5	4	2	2
2. Non-Fossil Fuel-Based	–	**196**	**227**	**232**	**855**	**873**	–	**54**	**61**	**-6**
Hydro	46	110	123	126	496	507	1.6	21	25	-4
Solar PV	17	38	47	48	70	71	0.7	6	7	-1
Wind	42	29	31	32	113	115	0.9	2	2	-1
Biomass	72	17	18	19	114	117	0.4	0	1	0
Nuclear	88	2	8	8	62	63	4.09	25	25	-1
3. Total (1 + 2)	–	**218**	**258**	**258**	**965**	**965**	–	**59**	**61**	**-2**
4. Storage	–	0.37	30.1	30.6	–	–	–	30.3	30.7	-0.6
Battery Storage	–	0.35	25	25.32	–	–	1,141[#]	23.8	24.3	-0.5
Pump Storage	–	0.02	5.21	5.32	–	–	1,220[#]	6.5	6.5	-0.1
Grand Total (3 + 4)	–	–	–	–	**965**	**965**	–	–	–	**-3**

ACE: Additional capital expenditure.

TWh: Terawatt-hours.

**The capacity (plant load) factor of fossil fuel-based sources of power is much larger than that of non-fossil fuel-based sources (other than nuclear-based sources). Therefore, the installed capacity of fossil fuel-based sources of power in the BAU was adjusted to match the power generated based on the projected installed capacity for 2030.*

[#]US$ Million per GW of storage installed capacity.

Note: 1. The capital cost for battery storage is expected to decrease by 2030. Therefore, the battery storage cost for each year from 2024 to 2030 has been based on the average cost for 2024 and 2030.

2. Since the estimates of battery storage and pumped storage were not available for Brazil, we used the global estimates of battery storage for Brazil and the average of four countries (India, China, Indonesia, and South Africa) for pumped storage.

3. Some totals may not add up due to rounding off of figures.

Source: IRENA, IEA, IHA, Energy Box, and authors' calculations.

Table A4.3: China - Power Sector

(Installed Capacity in GW; Amount in US$ Billion)

		Installed Capacity (GW)			Total Electricity Generation (TWh)			Capex (US$ Billion)		
Source	**Capacity Factor* (per cent)**	**Installed Capacity - 2023 (Actual)**	**Projected - 2030**	**BAU Scenario - 2030**	**Based on Projected Installed Capac-ity—2030**	**Based on BAU Scenario - 2030**	**Unit Capital Cost (US$ Million per MW of Installed Capacity)**	**Based on Projected Installed Capacity (2024–2030)**	**Based on BAU Scenario (2024–2030)**	**ACE 2024-2030**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11) = (9-10)**
1. Fossil-Based	–	**1,272**	**1,655**	**1,718**	**6,969**	**7,233**	–	**331**	**382**	**-52**
Coal-Based	53	1,160	1,300	1,349	6,036	6,265	0.80	112	151	-39
Gas-Based	30	112	355	368	933	968	0.90	219	231	-12
2. Non-Fossil Fuel-Based	–	**1,562**	**3,141**	**3,044**	**8,570**	**8,305**	–	**1,686**	**1,584**	**102**
Hydro	46	410	550	533	2,216	2,148	1.20	168	148	20
Solar PV	13	610	1,200	1,163	1,367	1,324	0.60	354	332	22
Onshore Wind	35	404	1,091	1,057	3,344	3,241	1.10	755	718	37
Offshore Wind	37	37	109	106	354	343	2.80	202	192	9
Biomass	72	44	71	69	448	434	1.60	43	40	4
Nuclear	80	57.00	120	116	841	815	2.60	164	154	10
3. Total (1+2)	–	**2,834**	**4,796**	**4,762**	**15,539**	**15,539**	**–**	**2,017**	**1,966**	**50**
4. Storage	–	74	316	306	–	–	–	105	101	5
Battery Storage	–	23	196	190	–	–	310[#]	50	49	2
Pump Storage	–	51	120	116	–	–	794[#]	55	52	**3**
Grand Total (3+4)	–	–	–	–	**15,539**	**15,539**	–	–	–	**55**

ACE: Additional capital expenditure.

TWh: Terawatt-hours.

**The capacity (plant load) factor of fossil fuel-based sources of power is much larger than that of non-fossil fuel-based sources (other than nuclear-based sources). Therefore, the installed capacity of fossil fuel-based sources of power in the BAU was adjusted to match the power generated based on the projected installed capacity for 2030.*

[#]US$ million per GW of storage installed capacity.

Note: 1. The capital cost for battery storage is expected to decrease by 2030. Therefore, the battery storage cost for each year from 2024 to 2030 has been based on the average cost for 2024 and 2030.

2. Some totals may not add up due to rounding off of figures.

Source: IRENA, IEA, IAEA IHA, and authors' calculations.

Table A4.4: Indonesia - Power Sector

(Installed Capacity in GW; Amount in US$ Billion)

		Installed Capacity (GW)			Total Electricity Generation (TWh)			Capex (US$ Billion)		
Source	**Capacity Factor* (per cent)**	**Installed Capacity - 2023 (Actual)**	**Projected - 2030**	**BAU Scenario - 2030**	**Based on Projected Installed Capacity - 2030**	**Based on BAU Scenario - 2030**	**Unit Capital Cost (US$ Million per MW of Installed Capacity)**	**Based on Projected Installed Capacity (2024–2030)**	**Based on BAU Scenario (2024–2030)**	**ACE 2024-2030**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11) = (9 - 10)**
1. Fossil-Based	–	**59**	**82**	**94**	**324**	**371**	–	**23.19**	**40.30**	**-17.11**
Coal-Based	49	41	45	51	192	219	2	7.99	20.93	-12.94
Gas-Based	40	18	38	43	133	152	0.7	15.20	19.37	-4.17
2. Non-Fossil Fuel-Based	–	**11**	**26**	**17**	**99**	**53**	–	**25.34**	**7.95**	**17.39**
Hydro	46	7	15	4	60	17	1.8	14.50	-4.84	19.34
Solar PV	17	0.4	5	10	7	14	0.9	4.08	8.39	-4.32
Wind	37	0.2	3	3	9	11	2.3	5.63	7.13	-1.50
Biomass	72	3	4	2	24	11	1.9	1.14	-2.73	3.87
3. Total (1 + 2)	–	**69**	**109**	**112**	**424**	**424**	–	**48.53**	**48.24**	**0.28**
4. Storage	–	1.06	4.6	3	–	–	–	5.69	3.15	2.55
Battery Storage	–	0.02	0.3	0.2	–	–	1,480#	0.40	0.25	0.14
Pump Storage	–	1.04	4	2.8	–	–	1,625#	5.30	2.89	2.41
Grand Total (3 + 4)	–	–	–	–	**424**	**424**	–	–	–	**2.83**

ACE: Additional capital expenditure.

TWh: Terawatt-hours.

**The capacity (plant load) factor of fossil fuel-based sources of power is much larger than that of non-fossil fuel-based sources (other than nuclear-based sources). Therefore, the installed capacity of fossil fuel-based sources of power in the BAU was adjusted to match the power generated based on the projected installed capacity for 2030.*

#US$ Million Per GW of storage installed capacity.

Note: 1. The capital cost for battery storage is expected to decrease by 2030. Therefore, the battery storage cost for each year from 2024 to 2030 has been based on the average cost for 2024 and 2030.

2. Some totals may not add up due to rounding off of figures.

Source: IRENA, IEA, IAEA IHA, McKinsey & Company, NREL, and authors' calculations.

Table A4.5: Mexico - Power Sector

(Installed Capacity in GW; Amount in US$ Billion)

		Installed Capacity (GW)			Total Electricity Generation (TWh)			Capex (US$ Billion)		
Source	**Capacity Factor* (per cent)**	**Installed Capacity - 2023 (Actual)**	**Projected - 2030**	**BAU Scenario - 2030**	**Based on Projected Installed Capacity - 2030**	**Based on BAU Scenario - 2030**	**Unit Capital Cost (US$ Million per MW of Installed Capacity)**	**Based on Projected Installed Capacity (2024–2030)**	**Based on BAU Scenario (2024–2030)**	**ACE 2024-2030**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11) = (9 - 10)**
1. Fossil-Based	–	**43**	**60**	**68**	**215**	**244**	–	**12**	**18**	**-6**
Coal-Based	50	6	6	6	25	28	1.04	0	0	-0.8
Gas-Based	40	37	54	62	190	216	0.7	12	17	-5
2. Non-Fossil Fuel-Based	–	**32**	**79**	**69**	**230**	**200**	–	**63**	**47**	**15**
Hydro	46	12	17	15	67	59	2.9	12	6	6
Solar PV	17	9	30	26	44	39	0.8	17	13	3
Wind	37	7	30	26	98	86	1.5	34	28	6
Biomass	72	1	1	1	8	7	1	0	0	0
Nuclear	88	2	2	1	12	11	2.1	0	0	0
3. Total (1 + 2)	–	**75**	**139**	**137**	**445**	**445**	–	**75**	**65**	**10**
4. Storage	–	2.7	44	39	–	–	–	42.0	36.5	5.5
Battery Storage	–	2.7	42	37	–	–	1,141#	39.8	34.6	5.2
Pump Storage	–	0	2	2	–	–	1,220#	2.2	1.9	0.3
Grand Total (3 + 4)	–	–	–	–	**445**	**445**	–	–	–	**15**

ACE: Additional capital expenditure.

TWh: Terawatt-hours.

**The capacity (plant load) factor of fossil fuel-based sources of power is much larger than that of non-fossil fuel-based sources (other than nuclear-based sources). Therefore, the installed capacity of fossil fuel-based sources of power in the BAU was adjusted to match the power generated based on the projected installed capacity for 2030.*

#US$ Million Per GW of storage installed capacity.

Note: 1. The capital cost for battery storage is expected to decrease by 2030. Therefore, the battery storage cost for each year from 2024 to 2030 has been based on the average cost for 2024 and 2030.

2. Since the estimates of battery storage and pumped storage were not available for Mexico, we used the global estimates of battery storage for Mexico and the average of four countries (India, China, Indonesia, and South Africa) for pumped storage. 3. Some totals may not add up due to rounding off of figures.

Source: IRENA, IEA, IAEA IHA, World Hydropower Outlook 2024, and authors' calculations

Table A4.6: The Russian Federation - Power Sector

(Installed Capacity in GW; Amount in US$ Billion)

		Installed Capacity (GW)			Total Electricity Generation (TWh)			Capex (US$ Billion)		
Source	**Capacity Factor* (per cent)**	**Installed Capacity - 2023 (Actual)**	**Projected - 2030**	**BAU Scenario - 2030**	**Based on Projected Installed Capacity - 2030**	**Based on BAU Scenario - 2030**	**Unit Capital Cost (US$ Million per MW of Installed Capacity)**	**Based on Projected Installed Capacity (2024–2030)**	**Based on BAU Scenario (2024–2030)**	**ACE 2024-2030**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11) = (9 - 10)**
1. Fossil-Based	–	**88**	**100**	**122**	**374**	**455**	–	**10**	**36**	**-25**
Coal-Based	50	38	39	47	170	208	1.8	1	16	-15
Gas-Based	38	50	62	75	204	246	0.8	9	20	-11
2. Non-Fossil Fuel-Based	–	**91**	**132**	**118**	**744**	**664**	–	**130**	**96**	**34**
Hydro	46	56	59	53	238	212	1.2	4	-4	8
Solar PV	17	2	6	6	9	8	1.7	7	6	1
Wind	37	2	3	3	10	9	2.3	2	1	1
Biomass	72	1	1	1	9	8	0.75	0	0	0
Nuclear	88	29	62	55	478	426	3.58	117	93	24
3. Total (1 + 2)	–	**179**	**232**	**240**	**1,118**	**1,118**	–	**140**	**132**	**8**
4. Storage	–	1.3	10.4	9.3	–	–	–	3.8	3.2	0.6
Battery Storage	–	0.00	7	6.6	–	–	28#	1.8	1.6	0.2
Pump Storage	–	1.3	3.02	2.7	–	–	1,220#	2.0	1.6	0.4
Grand Total (3 + 4)	–	–	–	–	**1,118**	**1,118**	–	–	–	**9**

ACE: Additional capital expenditure.

TWh: Terawatt-hours.

**The capacity (plant load) factor of fossil fuel-based sources of power is much larger than that of non-fossil fuel-based sources (other than nuclear-based sources). Therefore, the installed capacity of fossil fuel-based sources of power in the BAU was adjusted to match the power generated based on the projected installed capacity for 2030.*

#US$ million per GW of storage installed capacity.

Note: 1. The capital cost for battery storage is expected to decrease by 2030. Therefore, the battery storage cost for each year from 2024 to 2030 has been based on the average cost for 2024 and 2030.

2. Since the estimates of battery storage and pumped storage were not available for the Russian Federation, we used the global estimates of battery storage for the Russian Federation and the average of four countries (India, China, Indonesia, and South Africa) for pumped storage.

3. Some totals may not add up due to rounding off of figures.

Source: IRENA, IEA, IAEA, World Hydropower Outlook 2024, World Bank, and authors' calculations

Table A4.7: South Africa - Power Sector

(Installed Capacity in GW; Amount in US$ Billion)

		Installed Capacity (GW)			Total Electricity Generation (TWh)			Capex (US$ Billion)		
Source	**Capacity Factor* (per cent)**	**Installed Capacity - 2023 (Actual)**	**Projected - 2030**	**BAU Scenario - 2030**	**Based on Projected Installed Capacity - 2030**	**Based on BAU Scenario - 2030**	**Unit Capital Cost (US$ Million per MW of Installed Capacity)**	**Based on Projected Installed Capacity (2024–2030)**	**Based on BAU Scenario (2024–2030)**	**ACE 2024-2030**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11) = (9 - 10)**
1. Fossil-Based	–	**47**	**44**	**50**	**158**	**182**	–	**-5**	**5**	**-10**
Coal-Based	50	44	34	39	148	170	1.5	-15	-7	-8
Gas-Based	12	3	10	12	11	12	1.4	10	12	-2
2. Non-Fossil Fuel-Based	–	**16**	**32**	**24**	**103**	**78**	–	**29**	**15**	**14**
Hydro	60	3	4	3	21	16	1.5	1	-1	2
Solar PV	25	7	8	6	17	13	1.2	1	-1	2
Wind	34	3	18	13	52	39	1.9	27	19	8
Biomass	72	0	0	0	3	2	2.5	0	0	0
Nuclear	62	2	2	1	10	8	5.4	0	-2	2
3. Total (1 + 2)	–	**63**	**75**	**75**	**261**	**261**	–	**24**	**20**	**4**
4. Storage	–	3.70	9.3	7	–	–	–	10	6	4
Battery Storage	–	0.30	2	2	–	–	2,113#	3	2	1
Pump Storage	–	3.4	7.30	6	–	–	1,682#	7	4	3
Grand Total (3 + 4)	–	–	–	–	**261**	**261**	–	–	–	**8**

ACE: Additional capital expenditure.

TWh: Terawatt-hours

**The capacity (plant load) factor of fossil fuel-based sources of power is much larger than that of non-fossil fuel-based sources (other than nuclear-based sources). Therefore, the installed capacity of fossil fuel-based sources of power in the BAU was adjusted to match the power generated based on the projected installed capacity for 2030.*

#US$ million per GW of storage installed capacity.

Note: 1. The capital cost for battery storage is expected to decrease by 2030. Therefore, the battery storage cost for each year from 2024 to 2030 has been based on the average cost for 2024 and 2030.

2. Some totals may not add up due to rounding off of figures.

Source: IRENA, IEA, Cigre Southern Africa, NPUC, Res4Africa Foundation, and authors' calculations.

Table A4.8: Türkiye - Power Sector

(Installed Capacity in GW; Amount in US$ Billion)

		Installed Capacity (GW)			Total Electricity Generation (TWh)			Capex (US$ Billion)		
Source	**Capacity Factor* (per cent)**	**Installed Capacity - 2023 (Actual)**	**Projected - 2030**	**BAU Scenario - 2030**	**Based on Projected Installed Capacity - 2030**	**Based on BAU Scenario - 2030**	**Unit Capital Cost (US$ Million per MW of Installed Capacity)**	**Based on Projected Installed Capacity (2024–2030)**	**Based on BAU Scenario (2024–2030)**	**ACE 2024-2030**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11) = (9 - 10)**
1. Fossil-Based	–	**45**	**59**	**59**	**337**	**338**	–	**6.38**	**6.50**	**-0.12**
Coal-Based	56	22	24	24	116	117	1.11	1.89	1.96	-0.08
Gas-Based	71	23	36	36	221	221	0.37	4.49	4.53	-0.04
2. Non-Fossil Fuel-Based	–	**57**	**109**	**109**	**365**	**364**	–	**80.30**	**79.84**	**0.46**
Hydro	46	32	35	35	141	141	2.3	7.83	7.64	0.19
Solar PV	17	11	30	30	44	44	1	19.10	19.03	0.07
Wind	34	12	30	30	89	89	1.8	33.12	32.99	0.13
Biomass	72	2	14	14	91	90	1.7	20.25	20.19	0.06
3. Total (1 + 2)	–	**102**	**168**	**168**	**702**	**702**	–	**86.68**	**86.34**	**0.34**
4. Storage	–	0.25	80	80	–	–	–	**96.98**	**96.75**	**0.23**
Battery Storage	–	0.25	2	2	–	–	1,141[#]	1.92	1.92	0.01
Pump Storage	–	0.00	78	78	–	–	1,220[#]	95.06	94.83	0.23
Grand Total (3 + 4)	–	–	–	–	**702**	**702**	–	–	–	**0.57**

ACE: Additional capital expenditure.

TWh: Terawatt-hours

**The capacity (plant load) factor of fossil fuel-based sources of power is much larger than that of non-fossil fuel-based sources (other than nuclear-based sources). Therefore, the installed capacity of fossil fuel-based sources of power in the BAU was adjusted to match the power generated based on the projected installed capacity for 2030.*

[#]US$ million per GW of storage installed capacity.

Note: 1. The capital cost for battery storage is expected to decrease by 2030. Therefore, the battery storage cost for each year from 2024 to 2030 has been based on the average cost for 2024 and 2030.

2. Since the estimates of battery storage and pumped storage were not available for Türkiye, we used the global estimates of battery storage for Türkiye and the average of four countries (India, China, Indonesia, and South Africa) for pumped storage.

3. Some totals may not add up due to rounding off of figures.

Source: IRENA, IEA, IBANET, World Hydropower Outlook 2024, Energy Trend, and authors' calculations

Appendix 5: Climate Finance Requirements - Road Transport Sector

Table A5.1: Argentina - Road Transport Sector

(Vehicle Sales in '000; Amount in US$ Billion)

Vehicle Category	Vehicle Type	Per unit Capital Cost (US$)	Vehicles Sold in 2022 (Actual)	Projected Sales - 2030	Capex Based on Projected Sales - 2030	BAU Sales - 2030	Capex Based on Sales in BAU Scenario - 2030	Climate Finance - 2030
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9) = (6 - 8)
ICEVs	2W	4,860	368	745	3.6	776	3.8	-0.15
	3W	–	–	–	–	–	–	–
	Cars & Taxis	22,050	263	783	17	816	18	-0.72
	Bus	2,12,500	2	2	0.4	2	0.5	-0.02
	Trucks/Goods Vehicles (light commercial vehicles [LCV])	28,350	145	146	4	152	4	-0.17
	TOTAL	–	778	1,676	25	1,746	27	-1.06
EVs	2W	8,245	20	39	0.32	26	0.22	0.11
	3W	–	–	–	–	–	–	–
	Cars & Taxis	31,950	25	170	5	114	4	1.81
	Bus	3,67,500	0.03	1	1	1	0	0.17
	Trucks/Goods Vehicles (LCV)	–	–	–	–	–	–	–
	TOTAL	–	45	211	6	141	4	2.09
A. Total (ICEVs + EVs)	–	–	823	1,887	32	1,887	31	1.02
B. Capex for Charging Infrastructure	**Refer to Table A5.2 for details**							**0.18**
Grand Total	–	–	–	–	–	–	–	**1**

ICEVs: Internal Combustion Engine Vehicles.

EVs: Electric Vehicles.

LCV: Light Commercial Vehicle

Source: Statista and authors' calculations..

Table A5.2: Charging Infrastructure

(Amount in US$ Billion)

	Per Unit Capital Cost ($)	Number of Charging Stations - 2022 (Actual)	Number of Charging Stations Based on Projections - 2030	Number of Charging Stations in BAU Scenario - 2030	Capex Based on Projections of Charging Stations (2024–2030)	Capex Based on Charging Stations in BAU Scenario (2024–2030)	Climate Finance (2024–2030)	Climate Finance - 2030
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8) = (6-7)	(9)
Charging Infrastructure	55,000	37	16,571	11,069	0.91	0.61	0.30	0.18

Source: Yamamura et al. (2022), Electromaps, and authors' calculations.

Table A5.3: Brazil - Road Transport Sector

(Vehicle Sales in '000; Amount in US$ Billion)

Vehicle Category	Vehicle Type	Per Unit Capital Cost (US$)	Vehicles Sold in 2022 (Actual)	Projected Sales - 2030	Capex Based on Projected Sales - 2030	BAU Sales - 2030	Capex Based on Sales in BAU Scenario - 2030	Climate Finance - 2030
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9) = (6 - 8)
ICEVs	2W	4,860	1,357	2,152	8.6	2,385	9.5	-1
	3W	–	–	–	–	–	–	–
	Cars & Taxis	22,050	1,262	1,359	30	1,506	33	-3
	Bus	2,12,500	12	12	2.6	13	2.9	0
	Trucks/Goods Vehicles (LCV)	28,350	516	516	15	572	16	-2
	TOTAL	–	3,147	4,039	56	4,477	62	-6
EVs	2W	8,245	53	420	2.63	162	1.01	2
	3W	–	–	–	–	–	–	–
	Cars & Taxis	31,950	107	272	9	105	3	5
	Bus	3,67,500	0	11	4	4	2	2
	Trucks/Goods Vehicles (LCV)	72,328	2	8	1	3	0	0
	TOTAL	–	162	712	16	274	6	10
A. Total (ICEVs + EVs)	–	–	3,309	4,751	72	4,751	68	4
B. Capex for Charging Infrastructure	**Refer to the Table A5.4 for details**							**2**
Grand Total	–	–	–	–	–	–	–	**6**

ICEVs: Internal Combustion Engine Vehicles.

EVs: Electric Vehicles.

LCV: Light Commercial Vehicle.

Source: Statista and authors' calculations.

Table A5.4: Charging Infrastructure

(Amount in US$ Billion)

	Per Unit Capital Cost ($)	Number of Charging Stations - 2022 (Actual)	Number of Charging Stations Based on Projections - 2030	Number of Charging Stations in BAU Scenario - 2030	Capex Based on Projections of Charging Stations (2024 - 2030)	Capex Based on Charging Stations in BAU Scenario (2024–2030)	Climate Finance (2024–2030)	Climate Finance - 2030
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8) = (6 - 7)	(9)
Charging Infrastructure	55,000	401	1,00,000	38,455	5.48	2.09	3.38	2

Source: Yamamura et al. (2022), Electromaps, National Platform for Electric Mobility (2021), and authors' calculations.

Table A5.5: China - Road Transport Sector

(Vehicle Sales in '000; Amount in US$ Billion)

Vehicle Category	Vehicle Type	Per Unit Capital Cost (US$)	Vehicles Sold in 2022 (Actual)	Projected Sales - 2030	Capex Based on Projected Sales - 2030	BAU Sales - 2030	Capex Based on Sales in BAU Scenario - 2030	Climate Finance - 2030
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9) = (6 - 8)
ICEVs	2W	600	5,100	10,910	6.5	12,595	7.6	-1
	3W	1,150	1,109	2,556	3	2,951	3	-0.45
	Cars & Taxis	21,679	23,836	9,334	202	10,776	234	-31
	Bus	75,000	89	178	13.4	206	15.4	-2
	Trucks/Goods Vehicles (LCV)	58,157	3,096	4,050	236	4,676	272	-36
	TOTAL	–	33,230	27,029	461	31,204	532	-71
EVs	2W	1,000	45,000	30,000	30	27,234	27.23	3
	3W	5,250	350	1,364	7	1,238	6	1
	Cars & Taxis	30,060	5,900	13,300	400	12,074	363	37
	Bus	2,45,000	54	165	40	149	37	4
	Trucks/Goods Vehicles (LCV)	63,303	183	450	28	409	26	3
	TOTAL	–	51,487	45,278	506	41,103	459	47
A. Total (ICEVs + EVs)	–	–	84,717	72,307	966	72,307	991	-25
B. Capex for Charging Infrastructure	**Refer to Table A5.6 for details**							**142**
Grand Total	–	–	–	–	–	–	–	**118**

ICEVs: Internal Combustion Engine Vehicles.

EVs: Electric Vehicles.

LCV: Light Commercial Vehicle.

Source: Statista and authors' calculations.

Table A5.6: Charging Infrastructure

(Amount in US$ Billion)

	Per Unit Capital Cost ($)	Number of Charging Stations - 2022 (Actual)	Number of Charging Stations Based on Projections - 2030	Number of Charging Stations in BAU Scenario - 2030	Capex Based on Projections of Charging Stations (2024–2030)	Capex Based on Charging Stations in BAU Scenario (2024–2030)	Climate Finance (2024–2030)	Climate Finance - 2030
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8) = (6 - 7)	(9)
Charging Infrastructure	3,45,127	18,00,000	1,40,00,000	1,27,09,040	4,211	3,765	446	142

Source: IEA, Moko Smart, authors' calculations.

Table A5.7: Indonesia - Road Transport Sector

(Vehicle Sales in '000; Amount in US$ Billion)

Vehicle Category	Vehicle Type	Per unit Capital Cost (US$)	Vehicles Sold in 2022 (Actual)	Projected Sales - 2030	Capex Based on Projected Sales - 2030	BAU Sales - 2030	Capex Based on Sales in BAU Scenario - 2030	Climate Finance - 2030
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9) = (6 – 8)
ICEVs	2W	3,648	4,841	5,950	21.7	8,455	30.8	-9
	3W	–	–	–	–	–	–	–
	Cars & Taxis	24,217	1,028	802	19	1,139	28	-8
	Bus	1,47,370	3	0	0.0	2	0.3	-0.33
	Trucks/Goods Vehicles (LCV)	45,592	248	271	12	384	18	-5
	TOTAL	–	6,121	7,023	53	9,981	76	-23
EVs	2W	4,466	28	2,450	10.94	83	0.37	11
	3W	-	–	–	-	–	–	–
	Cars & Taxis	30,365	20	600	18	20	1	18
	Bus	3,52,275	0	11	4	0	0	3
	Trucks/Goods Vehicles (LCV)	1,77,182	0	0	0	0	0	0.08
	TOTAL	–	48	3,061	33	104	1	32
A. Total (ICEVs + EVs)	–	–	6,169	10,084	86	10,084	77	9
B. Capex for Charging Infrastructure	**Refer to Table A5.8 for details**							**1.42**
Grand Total	–	–	–	–	–	–	–	**10**

ICEVs: Internal Combustion Engine Vehicles.

EVs: Electric Vehicles.

LCV: Light Commercial Vehicle.

Source: Statista and authors' calculations.

Table A5.8: Charging Infrastructure

(Amount in US$ Billion)

	Per Unit Capital Cost ($)	Number of Charging Stations - 2022 (Actual)	Number of Charging Stations Based on Projections - 2030	Number of Charging Stations in BAU Scenario - 2030	Capex Based on Projections of Charging Stations (2024 – 2030)	Capex Based on Charging Stations in BAU Scenario (2024 – 2030)	Climate Finance (2024 – 2030)	Climate Finance - 2030
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8) = (6 - 7)	(9)
Charging Infrastructure	1,08,284	439	31,859	1,081	3.40	0.07	3.33	1.42

Source: The Jakarta Post, Bolt Earth, and authors' calculations.

Table A5.9: Mexico - Road Transport Sector

(Vehicle Sales in '000;
Amount in US$ Billion)

Vehicle Category	Vehicle Type	Per unit Capital Cost (US$)	Vehicles Sold in 2022 (Actual)	Projected Sales - 2030	Capex Based on Projected Sales - 2030	BAU Sales - 2030	Capex Based on Sales in BAU Scenario - 2030	Climate Finance - 2030
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9) = (6 – 8)**
ICEVs	2W	7,823	374	755	5.9	771	6.0	-0.12
	3W	–	–	–	–	–	–	–
	Cars & Taxis	17,500	387	1,505	26	1,536	27	-0.54
	Bus	2,12,500	1.1	1	0.2	1	0.3	-0.01
	Trucks/Goods Vehicles (LCV)	49,611	646	659	33	673	33	-0.67
	TOTAL	–	1,408	2,921	65	2,981	67	-1.34
EVs	2W	12,453	18	35	0.44	23	0.29	0.15
	3W	–	–	–	-	-	–	–
	Cars & Taxis	39,500	31	121	5	80	3	1.63
	Bus	3,67,500	0.2	4	2	3	1	0.55
	Trucks/Goods Vehicles (LCV)	1,90,522	1	16	3	11	2	1.05
	TOTAL	–	50	177	10	117	7	3.38
A. Total (ICEVs + EVs)	–	–	1,458	3,098	75	3,098	73	2.03
B. Capex for Charging Infrastructure	**Refer to Table A5.10 for details**							**0.58**
Grand Total	–	–	–	–	–	–	–	**3**

ICEVs: Internal Combustion Engine Vehicles.

EVs: Electric Vehicles.

LCV: Light Commercial Vehicle.

Source: Statista and authors' calculations.

Table A5.10: Charging Infrastructure

(Amount in US$ Billion)

	Per Unit Capital Cost ($)	Number of Charging Stations - 2022 (Actual)	Number of Charging Stations Based on Projections - 2030	Number of Charging Stations in BAU Scenario - 2030	Capex Based on Projections of Charging Stations (2024 – 2030)	Capex Based on Charging Stations in BAU Scenario (2024 – 2030)	Climate Finance (2024 – 2030)	Climate Finance - 2030
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8) = (6 - 7)**	**(9)**
Charging Infrastructure	77,500	1,189	50,000	32,992	3.78	2.46	1.32	0.58

Source: Mexico Business News and authors' calculations.

Table A5.11: The Russian Federation - Road Transport Sector

(Vehicle Sales in '000; Amount in US$ Billion)

Vehicle Category	Vehicle Type	Per unit Capital Cost (US$)	Vehicles Sold in 2022 (Actual)	Projected Sales - 2030	Capex Based on Projected Sales - 2030	BAU Sales - 2030	Capex Based on Sales in BAU Scenario - 2030	Climate Finance - 2030
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9) = (6 - 8)
ICEVs	2W	4,622	3	19	0.1	22	0.1	-0.01
	3W	–	–	–	–	–	–	–
	Cars & Taxis	13,296	593	938	12	1,063	14	-1.66
	Bus	98,963	12	13	1.3	15	1.5	-0.18
	Trucks/Goods Vehicles (LCV)	51,475	148	165	9	187	10	-1.14
	TOTAL	–	756	1,135	22	1,287	25	-2.99
EVs	2W	19,502	0.1	0.2	0.00	0.04	0.00	0.00
	3W	-	–	–	–	–	–	–
	Cars & Taxis	55,204	37	189	10	42	2	8.13
	Bus	2,92,064	1	4	1	1	0	0.96
	Trucks/Goods Vehicles (LCV)	1,96,922	1	1	0	0	0	0.20
	TOTAL	–	38	195	12	43	3	9.29
A. Total (ICEVs + EVs)	–	–	795	1,330	34	1,330	28	6.30
B. Capex for Charging Infrastructure	**Refer to Table A5.12 for details**							**0.79**
Grand Total	–	–	–	–	–	–	–	7

ICEVs: Internal Combustion Engine Vehicles.

EVs: Electric Vehicles.

LCV: Light Commercial Vehicle.

Source: Statista and authors' calculations.

Table A5.12: Charging Infrastructure

(Amount in US$ Billion)

	Per Unit Capital Cost ($)	Number of Charging Stations – 2022 (Actual)	Number of Charging Stations Based on Projections – 2030	Number of Charging Stations in BAU Scenario - 2030	Capex Based on Projections of Charging Stations (2024 - 2030)	Capex Based on Charging Stations in BAU Scenario (2024 – 2030)	Climate Finance (2024–2030)	Climate Finance – 2030
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8) = (6 - 7)	(9)
Charging Infrastructure	33,789	1,664	73,000	16,090	2.41	0.49	1.92	0.79

Source: Interfax, Oreanda News, CE Energy News, and authors' calculations.

Table A5.13: South Africa – Road Transport Sector

(Vehicle Sales in '000; Amount in US$ Billion)

Vehicle Category	Vehicle Type	Per unit Capital Cost (US$)	Vehicles Sold in 2022 (Actual)	Projected Sales – 2030	Capex Based on Projected Sales – 2030	BAU Sales – 2030	Capex Based on Sales in BAU Scenario – 2030	Climate Finance – 2030
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9) = (6 - 8)
ICEVs	2W	3,040	15	30	0.1	31	0.1	0.00
	3W	–	–	–	–	–	–	–
	Cars & Taxis	34,667	317	366	13	381	13	-0.49
	Bus	2,52,927	1	0	0.1	0	0.1	0.00
	Trucks/Goods Vehicles (LCV)	60,223	165	166	10	173	10	-0.39
	TOTAL	–	497	563	23	585	24	-0.88
EVs	2W	14,406	1	2	0.03	2	0.02	0.01
	3W	–	–	–	–	–	–	–
	Cars & Taxis	42,710	40	66	3	47	2	0.81
	Bus	4,79,230	0	3	2	2	1	0.44
	Trucks/Goods Vehicles (LCV)	1,93,962	0	4	1	3	1	0.22
	TOTAL	–	41	75	5	54	4	1.48
A. Total (ICEVs + EVs)	–	–	538	638	28	638	27	0.60
B. Capex for Charging Infrastructure	**Refer to Table A5.14 for details**							**0.06**
Grand Total	–	–	–	–	–	–	–	**1**

ICEVs: Internal Combustion Engine Vehicles.

EVs: Electric Vehicles.

LCV: Light Commercial Vehicle.

Source: Statista and authors' calculations.

Table A5.14: Charging Infrastructure

(Amount in US$ Billion)

	Per Unit Capital Cost ($)	Number of Charging Stations – 2022 (Actual)	Number of Charging Stations Based on Projections – 2030	Number of Charging Stations in BAU Scenario – 2030	Capex Based on Projections of Charging Stations (2024 – 2030)	Capex Based on Charging Stations in BAU Scenario (2024 – 2030)	Climate Finance (2024 – 2030)	Climate Finance – 2030
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8) = (6 - 7)	(9)
Charging Infrastructure	77,500	316	7,033	5,013	0.52	0.36	0.16	0.06

Source: Parking Today, Bolt Earth, and authors' calculations.

Table A5.15: Türkiye – Road Transport Sector

(Vehicle Sales in '000; Amount in US$ Billion)

Vehicle Category	Vehicle Type	Per unit Capital Cost (US$)	Vehicles Sold in 2022 (Actual)	Projected Sales – 2030	Capex Based on Projected Sales – 2030	BAU Sales – 2030	Capex Based on Sales in BAU Scenario – 2030	Climate Finance – 2030
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9) = (6 - 8)
ICEVs	2W	3,970	210	441	1.7	459	1.8	-0.07
	3W	–	–	–	–	–	–	–
	Cars & Taxis	38,827	485	632	25	658	26	-1.03
	Bus	1,13,000	12	5	0.6	5	0.6	-0.02
	Trucks/Goods Vehicles (LCV)	1,18,399	20	20	2	21	3	-0.10
	TOTAL	–	727	1,098	29	1,144	31	-1.22
EVs	2W	11,046	9	18	0.20	10	0.11	0.09
	3W	–	–	–	–	-	–	–
	Cars & Taxis	57,100	16	84	5	48	3	2.05
	Bus	2,31,810	1	5	1	3	1	0.51
	Trucks/Goods Vehicles (LCV)	1,36,500	NA	NA	NA	NA	NA	NA
	TOTAL	–	26	107	6	61	4	2.65
A. Total (ICEVs + EVs)	–	–	753	1,205	35	1,205	34	1.42
B. Capex for Charging Infrastructure	**Refer to Table A5.16 for details**							**0.14**
Grand Total	–	–	–	–	–	–	–	**2**

ICEVs: Internal Combustion Engine Vehicles.

EVs: Electric Vehicles.

LCV: Light Commercial Vehicle.

Source: Statista and authors' calculations.

Table A5.16: Charging Infrastructure

(Amount in US$ Billion)

	Per Unit Capital Cost ($)	Number of Charging Stations – 2022 (Actual)	Number of Charging Stations Based on Projections – 2030	Number of Charging Stations in BAU Scenario – 2030	Capex Based on Projections of Charging Stations (2024 – 2030)	Capex Based on Charging Stations in BAU Scenario (2024 – 2030)	Climate Finance (2024 – 2030)	Climate Finance – 2030
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8) = (6 - 7)	(9)
Charging Infrastructure	1,39,050	1,647	8,571	4,895	0.96	0.45	0.51	0.14

Source: Energy Terminal, authors' calculations.

Appendix 6: Data Sources - Steel and Cement Sectors

Table A6.1: Sources

Variables	Year	Cement	Steel
Production Volume	2022	Cembureau	Net-Zero Industry
CO_2 Emissions	2022	Our World in Data	Net-Zero Industry
Cost of Carbon Capture Storage Technology	Various Years	Global CCS Institute, IEA	Global CCS Institute, IEA
Production Projection	2030	World Cement Association	Net-Zero Industry

Appendix 7: Projected External Financial Flows - Business-as-Usual

The indicators, *i.e.*, (i) CAD, (ii) capital and financial flows, and (iii) monetary base (M0) have been arrived at as indicated below:

1. **Current Account Balance:** Projected using the historical 10-year average of exports-to-world GDP and imports-to-domestic GDP ratios (excluding COVID-19 years 2020–2021 and 2021–2022), applied to IMF's GDP forecasts up to 2030. Exports and imports include goods, services, and primary and secondary income flows.

2. **Capital and Financial Flows and Foreign Exchange Reserves:** The foreign exchange reserves have been maintained at a constant percentage of GDP each year for each economy, consistent with the last year's (2022–2023) forex reserve levels. It is expected that the economies will continue to maintain the same level of foreign exchange reserves as 2022–2023 as percentage of GDP. As such capital and financial flows and CAB are all reflected in changes in foreign exchange reserves, as indicated by:

$$\Delta Foreign\ Exchange\ Reserves_t = Current\ Account\ Balance_t + Capital\ Inflows_t + Financial\ Inflows_t$$

3. **Monetary Base (M0):** The ratio of M0 to GDP was modelled through linear regression using data from 2008–2023, showing a strong fit (adjusted R^2 of 0.85–0.96 across economies). This relationship was then used to project M0 for 2024–2030 based on IMF's GDP forecasts.

Table A7.1: Country-Wise External Financial Flows and Monetary Base

Argentina

	Year	CAB		Capital and Financial Inflows		External Financial Flows*		Expansion in Monetary Base**	
		(Billion US$)	(percentage of GDP)	(Billion US$)	(percentage of GDP)	(Billion US$)	(percentage of GDP)	(Billion US$)	(percentage of GDP)
(1)	(2)	(3)	(4)	(5)	(6)	(7) = (3 + 5)	(8) = (4 + 6)	(9)	(10)
Actuals	2017–2018	-27	-5.2	28	5.3	11	2.1	20	3.8
	2018–2019	-3	-0.8	5	1.1	-21	-4.6	12	2.6
	2019–2020	3	0.7	-2	-0.4	-6	-1.5	9	2.3
	2020–2021	7	1.4	-5	-1.0	1	0.2	13	2.7
	2021–2022	-4	-0.7	7	1.2	5	0.8	14	2.2
	2022–2023	-23	-3.7	25	4.0	-22	-3.5	21	3.5
Projections	2023–2024	6	0.9	11	1.7	16	2.6	15	2.4
	2024–2025	5	0.8	6	1.0	11	1.8	15	2.4
	2025–2026	6	0.9	10	1.4	15	2.3	13	2.0
	2026–2027	7	1.0	11	1.6	19	2.7	10	1.4
	2027–2028	9	1.2	13	1.8	22	3.0	7	0.9
	2028–2029	10	1.4	15	2.0	26	3.4	6	0.8
	2029–2030	12	1.5	17	2.1	28	3.6	7	0.9

CAB - Current Account Balance.

**External Financial Flows = CAB + Capital and Financial Inflows.*

***Assuming the currency depreciates by 10 per cent every year against US$ (based on five years' CAGR before crisis in Argentina).*

Note: (i) This analysis was conducted before actual 2023–2024 data became available. Therefore, 2023–2024 figures are shown as projections, not actuals.

(ii) Projections for Argentina have been directly taken from the IMF's Article IV Report, 2023—Argentina. We have refrained from making independent projections due to the highly volatile and unstable nature of Argentina's economy in recent years.

Source: Balance of Payments and International Investment Position, IMF and IMF Article IV Report, Argentina.

Table A7.2: Brazil

	Year	CAB		Capital and Financial Inflows		External Financial Flows*		Expansion in Monetary Base**	
		(Billion US$)	(percentage of GDP)	(Billion US$)	(percentage of GDP)	(Billion US$)	(percentage of GDP)	(Billion US$)	(percentage of GDP)
(1)	(2)	(3)	(4)	(5)	(6)	(7) = (3 + 5)	(8) = (4 + 6)	(9)	(10)
Actuals	2017–2018	-55	-2.9	55	2.9	1	0.0	3	0.2
	2018–2019	-68	-3.6	67	3.6	-18	-1.0	6	0.3
	2019–2020	-28	-1.9	12	0.8	-1	-0.1	11	0.8
	2020–2021	-46	-2.8	50	3.0	7	0.4	4	0.2
	2021–2022	-48	-2.5	47	2.4	-38	-2.0	29	1.5
	2022–2023	-29	-1.4	29	1.4	21	1.0	39	1.9
Projections	2023–2024	-31	-1.4	55	2.5	24	1.1	-5	-0.2
	2024–2025	-35	-1.5	56	2.4	20	0.9	11	0.5
	2025–2026	-39	-1.6	60	2.5	21	0.9	11	0.5
	2026–2027	-44	-1.7	67	2.6	23	0.9	12	0.5
	2027–2028	-49	-1.8	74	2.7	24	0.9	12	0.4
	2028–2029	-56	-2.0	82	2.9	26	0.9	12	0.4
	2029–2030	-63	-2.1	90	3.0	27	0.9	12	0.4

CAB - Current Account Balance.

**External Financial Flows = CAB + Capital and Financial Inflows.*

***Assuming the currency depreciates by 5 per cent every year against US$ (based on five years' CAGR).*

Note: This analysis was conducted before actual 2023–2024 data became available. Therefore, 2023–2024 figures are shown as projections, not actuals.

Source: Balance of Payments and International Investment Position, IMF, and authors' calculations.

Table A7.3: China

	Year	CAB		Capital and Financial Inflows		External Financial Flows*		Expansion in Monetary Base**	
		(Billion US$)	(percentage of GDP)	(Billion US$)	(percentage of GDP)	(Billion US$)	(percentage of GDP)	(Billion US$)	(percentage of GDP)
(1)	(2)	(3)	(4)	(5)	(6)	(7) = (3 + 5)	(8) = (4 + 6)	(9)	(10)
Actuals	2017–2018	24	0.2	173	1.3	-67	-0.5	302	2.2
	2018–2019	103	0.7	8	0.1	55	0.4	-263	-1.8
	2019–2020	249	1.7	-61	-0.4	134	0.9	199	1.3
	2020–2021	353	2.0	-30	-0.2	71	0.4	140	0.8
	2021–2022	443	2.5	-257	-1.4	-121	-0.7	134	0.7
	2022–2023	253	1.4	-210	-1.1	-8	0.0	417	2.2
Projections	2023–2024	384	1.9	-182	-0.9	201	1.0	427	2.2
	2024–2025	368	1.8	-165	-0.8	203	1.0	236	1.1
	2025–2026	360	1.6	-149	-0.7	211	1.0	242	1.1
	2026–2027	347	1.5	-124	-0.5	223	1.0	252	1.1
	2027–2028	344	1.4	-120	-0.5	223	0.9	248	1.0
	2028–2029	327	1.3	-87	-0.3	240	0.9	263	1.0
	2029–2030	319	1.2	-76	-0.3	244	0.9	263	1.0

CAB - Current Account Balance.

**External Financial Flows = CAB + Capital and Financial Inflows.*

***Assuming the currency depreciates by 1.5 per cent every year against US$ (based on 10 years' CAGR).*

Note: This analysis was conducted before actual 2023–2024 data became available. Therefore, 2023–2024 figures are shown as projections, not actuals.

Source: Balance of Payments and International Investment Position, IMF, and authors' calculations.

Table A7.4: Indonesia

	Year	CAB		Capital and Financial Inflows		External Financial Flows*		Expansion in Monetary Base**	
		(Billion US$)	(percentage of GDP)	(Billion US$)	(percentage of GDP)	(Billion US$)	(percentage of GDP)	(Billion US$)	(percentage of GDP)
(1)	(2)	(3)	(4)	(5)	(6)	(7) = (3 + 5)	(8) = (4 + 6)	(9)	(10)
Actuals	2017–2018	-31	-2.9	32	3.1	-10	-0.9	0	0.0
	2018–2019	-30	-2.7	32	2.8	9	0.8	2	0.2
	2019–2020	-4	-0.4	5	0.5	7	0.6	0	0.0
	2020–2021	4	0.3	-1	-0.1	9	0.8	16	1.3
	2021–2022	13	1.0	-14	-1.0	-8	-0.6	24	1.8
	2022–2023	-2	-0.1	2	0.2	5	0.4	-2	-0.1
Projections	2023–2024	11	0.7	1	0.1	13	0.8	11	0.7
	2024–2025	0	0.0	13	0.8	13	0.8	9	0.5
	2025–2026	-11	-0.6	25	1.4	14	0.7	9	0.5
	2026–2027	-24	-1.2	39	2.0	15	0.7	9	0.5
	2027–2028	-36	-1.7	50	2.4	14	0.7	10	0.5
	2028–2029	-52	-2.3	69	3.0	17	0.7	10	0.5
	2029–2030	-56	-2.3	74	3.0	18	0.7	11	0.4

CAB - Current Account Balance.

**External Financial Flows = CAB + Capital and Financial Inflows.*

***Assuming the currency depreciates by 3.5 per cent every year against US$ (based on 10 years' CAGR).*

Note: This analysis was conducted before actual 2023–2024 data became available. Therefore, 2023–2024 figures are shown as projections, not actual.

Source: Balance of Payments and International Investment Position, IMF, and authors' calculations.

Table A7.5: Mexico

	Year	CAB		Capital and Financial Inflows		External Financial Flows*		Expansion in Monetary Base**	
	(Billion US$)	(percentage of GDP)	(Billion US$)	(percentage of GDP)	(Billion US$)	(percentage of GDP)	(Billion US$)	(percentage of GDP)	(Billion US$)
(1)	(2)	(3)	(4)	(5)	(6)	(7) = (3 + 5)	(8) = (4 + 6)	(9)	(10)
Actuals	2017–2018	-26	-2.1	31	2.5	1	0.1	7	0.6
	2018–2019	-4	-0.3	16	1.2	7	0.5	4	0.3
	2019–2020	27	2.4	-21	-1.9	16	1.4	16	1.4
	2020–2021	-4	-0.3	2	0.1	9	0.7	16	1.2
	2021–2022	-18	-1.2	15	1.0	-7	-0.5	13	0.9
	2022–2023	-6	-0.4	6	0.4	11	0.7	14	0.9
Projections	2023–2024	-18	-1.1	35	2.0	17	1.0	16	0.9
	2024–2025	-20	-1.1	32	1.8	11	0.6	13	0.7
	2025–2026	-23	-1.2	35	1.9	13	0.7	14	0.7
	2026–2027	-25	-1.3	38	1.9	13	0.6	14	0.7
	2027–2028	-29	-1.4	43	2.0	14	0.7	15	0.7
	2028–2029	-33	-1.5	48	2.2	14	0.6	15	0.7
	2029–2030	-38	-1.6	53	2.3	15	0.6	15	0.7

CAB - Current Account Balance.

**External Financial Flows = CAB + Capital and Financial Inflows.*

***Assuming the currency depreciates by 2.4 per cent every year against US$ (based on 10 years' CAGR).*

Note: This analysis was conducted before actual 2023–2024 data became available. Therefore, 2023–2024 figures are shown as projections, not actuals.

Source: Balance of Payments and International Investment Position, IMF, and authors' calculations.

Table A7.6: The Russian Federation

	Year	CAB		Capital and Financial Inflows		External Financial Flows*		Expansion in Monetary Base**	
		(Billion US$)	(percentage of GDP)	(Billion US$)	(percentage of GDP)	(Billion US$)	(percentage of GDP)	(Billion US$)	(percentage of GDP)
(1)	(2)	(3)	(4)	(5)	(6)	(7) = (3 + 5)	(8) = (4 + 6)	(9)	(10)
Actuals	2017–2018	116	7.0	-116	-7.0	36	2.2	24	1.4
	2018–2019	66	3.9	-63	-3.7	87	5.1	11	0.7
	2019–2020	35	2.4	-39	-2.6	42	2.8	21	1.4
	2020–2021	125	6.8	-124	-6.8	35	1.9	25	1.3
	2021–2022	238	10.6	-222	-9.9	-50	-2.2	-14	-0.6
	2022–2023	50	2.5	-42	-2.1	17	0.8	59	3.0
Projections	2023–2024	32	0.0	-14	-0.7	18	0.9	8	0.4
	2024–2025	18	0.9	-8	-0.4	10	0.5	14	0.6
	2025–2026	40	1.9	-32	-1.5	8	0.4	14	0.6
	2026–2027	61	2.8	-52	-2.4	9	0.4	13	0.6
	2027–2028	83	3.8	-73	-3.4	10	0.5	13	0.6
	2028–2029	107	4.8	-98	-4.4	9	0.4	13	0.6
	2029–2030	131	5.8	-119	-5.3	11	0.5	13	0.6

CAB - Current Account Balance.

**External Financial Flows = CAB + Capital and Financial Inflows.*

***Assuming the currency depreciates by 6 per cent every year against US$ (based on five years' CAGR).*

Note: (i) This analysis was conducted before actual 2023–2024 data became available. Therefore, 2023–2024 figures are shown as projections, not actuals.

(ii) Projections for the Russian Federation should be interpreted with caution, as ongoing geopolitical tensions could significantly impact these forecasts. Since our projections are based on historical data, it was not possible to factor in the potential impact of war in the BAU.

Source: Balance of Payments and International Investment Position, IMF, and authors' calculations.

Table A7.7: South Africa

	Year	CAB		Capital and Financial Inflows		External Financial Flows*		Expansion in Monetary Base**	
		(Billion US$)	(percentage of GDP)	(Billion US$)	(percentage of GDP)	(Billion US$)	(percentage of GDP)	(Billion US$)	(percentage of GDP)
(1)	(2)	(3)	(4)	(5)	(6)	(7) = (3 + 5)	(8) = (4 + 6)	(9)	(10)
Actuals	2017–2018	-12	-3.0	12	3.0	1	0.2	1	0.2
	2018–2019	-10	-2.6	9	2.3	3	0.9	1	0.2
	2019–2020	7	2.0	-15	-4.6	0	0.0	1	0.3
	2020–2021	16	3.7	-13	-3.0	3	0.6	1	0.2
	2021–2022	-2	-0.4	10	2.5	3	0.7	3	0.8
	2022–2023	-6	-1.6	4	1.1	0	-0.1	2	0.5
Projections	2023–2024	-10	-2.5	13	3.3	3	0.8	1	0.1
	2024–2025	-10	-2.3	12	2.9	3	0.6	1	0.3
	2025–2026	-8	-1.8	10	2.3	2	0.5	1	0.3
	2026–2027	-5	-1.1	7	1.5	2	0.5	1	0.3
	2027–2028	-2	-0.4	4	0.9	2	0.5	1	0.3
	2028–2029	0	0.1	2	0.4	2	0.5	1	0.3
	2029–2030	3	0.6	0	-0.1	3	0.5	2	0.3

CAB - Current Account Balance.

**External Financial Flows = CAB + Capital and Financial Inflows.*

***Assuming the currency depreciates by 5.4 per cent every year against US$ (based on five years' CAGR).*

Note: This analysis was conducted before actual 2023–2024 data became available. Therefore, 2023–2024 figures are shown as projections, not actuals.

Source: Balance of Payments and International Investment Position, IMF, and authors' calculations.

Table A7.8: Türkiye

	Year	CAB		Capital and Financial Inflows		External Financial Flows*		Expansion in Monetary Base**	
		(Billion)	(percentage of GDP)	(Billion US$)	(percentage of GDP)	(Billion US$)	(percentage of GDP)	(Billion US$)	(percentage of GDP)
(1)	(2)	(3)	(4)	(5)	(6)	(7) = (3 + 5)	(8) = (4 + 6)	(9)	(10)
Actuals	2017–2018	-20	-2.6	-12	-1.5	-15	-1.9	11	1.4
	2018–2019	11	1.4	1	0.1	13	1.7	12	1.5
	2019–2020	-32	-4.4	7	1.0	-12	-1.7	55	7.6
	2020–2021	-7	-0.9	29	3.5	16	2.0	104	12.7
	2021–2022	-49	-5.4	35	3.9	14	1.6	58	6.4
	2022–2023	-45	-4.1	54	4.9	-22	-1.9	97	8.7
Projections	2023–2024	-46	-4.2	47	4.2	0	0.0	39	3.5
	2024–2025	-28	-2.5	28	2.5	-1	-0.1	36	3.3
	2025–2026	-27	-2.3	31	2.7	4	0.4	38	3.3
	2026–2027	-23	-2.0	28	2.3	4	0.3	40	3.3
	2027–2028	-20	-1.6	24	1.9	4	0.3	46	3.7
	2028–2029	-16	-1.2	20	1.5	4	0.3	50	3.9
	2029–2030	-7	-0.5	10	0.7	3	0.2	54	4.1

CAB - Current Account Balance.

**External Financial Flows = CAB + Capital and Financial Inflows.*

***Assuming the currency depreciates by 14.3 per cent every year against US$ (based on five years' CAGR before crisis in Türkiye).*

Note: This analysis was conducted before actual 2023–2024 data became available. Therefore, 2023–2024 figures are shown as projections, not actuals.

Source: Balance of Payments and International Investment Position, IMF, and authors' calculations.

Appendix 8: Projected Nominal GDP Growth Rates and Climate Finance Estimates - Nine EMEs

Country	GDP Growth Rate (at Market Prices)							Total Capex	
	2023–2024	2024–2025	2025–2026	2026–2027	2027–2028	2028–2029	2029–2030	Annual Average#	
	per cent							US$ Billion	Percentage of GDP
Argentina	1.7	0.5	3.8	5.3	4.7	3.6	3.6	2	0.3
Brazil	6.5	4.3	4.8	6.3	5.4	5.2	5.2	8	0.3
China	4.9	6.6	6.5	5.8	5.9	6.2	6.2	155	0.7
India	10.0	9.9	9.7	9.6	9.5	9.7	9.7	54*	1.3*
Indonesia	8.8	8.3	8.1	8.0	7.4	7.9	7.9	10	0.6
Mexico	10.1	4.4	4.3	4.1	4.3	4.3	4.3	5	0.3
The Russian Federation	2.2	1.2	1.6	0.6	0.9	1.1	1.1	14	0.7
South Africa	5.4	4.1	3.5	3.0	3.0	3.4	3.4	2	0.5
Türkiye	16.1	4.6	3.7	4.2	4.0	4.1	4.1	4	0.3
World	5.0	5.3	5.2	4.9	4.9	5.1	5.1	–	–

#Annual average values are based on years 2022–2030 for the cement and steel sectors, 2023 to 2030 for the road transport sector and 2024–2030 for the power sector.

**Refer to Raj and Mohan (2025) for details of India's figures.*

Source: IMF World Economic Outlook, April 2024.

About the authors

Janak Raj leads the macroeconomic segment in the Growth, Finance, and Development vertical. His areas of interest are health, climate finance and MDB reforms. He has worked with the Reserve Bank of India, the International Monetary Fund, and Ministry of Finance. Dr. Janak Raj served as an Executive Director in the Reserve Bank of India and as a member of its Monetary Policy Committee. In the IMF, he was Senior Advisor to the Executive Director for Bangladesh, Bhutan, India and Sri Lanka. He also served as a nominee director on the governing Board of BSE (formerly Bombay Stock Exchange). He holds a Ph.D in Economics from IIT Bombay.

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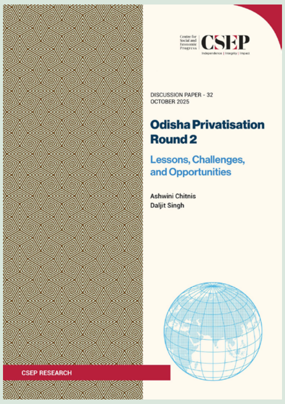
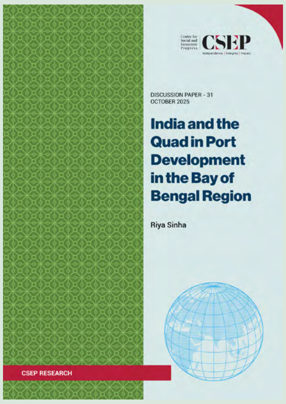
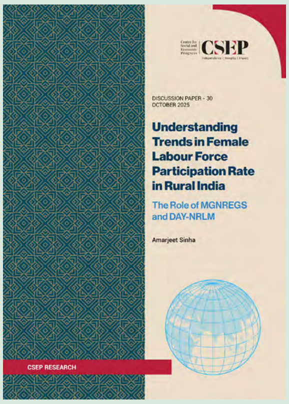
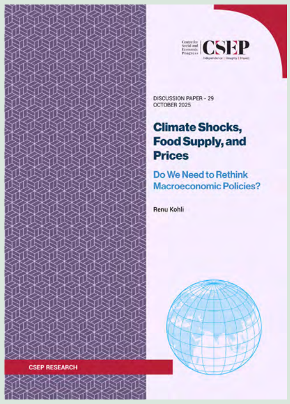
He has authored three books on urban economics and urban development; two on monetary policy: *'Monetary Policy in a Globalized Economy: A Practitioner's View' (2009), and "Growth with Financial Stability: Central Banking in an Emerging Market"*. His most recent book (edited) is *"India Transformed: 25 Years of Economic Reforms"*.

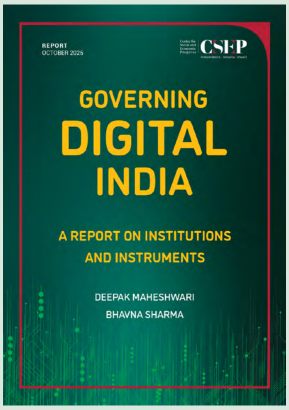
Other publications

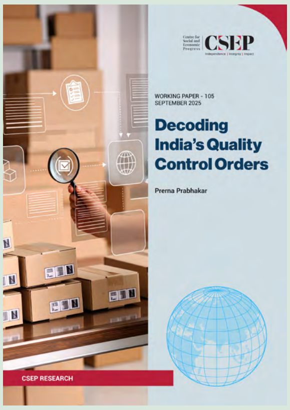


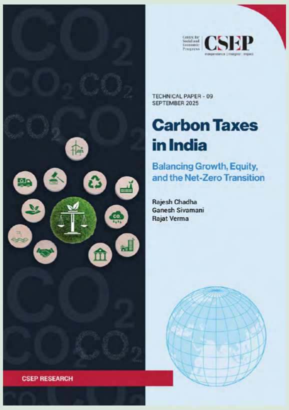


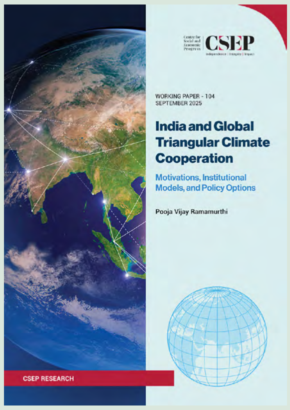


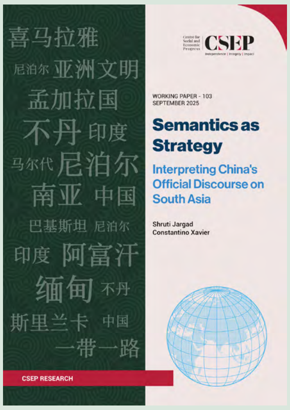


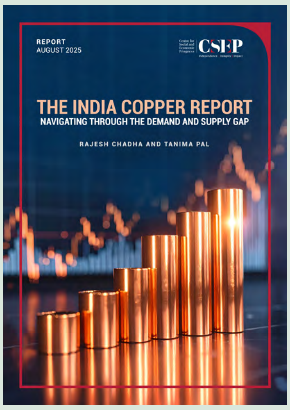


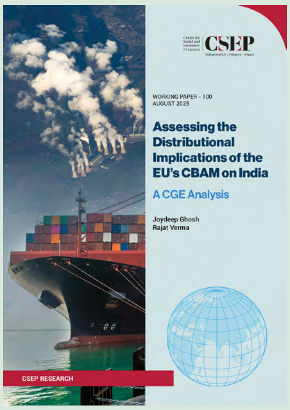


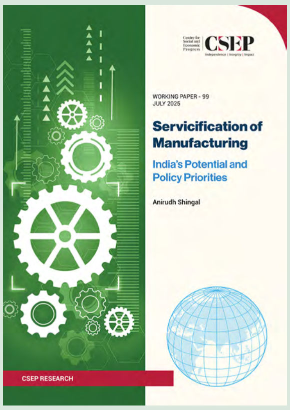


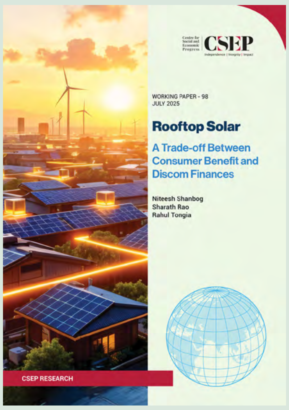


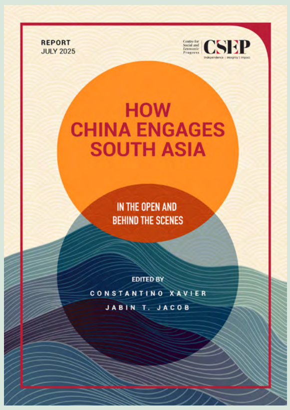












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