ASIA SOCIETY POLICY INSTITUTE

REPORT

Getting India to Net Zero

GETTING ASIA TO NET ZERO

A High-level Policy Commission Convened by the Asia Society Policy Institute

Getting India to Net Zero

A REPORT OF THE HIGH-LEVEL POLICY COMMISSION ON GETTING ASIA TO NET ZERO

CONVENED BY THE ASIA SOCIETY POLICY INSTITUTE AS SECRETARIAT

Appendix & modelling prepared by Cambridge Econometrics

With a solution-oriented mandate, the Asia Society Policy Institute (ASPI) tackles major policy challenges confronting the Asia Pacific in security, prosperity, sustainability, and the development of common norms and values for the region. The Asia Society Policy Institute is a think- and do-tank designed to bring forth policy ideas that incorporate the best thinking from top experts in Asia and to work with policymakers to integrate these ideas and put them into practice.

GETTING ASIA TO NET ZERO

The High-level Policy Commission on Getting Asia to Net Zero aims to urgently accelerate Asia's transition to net zero emissions while ensuring that the region thrives and prospers through this transition. Through research, analysis and engagement, the commission's diverse set of recognized Asian leaders seek to advance a powerful, coherent, and Paris-aligned regional vision for net zero emissions in Asia. The Asia Society Policy Institute serves as the Commission's secretariat. For more information and a list of commissioners, visit: AsiaSociety.org/NetZero

ACKNOWLEDGEMENTS

We gratefully acknowledge Cambridge Econometrics for their preparation of the research and modelling contained in the appendix to this report. We especially thank the appendix authors – Ha Bui, Zsófi Kőműves, Unnada Chewpreecha, Ioannis Gutzianas, and Jon Stenning – as well as the expert reviewers: Dr. Surabhi Joshi; and Deepthi Swamy, Garima Vats, and Varun Agarwal of the World Resources Institute.

Cambridge Econometrics' mission is to provide clear and useful insights, based on rigorous and independent economic analysis, to address the complex challenges facing society. www.camecon.com

Cambridge Econometrics Limited is owned by a charitable body, the Cambridge Trust for New Thinking in Economics. www.neweconomicthinking.org

THE ASIA SOCIETY POLICY INSTITUTE
Web: AsiaSociety.org/Policy-Institute
Twitter: @AsiaPolicy
Facebook: Facebook.com/AsiaPolicy
Email: policyinstitute@asiasociety.org

NEW YORK
725 Park Avenue
New York, NY 10021
+1 212 288 6400

WASHINGTON, D.C.
1779 Massachusetts Avenue NW, Suite 805
Washington, D.C. 20036
+1 202 833 2742

COVER IMAGE: Abhishek Chinnappa / Stringer

CONTENTS

ABOUT THIS DOCUMENT

This report was spearheaded by the High-level Policy Commission on Getting Asia to Net Zero, which launched in May 2022 to advance a powerful, coherent, and Paris-aligned regional vision for net zero emissions in Asia. Through research, analysis and engagement, the commission's diverse set of recognized Asian and global leaders aim to provide recommendations for how Asia and key countries can realize net zero emissions, including how climate action can boost the region's economy, trade, interconnectedness, and livelihoods. The Asia Society Policy Institute (ASPI) serves as the commission's secretariat.

The document itself consists of two core parts:

- The first part is a **foreword** that outlines the commission's recommendations for how India can achieve net zero emissions in a manner that is beneficial to its economy, society, and place in the world. This summary was prepared by members of the High-level Commission and is aimed at elevating political and policy strategies to help India realize its vision of achieving net zero emissions.

- The second part — which informed the development of the summary — is an **appendix** that contains **new research and modelling** to show the opportunities and tradeoffs associated with India's options to meet its existing emissions reduction targets and increase its medium- and long-term ambition. The commission and its secretariat at ASPI commissioned this analysis from Cambridge Econometrics, an independent organization that specializes in economic analysis. The appendix and its findings are solely the work of Cambridge Econometrics; ASPI and the commission are not directly responsible for the content of the findings within.

GETTING INDIA TO NET ZERO: FOREWORD

At the World Leaders Summit at COP26 in Glasgow in November 2021, Indian Prime Minister Narendra Modi took everyone by surprise by announcing that India will achieve net zero emissions by 2070. What India does matters to the decision-making of a vast number of countries, especially in the developing world. If the largest democracy in the world drops all ifs, ands, or buts and, despite its low per-capita income, wholeheartedly joins the global effort to save the only planet we have, it is bound to capture the imagination of other countries sitting on the fence.

PM Modi also announced a series of ambitious updates to India's 2030 targets in his five-part *panchamrit* on climate while offering a vision of sustainable lifestyles. Together, the updated pledges reflect India's political will to seek a cleaner development pathway in the face of projected rapid economic growth. India's efforts to decouple its growth from emissions will be critical in preventing a future carbon bomb of emissions from derailing global climate efforts.

India's decision to step up on climate is fully consistent with its long-term economic ambitions and interests. As the enclosed modelling and research commissioned by the High-level Policy Commission on Getting Asia to Net Zero illustrates, achieving net zero emissions by 2070 could boost India's economy by as much as 4.7 percent above projected baseline growth in GDP terms by 2036 — worth a total of $371bn — with long-run effects still maintaining 3.5 percent growth above baseline by 2060.

To set the tone of this report at the outset, let us be clear: this is not about prompting India to do more than it has already committed to do. Rather, it is about offering constructive ideas that could help India fully capitalize on the opportunity to make itself into a more efficient, clean, and powerful economy. The suggestions offered are aimed at enabling India to attract the financial and technical support it needs to succeed — as well as to do so at the necessary scale.

Positive economic impacts are driven in part by an improved trade balance of $236bn due to reduced demand for fossil fuels. This will directly support PM Modi's drive for India's energy independence, which he underscored in a high-profile speech this August on the 75th anniversary of India's independence that highlighted the country's self-reliance on solar, wind and other clean energy sources like hydrogen, biofuels and electric vehicles.

Net zero will also bring notable benefits for the Indian people. The transition will see a net increase in employment opportunities, creating as many as 15 million jobs beyond a baseline scenario by 2047. Households could save as much as $9.7bn in energy costs by 2060.

Yet achieving net zero emissions will require India to grapple with a series of challenges. Foremost is finance: according to the modelling, India will need around $10.1trn in cumulative economy-wide investment to meet its 2070 target. Should the transition be funded only with domestic resources, Indian households may on average be worse off, with consumption reduced by up to $165bn by 2060 (equivalent to 2 percent below baseline consumption) due to higher product prices and taxes, including carbon taxes to finance additional investment.

In addition, despite the overall job gains in a net zero economy, India will obviously want to ensure a just and equitable transition for its workforce currently employed in fossil fuel industries. While the loss of nearly 5 million jobs in primary and fossil fuel sectors will be compensated by new opportunities in the industry and services sectors, with 12 million more jobs created by 2060, additional policies and investment will of course be needed to reskill displaced workers and train India's future workforce to access new employment opportunities in a net zero economy.

India took another step forward this August by approving the submission of a portion of the 2030 targets announced by PM Modi at COP26 to the UN's climate change body before COP27. Buttressing these commitments is the advancement through its parliament of India's Energy Conservation (Amendment) Bill 2022, which includes key provisions to promote non-fossil energy, improve energy efficiency, and establish carbon markets.

It is hoped that India will also soon submit its first Long-Term Strategy (LTS) to the UNFCCC. The scope and nature of the strategy will have major implications for how much India's chosen pathway to net zero can boost its economy, trade, interconnectedness, and livelihoods.

These actions all reiterate the seriousness of India's commitment to climate action — and moreover, that India is open for business to implement its targets. As PM Modi has made clear, the developed world can support India's transition by providing "new and additional financial resources as well as transfer of technology." Luckily for India, this green and sustainable financing increasingly exists from a multitude of sources across the spectrum.

In order to attract these resources at the scale that India seeks, however, India would be well placed to consider opportunities to demonstrate that it is also ready and willing to pursue its sustainable transition in a manner that is cohesive and constructive for its society and the world. Doing so will de-risk the capital India needs to support its net zero journey, but it will likely require additional action from India beyond setting targets to demonstrate that India also possesses the political will to implement them.

Ultimately, we believe three key actions could help to attract the resources and support needed to supercharge India's net zero transition. In doing so, India could also create a pipeline of bankable projects that can easily be picked up by international investors with the capital and appetite to invest in India's net zero transition.

First, India must continue to grapple with the most pressing challenges of the transition for its political economy. The bulk of these obstacles stems from ensuring that the actors that depend on fossil fuels for profits will continue to thrive as fossil fuels are inevitably phased down. These include people, businesses, and local governments.

For example, India could prioritize developing a comprehensive and holistic plan to ensure a just and equitable transition. This would require managing new economic opportunities for those most affected, especially the estimated 70 percent of India's approximately 2.6 million people employed in coal mining who are informal workers. New employment opportunities could be embedded locally to ensure that former fossil-economy workers can take advantage of them.

India could also consider addressing the dependency of its local governments and businesses on fossil fuels. Close to 40 percent of India's 736 districts have some sort of financial dependency on coal, and coal also accounts for 44 percent of the freight revenues for the state-owned Indian Railways (IR). A national action plan for India's just transition can help avoid immediate costly consequences from stymieing India's climate progress, especially during the urgent "decade of delivery" out to 2030.

Second, India could consider identifying and resolving the technical challenges that may otherwise hinder progress on achieving net zero emissions. Some of these barriers are physical. Realizing India's commitment to install a total of 500GW of nonfossil power generation capacity by 2030 will not only require a massive amount of solar, wind and other renewables investment; it will also require massive upgrading of India's transmission and distribution infrastructure. This does not necessarily mean that centralized distribution is the only answer. Beyond large-scale solar, India can leverage blended finance to concurrently de-risk and bring down the costs of solar mini-grids and accelerate progress.

Technical challenges on the administrative side should also bear attention. While India is taking steps to implement carbon pricing, it would benefit from developing the monitoring, reporting and verification structures necessary to implement a robust and comprehensive cap-and-trade-style market. A combination of investments in monitoring systems, data collection networks, and policies to incentivize data accuracy and disclosure could help speed up the potential for carbon markets to play a substantive role in incentivizing emissions reductions in India.

Third, India could tap into its economies of scale to become a global clean manufacturing hub. India is already taking advantage of its enormous population and varied resources to invest in cleantech production. Two key areas of emphasis so far are solar photovoltaic (PV) manufacturing and green hydrogen. For instance, in April 2021, India's union cabinet approved its National Programme on High Efficiency Solar PV Modules to promote manufacturing of a range of high-efficiency solar PV components through a production-linked incentive scheme. And earlier this year, India launched a Green Hydrogen Mission that is expected to generate 4.1 million tonnes of green hydrogen annually.

A ripe opportunity exists in the heavy industry sector to build on this progress. If India invests in developing the policy frameworks necessary to support zero-carbon manufacturing of steel and aluminum, the country could position itself well to take advantage of future infrastructure markets created through such policies as the US Inflation Reduction Act and the EU's proposed carbon border adjustment mechanism. Cooperative initiatives could help accelerate progress. These include both government programs, such as the Green Strategic Partnership between India and Denmark, and private sector initiatives, such as the Mission Possible Partnership. Beyond heavy industry, India could also incentivize the greening of its light manufacturing and services sectors. India's 2023 hosting of the Clean Energy Ministerial and Mission Innovation is a prime opportunity for India to showcase its action and jumpstart progress in these areas. As India embarks on ramping up its manufacturing, adopting low-carbon pathways will ensure it will be a part of global value chains in the coming decades.

With India on the cusp of assuming the G20 presidency in 2023 and the Asia-Pacific Group due to host COP28 the same year, now is an opportune moment for India to double down on net zero policy reform. These summits provide an opportunity for India to help showcase its constructive climate policies, as well as those of the region. This would shift the balance from India's historical position as the recipient of calls to increase ambition to one of India taking the lead on catalyzing global progress in a manner that is beneficial to India's economy, society, and place in the world. With global geopolitics remaining tense, India could also position climate action as a unique space for cooperation.

In particular, pursuing climate finance as a key G20 priority next year could establish a platform for India to elevate a pipeline of bankable projects. This would be even more powerful should the G7 and other developed countries make good on their proposed Just Energy Transition Partnership deals by demonstrating how such large-scale initiatives can open up the financial floodgates to boost climate action and livelihoods together. India could start working closely with Indonesia to realize a seamless transition for the G20 presidency that embodies Asian leadership.

Beyond this, India could potentially benefit its economy even more by considering additional steps on climate. The modelling that we commissioned shows that under a scenario where it achieves net zero emissions by 2070, India would amplify its economic gains by peaking emissions as soon as 2030. Just by phasing down unabated coal by 2040 and stopping all new coal projects apart from those already under construction, India could achieve net zero emissions in 2065, a full five years earlier than projected. The modelling indicates that both of these steps are not just feasible — they are also in India's economic favor. Should India ramp up its ambition to achieve net zero emissions by 2050, it could maximize its GDP growth above baseline by as much as 7.3 percent in the 2030s.

We hope India will take full advantage of its strengths and global platforms to embody a transition that leverages its unique strengths while also inciting global momentum for other regional and global actors to act in tandem. By considering opportunities to ramp up its own action — whether through concrete steps to address its political economy and technical elements or by raising its headline ambition level over time — India can create opportunities and markets that in turn incentivize other countries to appropriately move up their own targets and climate action.

As PM Modi said at COP26, the case for net zero in India is clear. And it is also a massive opportunity.

HON. KEVIN RUDD AC
President & CEO, Asia Society
President, Asia Society Policy Institute
26th Prime Minister of Australia

HON. BAN KI-MOON
President & Chair,
Global Green Growth Institute
8th Secretary-General, United Nations

DR. ARVIND PANAGARIYA
Jagdish N. Bhagwati Professor of
Indian Political Economy,
Columbia University
Vice Chairman (2015-2017),
NITI Aayog, Republic of India

VIVEK PATHAK
Global Head & Director
of Climate Business,
International Finance Corporation

As members of the High-level Policy Commission on Getting Asia to Net Zero

APPENDIX: RESEARCH & MODELLING

PREPARED BY CAMBRIDGE ECONOMETRICS

CONTACT PERSON Ha Bui

AUTHORS Ha Bui, Zsófi Kőműves, Unnada Chewpreecha, Ioannis Gutzianas & Jon Stenning (Cambridge Econometrics)

CONTRIBUTORS Dr. Surabhi Joshi; Deepthi Swamy, Garima Vats & Varun Agarwal (World Resources Institute)

PROJECT DIRECTOR Jon Stenning

cambridge econometrics
clarity from complexity

Cambridge Econometrics' mission is to provide clear and useful insights, based on rigorous and independent economic analysis, to address the complex challenges facing society. www.camecon.com

Cambridge Econometrics Limited is owned by a charitable body, the Cambridge Trust for New Thinking in Economics. www.neweconomicthinking.org

TABLES & FIGURES

TABLES

FIGURES

ACRONYMS

ASPI	Asia Society Policy Institute
BECCS	Bioenergy with carbon capture and storage
CHP	Combined heat and power
CCS	Carbon capture and storage
CGE	Computable General Equilibrium
COP26	26th United Nations Climate Change Conference
EU27	Current member states of the European Union
EV	Electric vehicle
FTT	Future Technology Transformation
G20	Group of Twenty
IAM	Integrated Assessment Model
ICE	Internal combustion engine
ILO	International Labor Organization
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
LTS	Long-Term Strategy
LULUCF	Land Use, Land-Use Change and Forestry
NDC	Nationally Determined Contribution
OECD STAN	Organization for Economic Co-operation and Development – Structural Analysis Database
UNFCCC	United Nations Framework Convention on Climate Change

EXECUTIVE SUMMARY

DELIVERING INDIA'S NET ZERO TARGETS IN FIGURES		
	NET ZERO 2070	**NET ZERO 2050**
Earliest year in which carbon emissions peak in India to deliver net zero emissions and realize economic benefits	2030	2025
Increase in GDP compared to baseline	3.5% in 2060 (peaking at 4.7% in 2036)	3.4% in 2060 (peaking at 7.3% in 2032)
Cumulative economy-wide investment required from now for achieving net zero emissions	$10.1trn	$13.5trn
Improvement to India's trade balance by 2060	$236bn	$205bn
Number of additional jobs created by 2060	12 million (peaking at 15 million in 2047)	13 million (peaking at 20 million in 2032)
Reduction in household spending by 2060	$79bn	$165bn
Household energy cost savings by 2060	$9.7bn	$10.3bn
Net costs of policy implementation by 2060	-$18bn (net gains)	$50bn

>> India is currently the fifth-largest economy globally and is projected to soon become the most populous country in the world. A large proportion of its population is exposed to climate-related risks, and air pollution levels are among the highest globally, posing a significant threat to the health of the country's population and economy. Emissions are still on the rise, fuelled in part by coal still remaining a dominant part of the energy mix.

>> **India's Nationally Determined Contribution (NDC) targets set in 2015 are likely to be met early within the next few years through current policies.** India's updated 2030 targets[1] and 2070 net zero target announced by Indian Prime Minister Narendra Modi at the World Leaders Summit at COP26 in Glasgow increased India's climate ambition substantially but are not yet fully aligned with the Paris Agreement's 1.5°C target. This assessment is in line with other evaluations (e.g., Climate Action Tracker 2022). Our analysis shows that **India implementing all of its current commitments with other countries doing the same would lead to a global warming of least 1.6°C** by 2100.

>> This report provides economic analysis to show the opportunities and trade-offs associated with India's options to meet its existing emissions reduction targets (a 45 percent reduction in emissions intensity and 1bn tonne of emissions reduction by 2030, and net zero emissions by 2070) and increase its medium- and long-term ambitions. The goal of the research is to evaluate the macroeconomic impacts of a range of policy options and provide recommendations for policymakers to address the social and other challenges of an accelerated energy transition. Five core scenarios with different levels of decarbonization ambition — including India's existing commitments — were modelled, complemented by sensitivities around policy choices.

1 A 45 percent reduction in emissions intensity compared to 2005, 1bn tonne of emission reduction, 500GW of nonfossil capacity, and 50 percent of energy requirement from renewable sources.

- The modelling, carried out using the global E3ME model, shows that **more ambitious and additional policies are needed to deliver long-term net zero emissions targets.** Accelerated action in the short- and medium-terms, such as **phasing out unabated coal power by 2040 and increasing the renewable capacity target well beyond 500GW by 2030, would help India transition to a low-carbon economy more rapidly.**

- **Utilizing all viable policy options can lead to India's CO_2 emissions peaking this decade, as early as 2025 in the most ambitious *2050 net zero* scenarios, and declining consistently thereafter**. Such a transition will be driven by rapid decarbonization of the whole energy system and economy, including moving away from fossil fuels to renewable electricity generation, increased electrification, innovation of low-carbon solutions, promotion of electric vehicles for road transport, and low-carbon technologies and alternative fuels in other sectors.

- **The most ambitious decarbonization goals (2050 net zero) could boost India's economy by 7.3 percent ($470bn) in GDP terms and create almost 20m additional jobs by 2032,** the peak year of impact, compared to a baseline pathway of pre-COP26 policies. **The long-run effects are milder but still sizeable: an additional 3.4 percent ($536bn) of annual GDP in 2060 and 12m additional jobs by 2060 on top of a baseline case.** Note that investment impacts are the key drivers of the GDP effects; thus, both follow a frontloaded profile. Because of this, the positive GDP impact of delivering net zero emissions by 2070, while comparable to the 2050 net zero scenario from 2050 onwards, is realized more slowly: absolute additions to baseline GDP peak at $371bn by 2036, and by 2032 (at $220bn) equate to less than half of the equivalent under 2050 net zero.

- **These economic impacts are primarily due to a substantial amount of investment and an improving trade balance in India** as a result of reduced demand for imported fossil fuels. It is estimated that **India would require more than $10trn of additional investment compared to baseline from now to deliver net zero emissions by 2070, and more than $13.5trn to reach carbon neutrality by 2050** and maintain it thereafter. Reducing fossil fuel import dependency also means improved energy security. Under the most ambitious *2050 net zero* scenarios, there are substantial savings in energy costs for households as well as for industries.

- However, these benefits come with trade-offs. **Should the transition be funded only with domestic resources, Indian households would on average be worse off. Household consumption would be reduced by up to $165bn by 2060 due to higher product prices and taxes, including carbon taxes, to finance additional investments.** Despite the substantial energy savings from decarbonization, the higher consumer prices decrease total consumption. Employment impacts are positive overall, but there will be winners and losers with many jobs lost in fossil fuel supply sectors, particularly in coal mines and wider coal networks, posing a social challenge for local communities.

- **To achieve a more rapid and just transition in India, a combination of policies will be needed, not just regulation or carbon pricing alone.** Coal regulation in power generation — particularly a no new coal policy from 2023 — is very effective at targeting large emissions reductions in the medium term, though it can be expensive because of the high costs of compensation for stranded assets. While India could decarbonize using carbon revenues or other domestic tax-raising mechanisms to fund green investments, **leveraging international support would free up domestic finance for development, poverty reduction, and management of social impacts, helping mitigate the negative impacts on households** from higher prices and taxes. Policies to support reskilling and upskilling of the workforce across all economies would also allow workers to take full advantage of new employment opportunities that arise in a low-carbon economy.

INTRODUCTION

BACKGROUND

Economic and Social Characteristics

India is currently the fifth-largest economy globally as well as the second (and soon to be most) populous country in the world. It has enormous growth potential due to its large workforce, resource abundance, and ability to attract investments. Until the COVID-19 pandemic, India had maintained very rapid GDP growth rates: around 8.9 percent annual growth, more than double the global average GDP growth rate. In 2020, its GDP shrunk by 7.3 percent as a result of the impacts of COVID-19; however, by 2022 the Indian economy had bounced back to its previous growth trend. Most preliminary statistics put the country's GDP growth between 7 percent and 9 percent in 2022 (World Bank 2021b; UNCTAD 2021). Due to its size and current growth trajectory, India therefore exerts strong economic influence on whether the world continues on a sustainable development path in the future.

TABLE 1.1 POPULATION, GDP, GDP PER CAPITA AND GDP GROWTH FOR INDIA, ASIA AND THE WORLD 2020-2021

	POPULATION (MILLIONS OF PEOPLE)	GDP, CURRENT PRICES (BILLIONS OF U.S. DOLLARS)	GDP PER CAPITA, CURRENT PRICES (U.S. DOLLARS PER CAPITA)	GDP GROWTH RATE (%PA)
	2021	2021	2021	2005-2020
India	1,392	3,042	2,185	8.9%
Asia[a]	3,310	29,584	8,938	6.9%
Asia incl. AU and NZ	3,341	31,465	9,418	6.8%
World	7,693	96,293	12,517	4.3%

Source(s): IMF.

[a]This includes India, Indonesia, China, Japan, South Korea, Malaysia, Taiwan, Brunei, Cambodia, Laos, Myanmar, Philippines, Singapore, Vietnam, and Thailand.

The fight against poverty has been a focus of consecutive Indian governments since the beginning of the 2000s. The share of India's population living under the national poverty line decreased steadily through the 2010s (World Bank 2021b). However, according to the latest estimates, Indian urban households are more vulnerable to falling into poverty than they were before COVID-19 (World Bank 2021b). While average incomes grew and poverty has declined in the past few decades in India, inequality has risen significantly (Rodgers 2018). If global trends of growing inequalities, both between and within countries, occur in India as well, tackling inequality poses a major policy challenge as part of a global transition toward a low-carbon economy (Bundervoet, Davalos and Garcia 2021); (Narayan, et al. 2022).

Environmental and Energy Characteristics

Due to its large economy, India has been one of the world's highest GHG emitters over the past decades, though its per capita emissions are still well below the global average. In 2020, the Indian sectors with the highest emissions were power generation, iron and steel manufacturing, and road transport. After the COVID-19 pandemic, the share of coal in power generation reached a new all-time high in India in 2021, pushing its emissions 13 percent above 2020 levels (IEA 2022). With coal continuing to be an important part of India's energy mix, the country's emissions are still on the rise.

TABLE 1.2: ELECTRICITY GENERATION BY SOURCE (SHARE OF TOTAL) AND CO_2 EMISSIONS IN ASIA AND THE WORLD IN 2020

	FOSSILS	NUCLEAR	RENEWABLES	CO_2 EMISSIONS, $MTCO_2$
India	77%	3%	20%	2,310
Asia	72%	2%	25%	14,935
Asia incl. AU and NZ	72%	2%	20%	15,345
World	63%	10%	26%	33,622

Source(s): IEA.

Phasing out unabated coal from power generation and industry is a key policy challenge for India to align its emissions with its current ambitions. However, the political economy for this is complex. Ideally, a coal phaseout policy should minimize trade-offs between welfare and decarbonization by mitigating rising electricity prices (due to the high cost of renewables capacity investment being passed on to consumers[2]) and job losses (linked to coal supply[3]), for instance, by recycling emissions-related taxes for supporting low-carbon solutions. This restructuring needs a redesign of power purchase agreements to remove commitments to purchase coal and enforce emissions regulations to make coal less competitive (MCC 2021). Analysis by Wood Mackenzie (2022) suggests that renewables were already less expensive than coal in India in 2021, excluding the full impact of the 2022 fossil fuel price increases and policy changes. Removing current coal subsidies would make low-carbon electricity more cost competitive but would still result in a loss of labor income as jobs in the coal industry and throughout supply chains were lost.

In a world with rising temperatures, India is one of the most disaster-prone countries globally. More than 80 percent of its population live in districts highly vulnerable to extreme hydrological and meteorological disasters (CEEW 2021c). Communities are exposed to floods, droughts, tropical cyclones, and other disasters that are expected to be more frequent and severe as warming accelerates (Climate Knowledge Portal 2022). This means all countries including India must urgently act to reduce their own emissions to lessen increases in risks, while concurrently investing in adaptations to protect its population from the effects of rising temperatures. This has been made even more important in recent years as COVID-19 hit India hard, especially in its second wave, which has further reduced the resilience of the most vulnerable populations to such risks.

India's air pollution levels are also among the highest globally, posing a major threat to the country's health and economy. Nearly all of India's population is exposed to unhealthy levels of ambient PM 2.5, a pollutant that contributes to the incidence and severity of fatal illnesses such as lung cancer and heart diseases. Lost labor productivity, lower incomes, and premature deaths have a high social and economic cost. According to

2 This would occur regardless of whether the investment is funded by the private or public sector, unless the investment is fully funded by zero-interest borrowing or international financial support.

3 This mainly relates to the extraction of coal. There are likely further job losses in coal-based power generation; however, given that renewables generation is more labor intensive, those losses would be outweighed by gains elsewhere in the power sector.

the World Bank, the total estimated lost labor income reached up to 0.3 percent–0.9 percent of India's GDP in 2017, and 1.7 million premature deaths were directly linked to pollution (World Bank 2021a). PM 2.5 pollution in India comes mostly from burning of coal, oil, gas, and biomass as well as dust from natural sources and construction. In India, indoor air pollution from burning solid fuels in simple cook stoves is also one of the major reasons for morbidity especially for women and children (CEEW 2021a). Decarbonizing power generation and industry, as well as other sectors (transport, buildings, and agriculture) in India, is not only vital for mitigation but would also result in substantial health co-benefits from reduced air pollution.

Current Policy Landscape for Decarbonization

India's current NDC target was set in 2015 and commits to reducing emissions intensity by 33 percent–35 percent below 2005 levels, reaching 40 percent nonfossil capacity in power generation and creating a carbon sink of 2.5–3 $GtCO_2e$ through additional forest and tree cover, all by 2030. These targets are on track to be achieved early in the next few years through current policies and are seen as not ambitious enough to keep on track toward limiting the global temperature increase to 1.5°C above preindustrial levels by 2100 (Climate Action Tracker 2022). At the World Leaders Summit at COP26 in Glasgow in 2021, Indian Prime Minister Narendra Modi announced updated 2030 targets and a new 2070 net zero target. The new 2030 commitments aim to reduce carbon intensity by more than 45 percent below 2005 levels, reduce emissions by 1bn tonnes, increase nonfossil fuel capacity to 500GW, and source at least 50 percent of energy from renewables (see section 2.2 for our interpretation of these targets). Although these commitments have not yet been formally submitted as part of India's NDC and/or Long-term Strategy (LTS), they point toward substantially increasing climate action ambition.

While recent announcements push for faster emissions reductions, India continues to expand its coal power capacities and subsidize fossil fuel supply chains (IISD 2022). Government action to help the post-COVID-19 economic recovery included a large stimulus package of $325bn (vivideconomics 2021). About two-thirds of the support went toward green recovery, including $3bn spent on batteries and solar PV. Despite these green elements, the package also supported industries with heavy fossil fuel use, and there is continuous support for coal (Climate Action Tracker 2022). India's coal plan includes a reveneue-sharing agreement with private sector producers to promote coal gasification, rebates on coal extraction, and removal of coal-washing regulations for supply to thermal power plants (vivideconomics 2021). Additionally, the government issued loans for coal-based power generation plans and support for using domestic instead of imported coal (vivideconomics 2021).

The IPCC's WGII report of AR6 (IPCC 2022) found that to stay within the Paris Agreement's goal of limiting temperature rise to 1.5°C by 2100, global emissions must peak before 2025. Reaching the 1.5°C target is only possible with all unabated coal phased out, methane emissions cut radically, a five-time increase in investments in low-carbon technologies compared to today, and strong reforestation and effectively all sectors taking immediate greening actions. India, as a major GHG emitter with substantial coal use, will play a critical role in closing this gap. India must formally update its NDC with stronger commitments and enact policies to ensure they can be implemented and achieved. Given that current NDC targets are achievable with current policies alone, India has the potential to reach net zero sooner than indicated in current commitments and to ensure that its economy contributes to keeping warming below 1.5°C. Reducing emissions would bring not only competitiveness gains in a global green economy but also come with health benefits from reducing pollution and would potentially lower the cost of climate-related disasters by contributing to slower global warming. Phasing out unabated coal and increasing support for renewables are key tools to support this.

OBJECTIVES

This report provides economic analysis to support the High-level Policy Commission on Getting Asia to Net Zero convened by the Asia Society Policy Institute (ASPI) in providing guidance and advice to India on the net zero transition. The analysis aims to identify the impacts and benefits of decarbonization under different policy combinations and ambition levels. The study also considers the potential synergies and/or trade-offs between decarbonization and development goals.

Given the strong case for India to decarbonize, the economic impacts of India choosing different potential emissions reduction pathways including progressing toward net zero, compared to its pre-COP26 policies baseline, are analyzed in detail as part of the report.

REPORT STRUCTURE

The rest of the report consists of three chapters describing the approach and findings, supplemented by technical appendices.

Chapter 2 describes the approach of the analysis, including the narratives of the modelled scenarios.

Chapter 3 shows the findings of the modelling for different climate ambition levels analyzed. Results are included for the pre-COP26 policies baseline, for scenarios achieving current commitments (2030 and 2070) through different policy mixes, and for scenarios featuring accelerated coal phaseout and stronger policies to reach net zero emissions by 2050.

Chapter 4 summarizes key conclusions and policy implications from the modelling results.

SCENARIO FRAMEWORK

MODELLING FRAMEWORK

This report presents a set of scenarios describing alternative decarbonization pathways for India using E3ME, a global macroeconometric model developed and maintained by Cambridge Econometrics. ASPI and local experts with strong knowledge of India's decarbonization and related policies were involved in designing the scenarios and reviewing the results to ensure their robustness and relevance.

E3ME is a simulation-based model that contains many policy instruments including taxes, subsidies, regulations, energy efficiency, and support for new technologies. The model solves annually and has detailed sectoral coverage including bottom-up technologies in key sectors (power, road transport, steelmaking, and heating or cooling). It shows where each alternative pathway will get to in terms of economic growth, jobs, emissions, and other key indicators. More details can be found in the technical appendices accompanying this report.

The modelling covers the period 2023–2060, the end of which is determined by the model setup (the model does not extend beyond 2060). The results outline impacts across this time frame, acknowledging that there will be additional impacts taking place beyond this point that are not included. Where there are targets for specific years before 2060, results for these years are also presented.

SCENARIO NARRATIVES

The scenarios were designed to provide answers for the following key research questions:

- Identify impacts and benefits — What would be the short- and long-term economic, social, and climate impacts of different levels of decarbonization effort/ambition?
- Accelerate ambition — How strong do policies and commitments need to be to deliver the 2070 net zero target? How must this ambition level shift if the date of the net zero target is brought forward?
- Support implementation — Which policy package is expected to deliver the most economic, social, and climate benefits? Which policies should be prioritized to further accelerate climate action without significantly compromising economic and social outcomes? What are the associated policy costs? What are potential barriers or trade-offs (and how can they be addressed)?

Therefore, the key narratives explored as part of this study include the following:

- **Pre-COP26 policies (*baseline*):** This scenario is our reference case for India to benchmark other scenarios against. It represents the least ambitious pathway, considering enacted decarbonization policies for India implemented before COP26 with no additional policies modelled thereafter.
- **Baseline + 2030 targets (*2030 targets*):** This scenario represents a pathway in which India's

2030 commitments announced before January 2022[4] are met but no new policies are implemented thereafter. It is intended to highlight how current policies need to be adjusted to enable India to meet its announced 2030 targets. This scenario treats short-term pledges to 2030 as credible and enforced, but it does not assume an increase in ambition beyond those policies.[5] In this and all subsequent scenarios, a cap-and-trade system is imposed on emissions from energy-intensive sectors from 2025, with differences in the cap reflecting the level of ambition.

- **All COP26 commitments including 2030 targets and 2070 net zero commitment (*2070 net zero*):** This narrative represents a pathway beyond the 2030 commitments that includes additional policies to deliver India's announced net zero commitment. The scenario is designed to understand how India's near-term, midterm, and long-term ambitions need to be calibrated to achieve its 2070 net zero target, including how its current 2030 targets stack up with the pathway toward its net zero goal.

  Variants of this scenario that use different policy mixes (balanced, regulation focused, and market based) are explored to achieve the same net zero target. These scenario variants help assess how the economic impacts and costs of the transition differ based on the policy choices made. The variants are intended to illustrate how the results may respond to small variations in the policy assumptions. Therefore, they focus on aspects of policy implementation that can be measured and modified quantitatively, namely timing, explicit targets, and rates, because they correspond to smaller variations, and responsiveness to these elements can be assessed directly from the numerical model outcomes. In contrast, they do not assume changes to scope (e.g., sector coverage) that are explored in the comparison of scenarios with different levels of ambition.

  - In the **regulation-focused variant**, regulatory measures (unabated coal phaseout and biofuel mandate) are brought forward so that the intended outcome of each measure is achieved earlier.[6] Carbon prices are set at a lower rate, so economy-wide net zero emissions are achieved by the same year (2070).
  - In the **market-based variant**, all subsidies for low-carbon technologies in all sectors are reduced by half, whereas regulatory-enforced outcomes are achieved later. Carbon prices are increased so that net zero emissions are achieved by 2070.

- **Accelerated coal phaseout:** This scenario represents a pathway in which India meets its current targets and there is an additional effort to phase out unabated coal power generation from the economy by 2040, more rapidly than current policies imply. It is designed to understand how India's ambition and overall emissions reductions could shift if it phases out coal in line with calls from the scientific community (UNFCCC 2022a). This scenario includes a no new coal policy from 2023 (excluding those already under construction). This means 33GW of new coal capacity that are under construction (IEEFA 2021) will be allowed to come into the system over the next three years, but no more. This

4 Since the analysis started, there have been new policy and political developments taking place that are acknowledged in the report but not included in the modelling.

5 Note that pre-COP26 announcements that had not been made into policies are only included in the *2070 net zero* and *2050 net zero* scenarios.

6 A period of five years was selected as it is long enough for policy changes to take effect and short enough to allow the modelling to quantify how sensitive results are to small changes in the assumptions.

is estimated to yield a total peak capacity of 220GW by 2025, which is likely lower than the government's current projection for peaking coal capacity of 250GW by 2030 (Ministry of External Affairs 2022). However, it is higher than projections by Ember (2021) for less than 200GW by 2025 under more stringent assumptions that in addition to a no new coal policy all coal plants over the age of 25 will be retired.[7]

- **2050 net zero:** Under this narrative, the climate policies applied in India are adjusted to reach net zero emissions by 2050. The scenario elucidates what needs to happen to fully align India's near-, mid-, and long-term ambition with a 1.5°C pathway. COP26-related commitments are strengthened, and a no new coal policy from 2023 (the same as under the *accelerated coal phaseout* scenario) and carbon pricing in non-energy-intensive sectors from 2031 are imposed. The rest of the world including other Asian economies are assumed to act in line with a 1.5°C global pathway. Similarly to the *2070 net zero* scenario, this narrative is analyzed with different policy packages (with a focus on either regulatory measures or market-based measures) to explore the role of policy choice on the outcomes.
    - In the **regulation-focused variant**, regulatory measures that are adjusted include a sales cap on internal combustion engines (ICEs) and a complete ban in the long term, as well as a phaseout regulation for fossil fuel use in buildings. These are in addition to the measures used in the *2070 net zero* regulation-focused variant.
    - In the **market-based variant**, the adjusted measures are the same as for the *2070 net zero* scenario; however, the magnitude of change is larger to reflect ambition.

In all scenarios, it is assumed that the government is responsible for financing investment in energy efficiency measures, financial support for low-carbon technologies, and compensation to power companies for stranded assets caused by coal regulations. It is also assumed that any carbon revenues received by the government will be specifically earmarked for these transition-related policy costs.

The evolution of different technologies is determined within the model, based on historical cost and market shares data (which drive future cost changes) and subject to technical potential constraints (particularly for relatively new solutions such as carbon capture and storage (CCS) and green hydrogen that will need time to become economically competitive).

Extended narratives and a description of scenario assumptions can be found in the technical appendices, while detailed policy assumptions are described in Appendix D. Specific assumptions are informed by or sense-checked against government announcements, expert advice, and the wider academic literature.

7 The modelling assumes that all coal plants over the age of 40 are retired.

Interpreting India's Updated Targets

Some of the announced targets by Prime Minister Modi at the World Leaders Summit at COP26 in Glasgow (Ministry of External Affairs 2021) are open to interpretation and lack precise definitions. The targets in this analysis are interpreted consistently with government-issued clarifications, available literature, and guidance from local experts. The targets are modelled as follows:

- **Reducing emissions by 1bn tonnes by 2030:** We interpret the target as a 1bn-tonne reduction in cumulative CO_2 emissions between 2021 and 2030 compared to a baseline scenario that includes only pre-COP26 commitments. This definition is in line with the interpretation of WRI India (WRI India 2021) and Centre for Science and Environment's interpretation as a 22 percent reduction from a business-as-usual scenario (CSE 2021). We focused on reducing CO_2 emissions, which are the largest share of GHG emissions and follow similar trajectories to total emissions.
- **Reducing the carbon intensity of the economy to 45 percent below 2005 levels:** For consistency, we interpreted this to apply to CO_2 emissions.
- **Increasing nonfossil capacity in power generation to 500GW:** In our modelling, this target includes renewables and nuclear energy but excludes fossil fuels plants with carbon capture and storage.
- **Achieving 50 percent of energy requirements from renewable energy sources by 2030:** We interpreted this as 50 percent of power generation capacity shares.
- **Net zero by 2070:** In our modelling, this target applies to CO_2 emissions. The year that net zero is achieved is the year in which annual CO_2 emissions are no longer positive (i.e., they are zero or lower).

STRENGTHS AND LIMITATIONS

E3ME's key strengths for supporting this analysis follow:

- The close integration of the economy, energy systems, and the environment, with two-way linkages between each component.
- The econometric approach, which provides a strong empirical basis for the model and means it is not reliant on some of the restrictive assumptions common to Computable General Equilibrium (CGE) models.
- The econometric specification of the model, making it suitable for short- and medium-term assessment, as well as longer-term trends.
- A high level of disaggregation, enabling detailed analysis of sectoral effects across a wide range of scenarios. The model captures individual country dynamics as well as interactions with other regions of the global economy.

- A wide range of climate policy options are available including regulations, taxes, tariffs, and subsidies, especially for the largest emitters in the economy (power, steel, road transport, and residential buildings) that also feature a detailed representation of technology diffusion
- The shift of focus away from just determining a least-cost policy implementation and toward identifying potential opportunities and trade-offs arising from decarbonization.

On the other hand, the analysis has a number of limitations:

- The modelled scenarios incorporate only information available in the public domain up until December 2021. Recent major events including the war in Ukraine and fossil fuel price spikes, as well as increases in countries' climate ambition since January 2022, are not included but all are likely to impact the results to some extent. In particular, our own previous research (Cambridge Econometrics 2022) suggests that high prices and fossil fuel supply disruptions would encourage investment in low-carbon alternatives; however, it still leads to long-term economic scarring in the largest economic blocs, which would eventually spread to India.
- As with any modelling tool, E3ME is an imperfect representation of reality. Both gaps in the data and an inability to predict the future contribute to uncertainty in the model results. Given the diverse characteristics of the economy and energy system, it is not technically possible to account precisely for every possible energy source and technology in each sector. For example, the model accounts for seasonal variations, implied demand for backup generation and storage, and technological constraints in India's context to determine the technology mix, but it does not fully capture detailed power grid balancing requirements (which can only be accounted for using real-time hourly data).
- The analysis focuses on evaluating the socioeconomic impacts of increased climate action with some consideration for costs, savings, and trade-offs. It does not quantify avoided climate-related physical damages (the cost of inaction) and co-benefits (from improved environmental outcomes), both of which would add more incentives to accelerate the low-carbon transition.
- The modelling considers costs of policies aimed specifically at encouraging the uptake of low-carbon technology options and assumes they are financed domestically. It does not quantify the costs of other policies to manage the transition (such as social and labor market interventions) and the role of alternative financing mechanisms (such as international support), which do not have a significant impact on emissions but do influence socioeconomic outcomes. The impact of these policies depends directly on their implementation and can be better explored in follow-up analysis.

FINDINGS

DELIVERING INDIA'S DECARBONIZATION TARGETS

Identified Pathways for Short-Term Targets

Emissions are projected to continue to increase significantly in India in the baseline scenario. Increasing energy demand and continued fossil fuel use in the power sector over the time frame analyzed are the main drivers. The share of coal-fired power generation is expected to fall slightly over the forecast period, driven by a modest shift to solar PV, yet it will still remain high. As a result of rapid economic growth in the medium term, the carbon intensity of GDP in India is expected to continue falling based on its historical trends until the 2040s before stabilizing, if no new policies are introduced. In this scenario, India's revised 2030 and 2070 targets announced by Prime Minister Modi at the World Leaders Summit at COP26 are not met.

The modelling assumes that relevant policies are implemented in the *2030 targets* and *2070 net zero* scenarios to achieve India's targets for reducing cumulative emissions by 1bn tonnes this decade and reducing GDP carbon intensity in 2030 by 45 percent compared to 2005 levels. Of those scenarios, the *2070 net zero* scenario has more policies to deliver an additional net zero target, which leads to overachieving against the 2030 targets (see Table 3.1). Since E3ME is not an optimization model that solves for exact targets, the results for target indicators vary slightly across scenarios and are driven by the policy assumptions. The modelling thus illustrates the impact of different policy combinations to meet or exceed stated targets.

To explore the impact of policy variations on delivering net zero by 2070, two sensitivities with different policy focuses were modelled besides the central case (which features a balanced policy mix):

- One sensitivity with stronger regulatory measures, such as capacity regulation (fossil fuel phaseout) and mandates
- One sensitivity with stronger market-based measures, including financial incentives (subsidies, carbon pricing) and taxation

More detailed policies are listed in Appendix D.

TABLE 3.1: ASSESSMENT OF INDIA'S DECARBONIZATION TARGETS IN 2030

INDICATOR	TARGET	BASELINE	2030 TARGETS	2070 NET ZERO (BALANCED POLICY MIX)	2070 NET ZERO (REGULATION-FOCUS)	2070 NET ZERO (MARKET-BASED)
Reduction in carbon intensity of GDP by 2030 compared to 2005 levels	45%	39%	48%	57%	57%	56%
Cumulative carbon emissions reductions over 2021-30 (tonnes)	1bn	-	1.9bn	3.8bn	3.9bn	3.7bn

TABLE 3.1: ASSESSMENT OF INDIA'S DECARBONIZATION TARGETS IN 2030						
INDICATOR	**TARGET**	**BASELINE**	**2030 TARGETS**	**2070 NET ZERO (BALANCED POLICY MIX)**	**2070 NET ZERO (REGULATION-FOCUS)**	**2070 NET ZERO (MARKET -BASED)**
Net zero emissions	By 2070	Not met	Not met	Met	Met	Met
Nonfossil capacity in 2030	500GW	279GW	500GW	583GW	598GW	571GW
Renewables capacity share in 2030	50%	42%	60%	66%	66%	65%

Source(s):Cambridge Econometrics, E3ME modelling result.

In the baseline, without any new policy action, the short- and long-term targets are not met.

The enhancement of existing policies (such as subsidies for electric vehicles) and implementation of policies in the pipeline (including support for renewables electricity generation and carbon pricing) in the *2030 targets* scenario ensures short-run targets are met. In this scenario, the main policies supporting delivery of the 500GW nonfossil capacity target (renewables subsidies and establishing an emissions trading scheme for energy intensive sectors) also enable India to overshoot other targets. However, these policies are still insufficient to deliver the *2070 net zero* target.

The *2070 net zero* scenario, by ramping up policy action even further, will put the country on track to overachieve all short-term targets and achieve long-term goals as well through a combination of enhanced and new policies. Although no change to *2030 targets* is explicitly assumed, implementing policy changes earlier and effectively overshooting existing *2030 targets* will make the *2070 net zero* target more achievable with lower long-run stranded asset costs. Rapid progress toward *2030 targets* in this scenario is driven primarily by policies to decarbonize the power sector. In the short term, carbon pricing and renewables subsidies signal investors to shift activity toward less polluting fossil fuels (such as natural gas) or invest in new renewables capacity. While switching to less polluting fossil fuels is less costly and can be implemented relatively easily, it is unlikely to be a viable long-term option as carbon pricing makes fossil fuel generation more costly, while subsidies provide added incentives for new investment in renewables. In the longer term, post-2030, new renewables power capacity coming into operation, electrification of road transport and decarbonization of other sectors through carbon pricing and energy efficiency play a stronger role in driving emissions down.

Aiming Toward Net Zero Emissions Targets

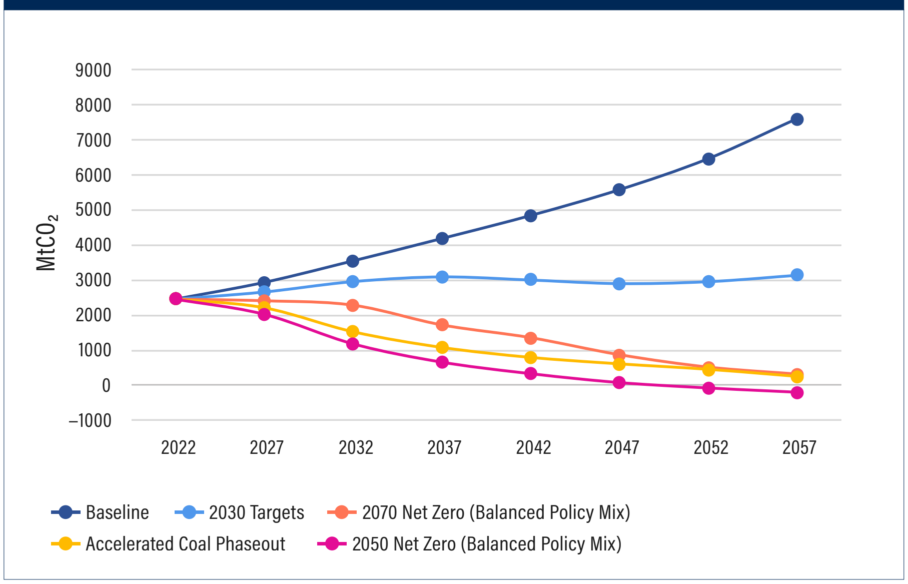
In the *2030 targets* scenario where policies are strengthened to meet 2030 targets but no further action is taken, CO_2 emissions are projected to fall by 60 percent from the baseline trajectory by 2060. However, without further policy measures aimed at achieving carbon neutrality in the future, emissions reductions are expected to stall by 2050, leading to CO_2 emissions stabilizing and starting to rise again toward the end of the forecast period due to increases in energy demand to support continued economic growth. The economy is therefore unlikely to reach net zero emissions by 2070 under this pathway,[8] but annual emissions stabilize after the 2040s. Additional long-term policies are needed to steer the economy toward net zero. In the *2070 net zero* scenario in which stronger measures are introduced and maintained throughout the forecast, emissions fall to 97 percent below baseline by 2060, putting India on track for reaching net zero by 2070.

Achieving India's commitments announced at COP26 represents a major step-up in climate action in India and comes with noticeable environmental and economic benefits. However, net zero emissions are not yet reached by mid-century, and emissions do not fall steeply enough to stay on track toward limiting global warming to 1.5°C by 2100. To do so, global emissions levels need to be 45 percent below 2010 levels and reach net zero around 2050 (IPCC 2022).

The *accelerated coal phaseout* and *2050 net zero* scenarios are designed to illustrate how India can further its actions to better align with this vision while bringing economic and other benefits to the country. Policies from the *2070 net zero* scenario are strengthened further, and a major additional policy is introduced that prevents new coal power plants from being built. This increased level of action opens up the potential for India to aim for more ambitious short-term targets and meet its net zero target by 2050.

The policy packages modelled (in particular, introduction of accelerated coal phaseout[9]) lead to CO_2 emissions peaking by 2025 in the *accelerated coal phaseout* and *2050 net zero* scenarios before falling rapidly, compared to emissions peaking by 2030 in the *2030 targets* and *2070 net zero* scenarios (see Figure 3.1). The most ambitious pathway for India therefore aligns with the need for global emissions to peak before 2025 to keep global warming to 1.5°C (IPCC 2022).

FIGURE 3.1: CO_2 EMISSIONS PATHWAYS FOR INDIA UNDER DIFFERENT LEVELS OF AMBITION



Source(s): Cambridge Econometrics, E3ME modelling result.

8 Note that the E3ME model solves annually until 2060. The emission pathway is extrapolated to 2070 using rolling five-year average growth rates. Based on this extrapolation, a 97% emission reduction by 2060 is aligned with achieving net zero emissions by 2070.

9 This refers to the no new coal policy from 2023 and unabated coal phaseout by 2040, implemented together.

Impact of Policy Choice on Meeting Targets

There are marked differences in both short- and long-term trajectories across the scenarios. In particular, an ambitious no new coal policy is highly effective in inducing further emissions reductions in the short and medium terms, which makes significant contributions to reducing cumulative emissions and slowing global warming while technologies in other sectors are still under development to make them commercially viable. It accounts for the majority of the difference in emissions before 2040 between the *2050 net zero* scenario and the 2070 *net zero* scenario.

Nevertheless, without rapid decarbonization of the whole economy, accelerated unabated coal phaseout ambition alone will not be enough to achieve net zero targets in the long term. Emissions levels in the *accelerated coal phaseout* scenario largely align with those in the *2070 net zero* scenario after 2050, despite much greater up-front emissions reductions.

Implementing policies consistent with *2050 net zero* target (which includes additional policies alongside accelerated coal phaseout regulation), on the other hand, leads to a trajectory where emissions reductions are accelerated to achieve net zero emissions by 2050.

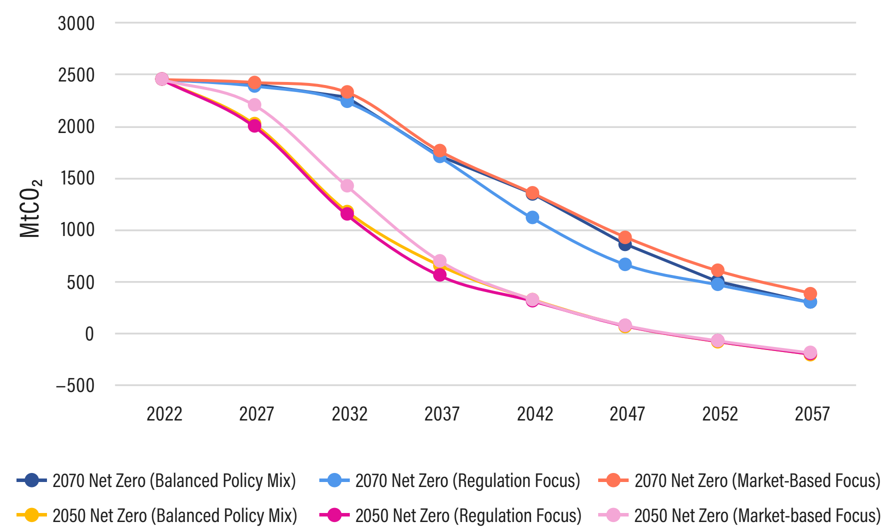
Of the targets set out under NDCs and COP26 commitments, the emissions reductions and renewables capacity targets are particularly sensitive to policy variations. In comparison to a balanced policy mix, stronger regulatory measures (particularly the no new coal policy from 2023) result in faster short-term emissions reductions and a slightly higher level of renewables capacity, whereas an emphasis on market-based instruments (in particular the emissions trading scheme or "ETS") leads to smaller reductions and a smaller renewables capacity: coal phase-down and phaseout regulation exerts the most influence (compared to other policies) on the power sector, the largest emitter in India, in the short term. The power sector is largely state owned and therefore responds more slowly to market signals, which is reflected in the sector's average responsiveness that the model data capture. On the other hand, market-based instruments, such as carbon pricing, are more effective and easily implemented (compared to regulation) in other sectors that consist mainly of demand from firms and consumers and therefore are more responsive to financial incentives.

The impact of policy choice on the emissions pathways can be seen in Figure 3.2. The regulation-focused sensitivity also leads to the steepest reduction in emissions in the years to 2050, whereas the sensitivity focused on market-based instruments results in a more gradual reduction before 2050 followed by a more accelerated reduction thereafter.

Policy choice does not have much influence on the year in which emissions peak; it is 2030 in all variants of the *2070 net zero* pathways because this is driven by the fixed 2030 targets. Specifically, once the targets of 500GW nonfossil capacity and 50 percent renewable energy are reached, the renewables subsidies and carbon pricing policies that deliver them are assumed to continue. Therefore, they not only prevent fossil fuel use and emissions from rising again but also accelerate the transition (relative to the baseline, which does not contain such policies) because the renewables cost reductions gained from their presence in the short term are carried over to subsequent years due to the model's path dependency.

In the *2050 net zero* scenario, there is little difference between the emissions pathway implied by a balanced policy mix and that implied by a regulation-focused policy mix. However, more ambitious market-based

FIGURE 3.2: POLICY CHOICE INFLUENCE ON INDIA'S CO_2 EMISSIONS PATHWAYS



Source(s): Cambridge Econometrics, E3ME modelling result.

instruments and delayed regulation push more of the cumulative emissions reductions into later years, similar to results for the *2070 net zero* sensitivities. This reason is that regulation is stringent and often binary (i.e., the presence or absence of regulation makes the most difference), whereas there is more flexibility to enforce market-based instruments at different levels of stringency over time.

Table 3.2 compares key decarbonization outcomes across the high-ambition scenarios compared to India's *2070 net zero* pathway.

TABLE 3.2: ASSESSMENT OF INDIA'S DECARBONIZATION TARGETS ACROSS SCENARIOS

INDICATOR	TARGET	2070 NET ZERO (BALANCED POLICY MIX)	ACCELERATED COAL PHASE-OUT	2050 NET ZERO (BALANCED POLICY MIX)	2050 NET ZERO (REGULATION-FOCUSED)	2050 NET ZERO (MARKET-BASED)
Reduction in carbon intensity of GDP by 2030 compared to 2005 levels	45%	57%	68%	73%	74%	64%
Cumulative carbon emissions reductions over 2021-30 (tonnes)	1bn	3.8bn	5.4bn	6.8bn	6.9bn	5.3bn
Net zero year	2070	2070	2065	2050	2050	2050
Nonfossil capacity in 2030	500GW	583GW	1068GW	967GW	977GW	579GW
Renewables capacity share in 2030	50%	66%	81%	81%	81%	67%

Source(s): Cambridge Econometrics, E3ME modelling result.

The inclusion of accelerated coal phaseout policies (a no new coal policy from 2023 and unabated coal phaseout by 2040) could allow India to reach net zero emissions five years earlier.

In addition, the comparison between scenarios with different levels of ambition highlights that a smooth transition toward net zero emissions by 2050 would require that India's targets for 2030 are significantly strengthened. In particular, the combination of a no new coal policy from 2023 and a higher rate of carbon pricing can contribute to a level of nonfossil capacity that is double the current target (almost 1TW compared to 500GW) by 2030. The impact on generation is likely smaller, given that power plants tend to operate below full capacity. This increase will deliver the majority of the required progress on emissions intensity, emissions reductions, and renewable energy supply targets.

The nonfossil capacity ambition, however, is conditional on complementing an ambitious unabated coal phaseout, because as shown in the market-based sensitivity, a delayed coal phaseout is not compatible with a more ambitious renewables capacity target. The reason is that state-owned power plants do not respond as strongly to financial incentives as privately owned plants (because of political and social constraints),[10] whereas regulation can be more easily and uniformly imposed on all types of ownership.

In fact, even if stronger market-based instruments are in place, the level of nonfossil capacity is relatively unchanged from the outcome of the *2070 net zero* scenario. This implies that an economy-wide target for net zero by 2050 is achievable with some of the existing 2030 targets (which tend to focus on the power sector) but will require the maximum level of financial support for low-carbon options and stronger carbon pricing (compared to a balanced or regulation-focused policy mix) in other sectors especially transport, industry, and building. The market-based measures for other sectors can be more costly to implement in the short term, and their effectiveness is subject to market conditions.

ENERGY AND TECHNOLOGICAL TRANSFORMATIONS

Underlying the emissions pathways described above are a series of technology transformations at the sectoral level. What sets the ambitious scenarios, and the *2050 net zero* scenario in particular, apart is the rate of progress in decarbonizing the power sector, which aids decarbonization in the rest of the economy.

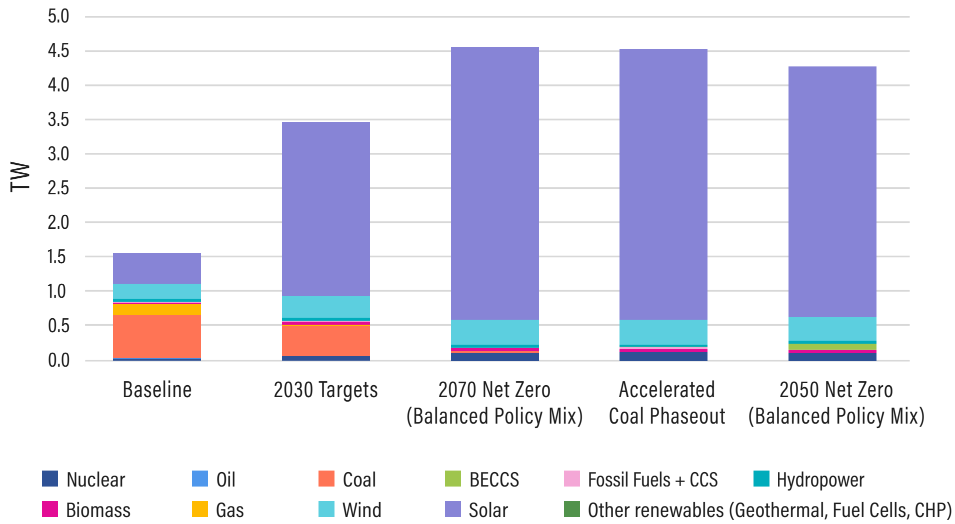
Power Sector

In the *2050 net zero* scenario, there will be a 35 percent higher demand for electricity compared to the baseline (30 percent in the *2030 targets* scenario and 40 percent in the *2070 net zero* scenario). This demand corresponds to a higher level of total electricity generation and capacity than in the baseline. It is mainly due to the higher rates of electrification of the economy (especially in road transport). The vast majority of this demand is met by solar, in contrast to a predominantly coal-based power mix in the baseline (see Figure 3.3). The lower level of electricity demand in the *2050 net zero* scenario, despite a higher rate of electrification than in the *2070 net zero* and *accelerated coal phaseout* scenarios, is due to higher rates of energy efficiency (enabled by additional revenues from higher rates of carbon pricing).

In the *2050 net zero* scenario, the modelling suggests that the power sector has the potential to completely decarbonize by the late 2030s, driven by a rapid coal phase-down in the short term, full coal phaseout in the

10 This is captured by model parameters (estimated from historical data) for the average sector of which state-owned plants make up the majority.

FIGURE 3.3: POWER CAPACITY BY TECHNOLOGY IN 2050 IN INDIA



Source(s): Cambridge Econometrics, E3ME modelling result.

medium term (2040), carbon pricing, and early procurement of carbon capture technologies. This implies that by 2040, more than 60 percent of primary energy demand will be from renewable sources, compared to 45 percent in the *2070 net zero* scenario where the power sector does not fully reach net zero until the early 2050s. Nonfossil-fuel capacity in India is projected to exceed the government's target of 500GW by 2030, with the potential to reach 1TW in this scenario. Because renewables have lower load factors[11] than fossil fuels due to intermittency, more capacity needs to be installed to meet the significantly higher demand for electricity.

It is possible to achieve net zero emissions by 2050 without meeting this high level of nonfossil capacity by following a different pathway, such as strengthening policies and ambitions in non-power sectors (as in the market-based policy variant). However, there are significant benefits from decarbonizing the power sector more rapidly and raising the nonfossil capacity target, given that electricity will become the dominant energy source in most sectors in a decarbonized future. These benefits include larger cumulative emissions reductions (which reduce climate risks from rising temperatures), macroeconomic gains being realized earlier (see section 3.3), and lower costs of compensation for stranded assets in the long term (see section 3.4).

The no new coal policy adopted in the *2050 net zero* and *Accelerated coal phaseout* scenarios plays a critical role in this transition. In the short term, a ban on new coal plants may trigger increased usage of existing coal plants (as well as other fossil fuel plants), which are currently operating well below full capacity, to meet rising energy demand. Specifically, the potential electricity generation from coal plants that would have been constructed without the no new coal regulation may be met in part by existing plants redistributing coal supply and maintaining or increasing load factors in those plants. If this were to happen, immediate impacts of

11 Load factors are a measurement of efficiency of power plants and indicate the average amount of electricity generated from the available capacity.

the policy on emissions reductions may be limited. However, there are reasons to assume that rapid growth in load factors among existing plants is not sustainable until 2050 and beyond:

- As of 2022, coal load factors in India have already increased to almost the highest levels seen in the past decade (Ministry of Power 2022b). Spare capacity that has been idle would have aged and become inefficient (and therefore extremely costly to renovate), so there is a limit to how much more spare capacity can be brought back into active use (limited to younger and more efficient plants). The existing stock will continue to age. Without new construction to replace retired plants (enforced by the no new coal policy), load factors will start falling again naturally at some point.
- Renewables have become much more affordable and will be increasingly so with the help of subsidy policies, which would incentivize a proportion of investors to start switching away from coal even if some plan to increase generation in existing plants. (TERI 2020) shows that there is an overall reduction in load factors among coal plants when renewables capacity increases, especially among plants with higher load factors, despite an increase among plants with lower load factors to support renewables integration.

The combination of coal phaseout regulation, carbon pricing, and renewables subsidies ensures that in the long term, retiring coal plants are replaced by renewables. This effect does take time to materialize, however, as investment decisions and new constructions have a time lag. This means that the results for power capacity and generation mix are particularly sensitive to policy choices, with regulation having a stronger influence than market-based instruments.

Final Energy Demand

Final energy demand by 2050 is lower in all scenarios than in the baseline scenario, primarily as a result of energy efficiency improvements.

The energy composition of final demand does not differ drastically from *2070 net zero* scenario (see Figure 3.4), apart from a modest further shift from oil to hydrogen in industry, construction, and transport sectors under more ambitious scenarios.

In transport, by 2060 most passenger vehicles are electric (driven by electric vehicle subsidies and petrol/diesel regulation), rail transport is significantly electrified, and a share of fuel demand for road freight and air and marine transport is replaced by alternative fuels such as hydrogen (by assumption, as per Appendix C) and biofuels (incentivized by carbon pricing and biofuel mandates).

On the other hand, industry, agriculture, and buildings decarbonize more slowly. There is a shift away from fossil fuels to electricity and biofuels in agriculture, and electricity becomes the dominant form of energy used in industries and buildings. Biofuel mandates and carbon pricing are key policy drivers in these sectors, with energy efficiency programs also facilitating the transition in the buildings sector. The complete decarbonization of the power sector, combined with increased electrification, indirectly helps decarbonize end-use sectors as well; hence, fewer sector-specific policies are needed.

It should be noted that biofuel mandates, a key policy especially in transport sectors, would compete for available land with agriculture and forestry sectors that are responsible for critical food production and creation of natural carbon sinks and also have biodiversity and ecosystem trade-offs. Therefore, biofuel potential has a limited role in the results, and electricity is expected to be the dominant energy type in all sectors in the long term.

Policy choices do not have an overbearing impact on the final energy consumption outcomes, except that the speed of the transition is increased slightly in industry sectors when there is a higher rate of carbon pricing and in transport sectors when there are stronger ICE regulations and biofuel mandates.

FIGURE 3.4: ENERGY MIX BY FINAL USER IN 2050 IN INDIA ACROSS SCENARIOS

Source(s): Cambridge Econometrics, E3ME modelling result.

SOCIOECONOMIC IMPACTS

In the baseline, India is projected to experience strong GDP growth of above 7 percent per annum (pa) in the next decade, followed by more modest growth of 5 percent pa over 2040–2050 and 2.5 percent pa thereafter, as it becomes more aligned with the growth path of current developed economies. Economic growth is supported by household consumption, investment, and exports, while employment grows modestly in line with population.

GDP Impacts

The macroeconomic impacts of all scenarios are positive all the way through the forecast period in GDP and employment terms (see Figure 3.5).

GDP impacts are positive and mainly drive by investment

In the *2030 targets* scenario, the impact on GDP is smallest, fluctuating between 1 percent and 2.8 percent above baseline levels over the forecast period, with the long-term impact at around 2.5 percent above baseline. GDP is projected to be 5 percent higher than the baseline in the *2070 net zero* scenario at its peak. The *Accelerated coal phaseout* and 2050 net zero scenarios see GDP impacts peaking at a higher rate (higher than 7 percent above baseline) and around five years earlier than the *2070 net zero* scenario. This implies a more rapid transition taking place earlier, leading to significantly more investment, value added, and jobs in the medium term. The long-term impacts across scenarios (apart from the *2030 targets* scenario that does not assume a net zero target) are similar from 2050 onward at around 3.4 percent–5 percent ($500bn–$550bn in absolute terms) per year above baseline.

The GDP impacts are driven mainly by higher levels of investment in the power sector in the short and medium terms, supported by investment in energy efficiency and carbon sink potentials in the longer term. In the power sector in particular, the assumption is that large amounts of investment will be frontloaded to facilitate the construction of critical infrastructure for the transition. These investments are frontloaded in all scenarios, peaking in the years to 2035 and levelling off as key sectors of the economy are decarbonized.

Investment is the strongest driver of overall GDP impacts, which are also influenced by household consumption and net trade. Therefore, GDP impacts follow a similar profile as investment, peaking in the early 2030s, soon after the peak in additional investments but later than the emissions peak year, which is driven more by coal regulation policies —policies are assumed to take effect immediately, whereas investment decisions have a time lag to materialize, and the wider secondary impacts have an additional time lag to fully circulate through the economy.

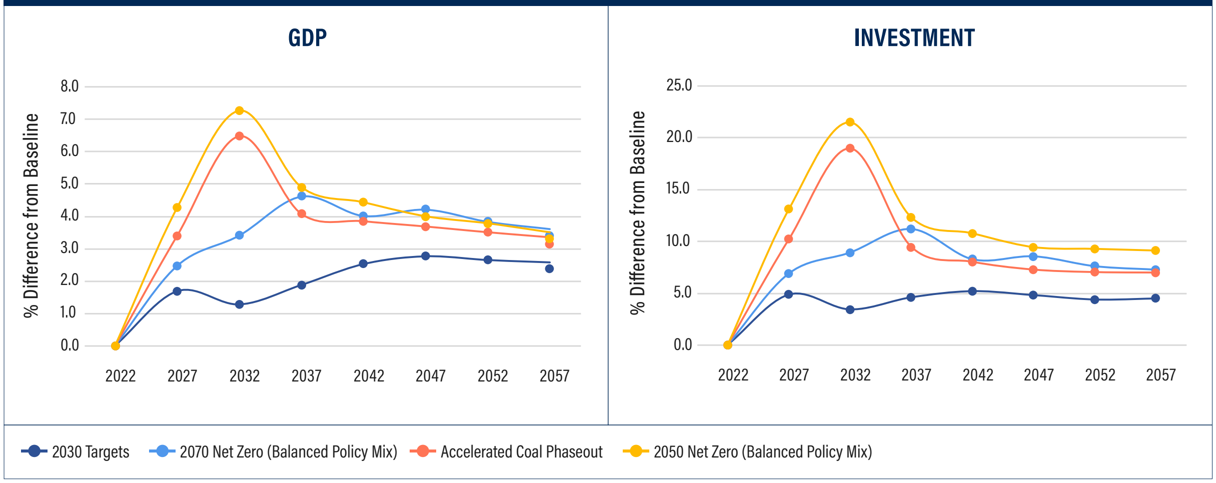
Investment requirements for a *2070 net zero* transition are estimated at more than $10.1trn from 2022 to 2060[12] compared to the baseline and to peak at 12 percent above baseline levels around 2035–2036. In comparison, reaching net zero emissions by 2050 will require additional investment of $3.4trn compared to the *2070 net zero* scenario over the same 2022–2060 period[13] (or $13.5trn relative to the baseline). The annual average investment requirement in the *2050 net zero* scenario is higher than the *2070 net zero* scenario, as expected given the different levels of ambition.

As a comparison, a study by CEEW finds that $10.1trn is needed for India to reach net zero by 2070, of which $6.3trn is anticipated in the years to 2060, whereas the investment required over 2020-60 for a 2050 net zero scenario is $8.5trn (CEEW 2021d). In both scenarios, over the period to 206015, the E3ME investment estimate is higher than the equivalent CEEW estimate, due to scope differences. Firstly, CEEW's investment calculations focus on power renewables integration, electrification in transport and hydrogen supply

12 This is the end of the modelling period, after which additional investment may be needed to lead India toward net zero emissions by 2070.

13 Once carbon neutrality is achieved in 2050, more investment will likely still be needed to maintain it and prevent emissions from rising again. These investments include renovation and replacement of equipment and infrastructure and continued energy efficiency and agricultural productivity improvements.

FIGURE 3.5: GDP AND INVESTMENT IMPACTS IN INDIA ACROSS SCENARIOS (% DIFFERENCE FROM BASELINE)



Source(s): Cambridge Econometrics, E3ME modelling result.

in industry, whereas additional investments in energy efficiency improvements (such as building insulation and industrial process retrofits) and negative emissions solutions (CCS and natural carbon sinks) are also included in E3ME alongside the above. An earlier study by CEEW (CEEW 2021b) acknowledges that reductions in energy intensity in buildings and industry sectors are needed to contribute to net zero targets. Secondly, E3ME projects a faster speed of decarbonization with emissions peaking by 2025 in the 2050 net zero scenario and 2030 in the 2070 net zero scenario, therefore reaping emission reduction and economic benefits earlier, compared to CEEW's assumption of peaking in 2030 and 2040 respectively. This is enabled by stringent no new coal regulation (in the 2050 net zero case), and renewables subsidies and a higher level of carbon pricing which also acts as a funding source for government-subsidized investments.

In the *2030 targets* scenario, delivering 2030 targets is estimated to require less than $500bn of additional investment between 2022 and 2029, $200bn of which is needed to build wind and solar capacity before 2030 to meet the government's 500GW nonfossil-fuel capacity target, similar to estimates by Jaiswal and Gadre (2022). The remaining investment is expected to be used for building capacities of other low-carbon power technologies (e.g., nuclear, hydro, and carbon capture and storage) and energy efficiency measures in other sectors.

The positive investment impact is reinforced by an improvement to the trade balance

In addition to the positive contribution to GDP from investment, reduced dependency on imported fossil fuels as part of the transition leads to a long-term improvement in India's trade balance, estimated at $205bn and $236bn in 2060 in the *2050 net zero* and *2070 net zero* scenarios, respectively, compared to the baseline (equal to around 1.5 percent of GDP). The slightly smaller improvement by 2060 in the more ambitious *2050 net zero* scenario, in relation to the *2070 net zero* scenario, results from the reduction in fossil fuel imports in the more ambitious scenario being greater, leading to a larger corresponding increase in demand for equipment and material inputs to low-carbon processes. This larger demand is more likely to stretch domestic production and result in a reduction in exports to prioritize domestic use and/or an increase in imports of those inputs, both of which offset some of the fuel trade balance improvement. Even the least ambitious scenario focusing on near-term targets with no net zero target (*2030 targets*) is likely to see an improvement in the trade balance of $124bn by 2060. Otherwise, IEA (2021a) estimates that 75 percent of India's oil demand is currently met by imports, which are projected to increase to 90 percent by 2040 under existing NDCs, policies implemented up to mid-2021, and some proposals announced but yet to be implemented.[14]

Improved energy security through lowering import dependency and replacing it with domestically produced renewable energy helps maintain an energy supply that is safe from global fossil fuel supply disruptions for the domestic population, especially households at risk of fuel poverty. Manufactured fuel imports into India already fall strongly by 55 percent and 76 percent compared to the baseline by 2060 in the *2030 targets* and the *2070 net zero* scenarios. Fossil raw material imports fall as well; oil and gas imports are 29 percent and 46 percent lower, while coal imports are 20 percent and 33 percent lower than the baseline in the two pathways. The reduction in fossil imports is the strongest driver of overall import reduction and improving India's trade balance.

However, consumers bear the cost of the transition

Additional investment represents an economic stimulus but requires funding, which is also a cost to the economy. The modelling assumes that additional investments and policy implementation are funded domestically by the government (through carbon pricing and other tax-raising measures) or by private industries (through increased borrowing). Modelling as such thus enables a baseline understanding of hypothetical worst-case impacts should the role of international finance be limited. Privately funded investments and higher industry costs due to carbon pricing are thus passed on to consumers in the form of higher product prices, which reduce purchasing power. Investments and policy costs funded by governments that are not covered by carbon revenues are assumed to be funded via additional taxes, directly increasing the tax burden on households and reducing disposable income.

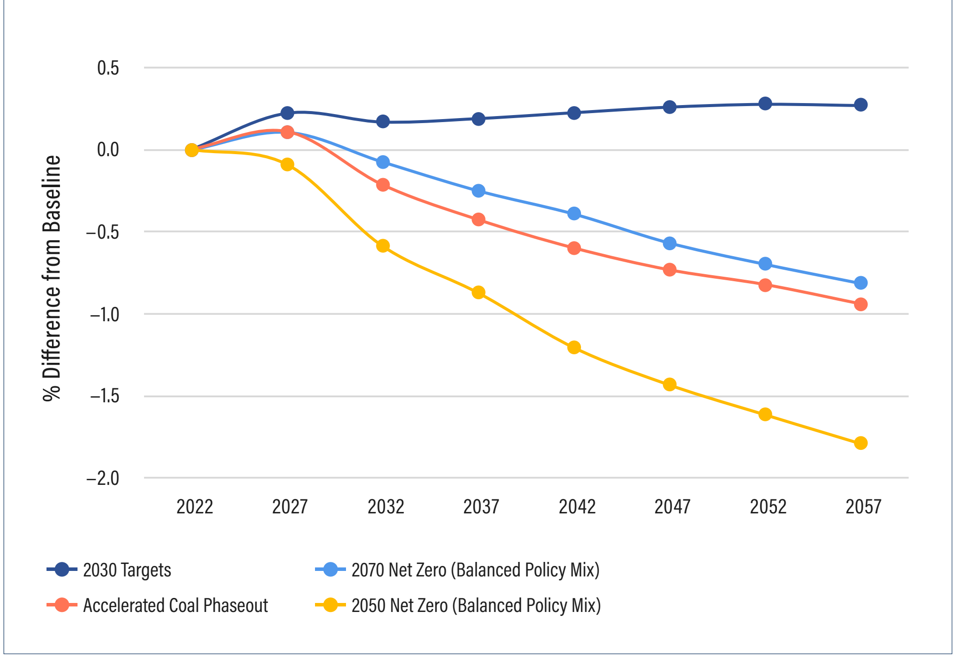
The impacts of both lower purchasing power and a higher tax burden outweigh the positive impact on nominal income associated with a higher level of GDP and employment relative to baseline. As a result, there is a net negative impact on household income and consumption, implying that consumers directly bear some of the cost burden of the transition. The second half of the forecast period coincides with the payback period when consumers indirectly bear these costs that reduce their spending abilities. This reduction in household consumption is equivalent to $79bn (1 percent below the baseline) by 2060 in the *2070 net zero* scenario and $165bn (2 percent below the baseline) in the *2050 net zero* scenario (see Figure 3.6). It lowers demand for all consumer goods.

A separate reduction in energy spending results from falling demand due to energy efficiency. In light of household budgets being squeezed by the cost burden of investment as mentioned above, this reduction frees up income that would have been spent on energy for other essential items such as food and housing. This energy cost saving does not influence or result directly from the aggregate consumption impact (which reduces consumer welfare) but rather acts in parallel and helps minimize the welfare loss for low-income households that spend a larger proportion of their income on energy.

These effects impact low-income households most significantly. While improved energy security and lower domestic energy demand create opportunities for them to gain better access to affordable energy, the costs of

14 Based on IEA's assessment of how likely the announcements are to be realized

FIGURE 3.6: HOUSEHOLD CONSUMPTION IMPACTS ACROSS SCENARIOS IN INDIA



Source(s): Cambridge Econometrics, E3ME modelling result.

additional investments and policy implementation constrain their spending power and real income growth. As such, shifting (some of) the cost burden away from consumers through other funding mechanisms would help mitigate the risk of pushing vulnerable households into poverty, particularly in fuel.

CEEW (2021) estimates that there is a substantial gap between India's investment needs for reaching net zero and the amount that could be "reasonably" covered by domestic sources. This investment gap reaches more than one-third of the investment needs and could be bridged through international investment support or other tools that generate government revenues. International support is not only important for India reaching net zero but also for maintaining India's economic and social development goals, including tackling poverty and improving energy access for the population. However, because the availability of international funding is uncertain, our modelling shows the full impact of decarbonization without reliance on it as a reference scenario. With international support, overall domestic consumption impacts would be less negative and overall macroeconomic impacts would be boosted further.

Employment Impacts

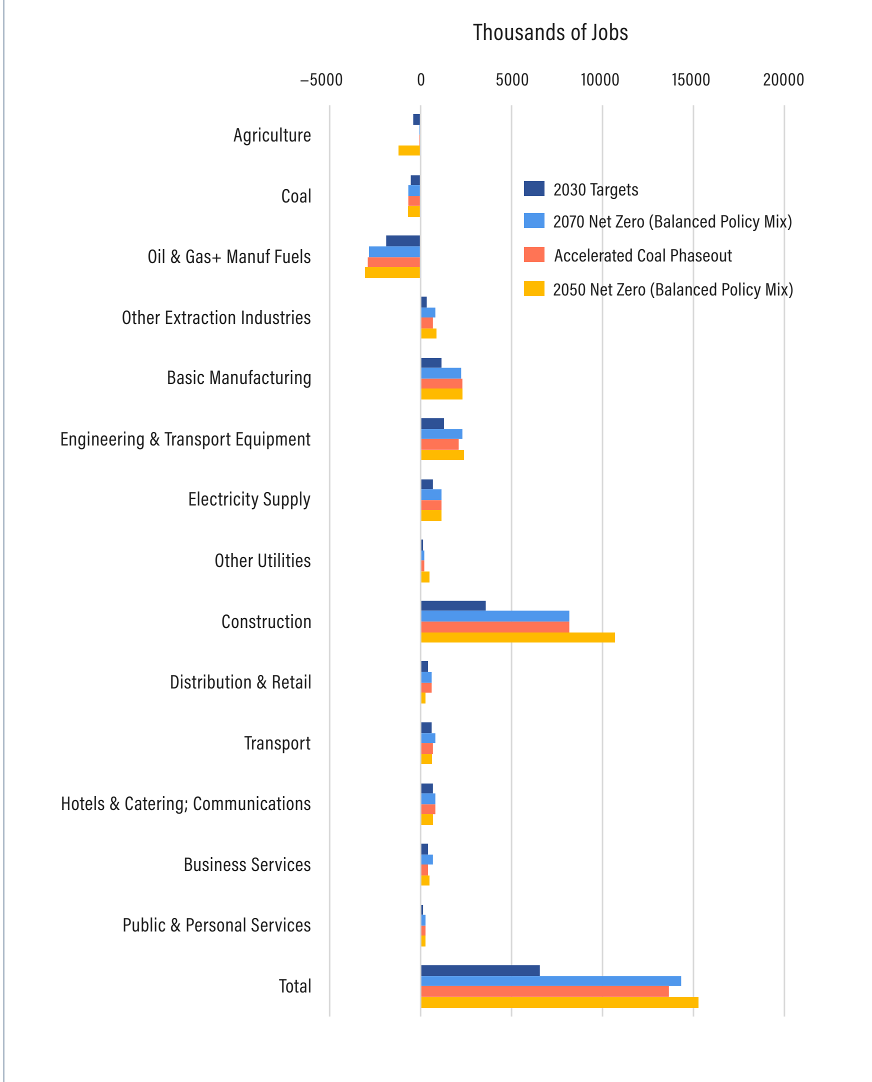
The employment impacts are positive and relatively smaller in magnitude compared to the GDP impacts, as higher efficiency leads to average wage gains from additional investment, meaning that in percentage terms employment gains are smaller than output gains.

Substantial job gains come from decarbonization, with winners and losers

The employment impact ranges between 1.5 percent and 1.75 percent higher than the baseline by 2060 in most scenarios, equivalent to 12–13 million additional jobs created across the Indian economy. In the least ambitious *2030 targets* scenario, the impact is smaller at 0.9 percent (7 million jobs) above the baseline in 2060.

Figure 3.7 shows the sectoral breakdown of the overall employment impact in 2050, when most of the transformational changes have taken place. The most substantial job losses are in the fossil fuel supply sectors (coal and oil and gas) due to the transition to renewables. Social protection policies as well as programs to support education and training and improve job searches are needed to minimize disruption and help workers transition into new jobs created in the low-carbon economy.

FIGURE 3.7: EMPLOYMENT IMPACT BY SECTOR IN 2050 IN INDIA ACROSS SCENARIOS



Source(s): Cambridge Econometrics, E3ME modelling result.

The job losses in fossil sectors are followed by milder negative impacts in agriculture, driven by lower levels of consumer spending (which could be mitigated and potentially reversed by measures such as international financial support) and increased investment in agricultural productivity to reduce land-use emissions and expand carbon sink potentials (which implies a substitution of machinery for labor).

All other sectors, however, present new job opportunities. Most notably, there are substantial gains in sectors that form the supply chain of the technology transition, including construction (responsible for infrastructure developments), other extraction industries (suppliers of minerals), and manufacturing sectors (suppliers of machinery, equipment, and manufactured materials).

Employment also increases in the electricity supply sector, for a number of reasons: (1) more demand for electricity creates more generation in the transition; (2) renewable energy technologies are more labor intensive per unit of capacity than conventional generation; and (3) the load factor of renewables is (mostly) lower than conventional generation, so the labor intensity per unit of generation increases more than per unit of capacity.

In addition, services sectors (predominantly) also benefit from increased investment, as they form the critical supply chain to the sectors that benefit directly.

All scenarios imply a redistribution of jobs opportunities in the Indian workforce. By 2060, the loss of almost 5 million jobs in primary and fossil fuel sectors is compensated by opportunities created in the industry and services sectors. Despite additional jobs in construction, electricity supply, manufacturing, and service sectors, India may need further investment (not modelled in these scenarios) to reskill displaced workers as well as upskill and train the future workforce to be able to access and take advantage of these opportunities.

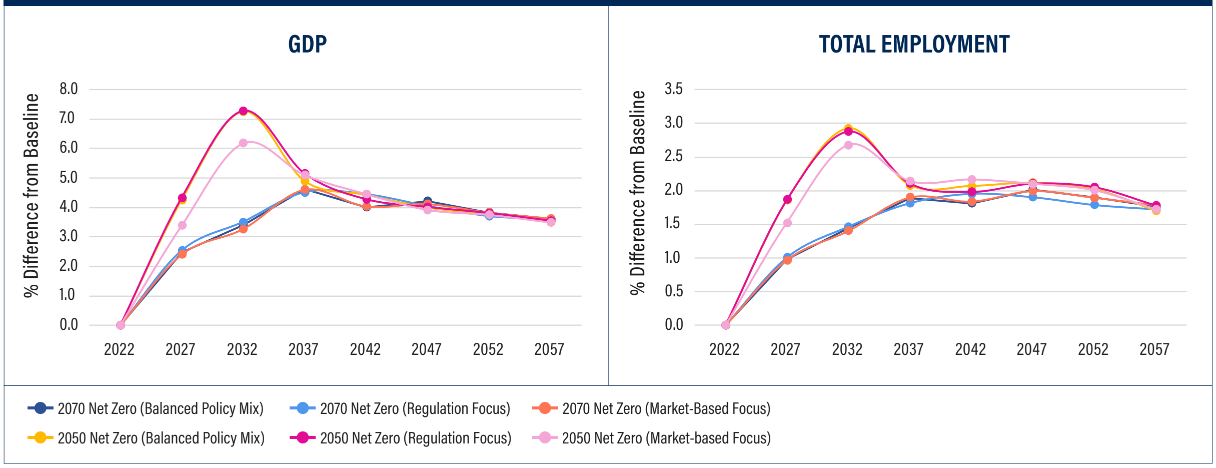
Policy Choice Sensitivity

Figure 3.8 shows that the years to 2040 will be the defining decades for policy intervention, as this is when policy choice noticeably influences the impacts. In particular, regulatory measures are likely to result in more rapid emissions reductions within a shorter amount of time but at a higher cost, and the opposite is true of market-based instruments. The long-term economic impacts do not vary greatly in their policy sensitivities, because at that point policies are well aligned with the central scenario by assumption.

In summary, stronger regulatory measures implemented earlier (e.g., a no new coal policy in power generation, a cap on ICE sales from 2023, and a higher biofuel mandate) result in more rapid emissions reductions and larger investments (which boost GDP and jobs), in contrast to slower emissions reductions and lower investments when market-based measures are prioritized, relative to the central (either *2070 net zero* or *2050 net zero*) scenario. However, this additional benefit does not come without a cost — mainly higher costs of compensation for stranded assets due to stronger regulation and costs of higher investments to households — discussed in section 3.4.

More detailed results for the policy sensitivities are provided in Appendix E.

FIGURE 3.8: POLICY CHOICE INFLUENCE ON GDP AND EMPLOYMENT IMPACTS IN THE NET ZERO SCENARIOS IN INDIA



Source(s): Cambridge Econometrics, E3ME modelling result.

POLICY COSTS, SAVINGS, AND WIDER BENEFITS

Policy Costs and Savings

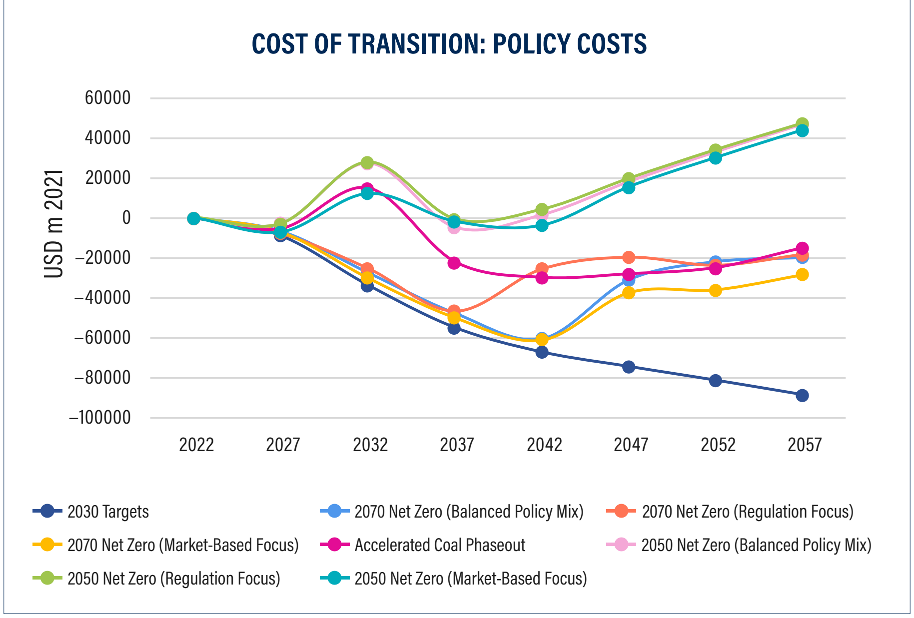
It is evident from the modelling that ambitious decarbonization goals are beneficial to the economy in GDP and employment terms. However, there are costs and savings from ambitious policies underlying those macro-level benefits.

Figure 3.9 presents net policy costs across all scenarios and sensitivities. "Net policy costs" are defined as the difference between the government's revenues from policies (namely, carbon pricing and fuel duties) and costs of policy implementation (including subsidies for renewables and low-carbon technologies, investment in energy efficiency, and compensation for stranded assets due to coal phaseout regulation in the power sector). Positive net policy costs indicate an increase in government deficits that are passed on to households in the form of higher taxes (this effect is responsible for the lower household consumption described in section 3.3), and vice versa.

As can be seen, net policy costs can be volatile over time to reflect sectors' readiness and evolving climate targets. In particular, spikes in net costs through the forecast period correspond to stranded asset compensation for early closures of coal power plants due to unabated phaseout regulation. This makes coal phaseout an effective yet costly policy. The sensitivity results support this, indicating that sensitivities with stricter regulatory measures also generate higher net costs than a scenario with a more balanced mix of policies or more emphasis on market-based instruments.

Note that decarbonization costs tend to increase over time. First, the least expensive emissions reduction options are implemented; in the later years, it is more expensive to decarbonize the remaining emissions from hard-to-abate sectors. Additionally, carbon revenues are falling with decreasing emissions in the economy, which further increases the net costs of decarbonization to government.

FIGURE 3.9: NET POLICY COSTS OF DECARBONIZING THE INDIAN ECONOMY ACROSS SCENERIOS



Source(s): Cambridge Econometrics, E3ME modelling result.

A net cost is incurred in all scenarios when new policies are introduced in 2023. However, from the second half of the modelled period (around 2040 onward), only the *2050 net zero* scenario and sensitivities incur a net cost, because of higher investment requirements and lower carbon revenues. In these scenarios, the increase in the rate of carbon pricing is far outweighed by emissions reductions that take place more rapidly because of stronger policy interventions, causing overall carbon revenues to fall. The main costs contributing to this are renewable subsidies[15] and stranded asset compensation in the short to medium term and energy efficiency investments in the long term. All other scenarios including *Accelerated coal phaseout* show net gains from excess carbon revenues in the long term, because the investment levels in these scenarios are significantly lower.

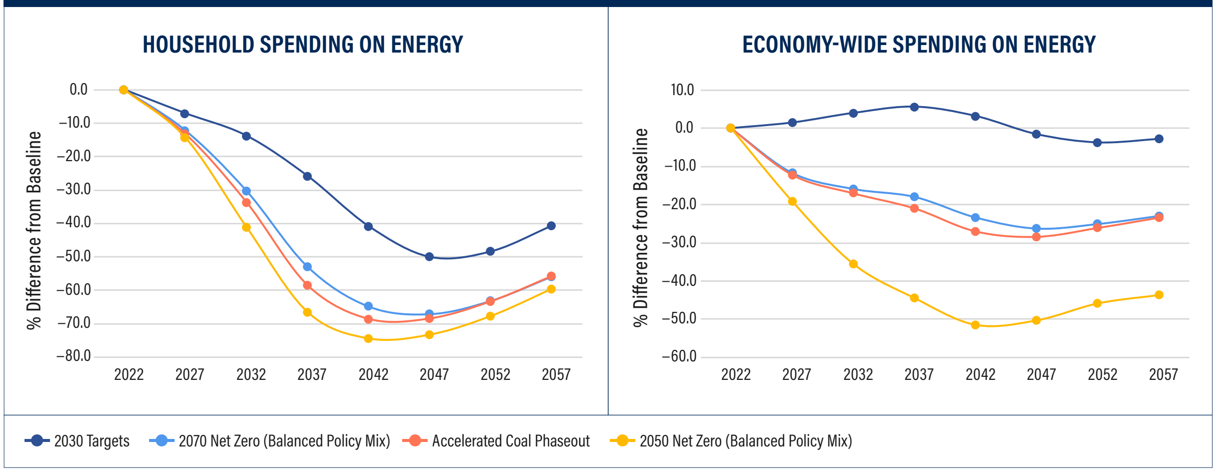
Overall, there are higher net costs in more ambitious scenarios, some of which are paid for by the private sector (industries and households), in comparison to standard ambition scenarios.

On the other hand, the overall demand for energy is reduced for households and across the economy as a whole, which results from energy efficiency improvements and technological transformations (see Figure 3.10). This includes potential impacts of energy price increases as a result of power generators passing on the cost of investment to consumers through higher prices. It is estimated that gas and electricity prices could increase by up to 15 percent and 65 percent, respectively, in India under all scenarios, relative to baseline. The electricity price increase is particularly substantial and seen mainly in the years to 2030 when renewables capacity is being built, given the major role of inexpensive and locally abundant coal in the current power mix and the need to phase out unabated coal completely by 2040. However, this estimated increase reflects a

15 These subsidies are set in proportion to investment requirements, so absolute subsidy values are higher in the ***2050 net zero*** scenario with more investment than the ***2070 net zero*** scenario, even though the subsidy rates are unchanged between scenarios.

worst-case scenario in which an increase in costs to generators is passed on directly to consumers (i.e., generators keep profit margins unaffected), therefore excluding the potential effect of mitigating policies (such as price caps and market reforms) aimed at closing the gap between wholesale and retail prices to utilize clean domestic electricity without hurting consumers.

FIGURE 3.10: ENERGY SAVINGS ACROSS SCENARIOS FOR INDIA



Source(s): Cambridge Econometrics, E3ME modelling result.

The *2050 net zero* scenario shows a 75 percent saving on household energy costs and a 50 percent saving on economy-wide energy spending by 2040. This is equivalent to almost $7bn and $230bn, respectively, that can be saved for other priorities such as food, housing, health care, and education. Rebound effects and continued economic growth mean that the long-term reductions are slightly smaller but still substantial, at 54 percent and 44 percent, respectively, under the same scenario. Economy-wide energy spending is particularly responsive to a more ambitious policy package aimed at rapidly decarbonizing the whole economy.

This reduction in energy spending coincides with lower demand for energy imports, which helps protect the domestic energy supply from external fossil fuel price volatility, therefore ensuring the population has reliable and affordable access to clean domestic energy. With recent price hikes and rising energy security concerns (which are not included in the scenarios), energy self-sufficiency is a strong benefit of decarbonization not captured elsewhere. Since such volatility hurts the poorest groups the most, reducing reliance on imports would help shield the most vulnerable populations in India.

It is assumed in all higher-ambition scenarios that all countries decarbonize at the same pace (countries have their own ambitions in the baseline, *2030 targets*, and the *2070 net zero* scenario). If India decarbonizes at a slower pace than others, the country may face higher costs in the form of stranded assets (given its role as a major fossil fuel exporter) and higher taxes due to potential carbon border adjustment schemes imposed by other countries. Moving faster than other countries, on the other hand, could mean India is faced with higher costs for some of the new technologies but would also create a first mover advantage and solidify its role in global low-carbon supply chains. These risks and opportunities are not quantified as part of the modelling exercise but are relevant to policymakers.

Wider Benefits

In addition to macroeconomic benefits, there are wider benefits from climate actions (or costs of no action) that are not quantified as part of this modelling exercise but are noteworthy.

India is one of the biggest emitters in the world; therefore, its progress toward carbon neutrality also contributes to the global challenge of limiting climate change. Table 3.3 shows the estimated global temperature change[16] by 2100 associated with each scenario, with the most ambitious *Accelerated coal phaseout* and *2050 net zero* scenarios assuming that India's climate action is matched by similar levels of ambition in the rest of the world.

TABLE 3.3: ESTIMATED GLOBAL TEMPERATURE CHANGE ACROSS SCENARIOS

SCENARIO	GLOBAL TEMPERATURE CHANGE BY 2100
Baseline (Pre-COP policies)	3.4°C
Baseline + 2030 targets	1.6-1.7°C
2070 net zero (All COP26 commitments)	1.6°C
Accelerated coal phase-out	1.5-1.6°C
2050 net zero	1.5°C

Source(s): Cambridge Econometrics, E3ME modelling result.

Delayed or insufficient climate action risks additional damage to economic growth, due to the disruption from global warming, causing extreme weather events and lost productivity and livelihoods. These physical risks are widely discussed in the literature, where application of Integrated Assessment Models (IAMs) and econometric analysis have previously been used to estimate the impact of climate change on future economic growth.

The literature reflects a wide range of estimated GDP impacts associated with future temperature and climatic change. For example, Burke, Hasiang, and Miguel (2015); Burke, Davis, and Diffenbaugh (2018); and Burke and Tanutama (2019), using econometric analysis on national-level data, estimate that a 3°C temperature increase (in line with the baseline) would harm global GDP by 25 percent, whereas a 1.5°C pathway would lead to an 11 percent reduction in global GDP by 2100. India would bear some of these damages.

Although not quantified as part of this study, additional co-benefits, such as better air quality, improved biodiversity, and other health benefits, are likely to result from enhanced climate protection and benefit the Indian population significantly.

16 These estimates are based on cumulative emissions results from E3ME and an average warming coefficient of 1.84°C/TtC, based on Millar and Friedlingstein (2018).

Policy Recommendations

Based on the environmental and socioeconomic impacts presented earlier in this chapter, the key policy recommendations are summarized in Table 3.4. This provides a qualitative assessment of how key policies contribute to decarbonization goals and the opportunities, constraints, and trade-offs associated with them. It is acknowledged that policies are often designed to complement each other in practice, and it is unlikely that one single policy will deliver all desired decarbonization targets at the economy-wide level. As such, the scenarios presented in this study show the combined effects of all policies (policy packages) and the impact of individual policies in isolation has not been quantified.

For example, carbon pricing on its own is likely to be less effective in reducing emissions than when combined with low-carbon technology subsidies or regulation of the use of coal for power generation (because such policies send reinforcing signals), despite generating additional revenues for the government. On the other hand, coal power regulation (particularly an accelerated phaseout) alone may generate high costs of compensation to the power sector for stranded assets and an excess supply of coal, making it cheaper for other sectors to use coal if there is no other policy in place to discourage fossil fuel use and encourage investment in low-carbon alternatives.

The results and policy recommendations set out here are intended to inform the design of such policy combinations that best balance between the identified opportunities and trade-offs. In summary, for India to reach net zero emissions by 2070 and potentially earlier by 2050, the most important recommendation is a comprehensive and balanced mix of policies, covering all sectors and combining enablers and penalties, as well as regulatory and market-based measures, in particular:

- Implementation of **carbon pricing** across the economy, starting with the most energy-intensive sectors in 2025, to encourage electrification and innovation in low-carbon solutions
- **Recycling carbon revenues** to fund energy efficiency investments and subsidies for low-carbon technologies
- Introduction of **no new coal policy** as soon as possible
- Strengthening **financial subsidies for renewables power and electric vehicles** to achieve price parity this decade
- **Investment in research and development** to bring pre-commercialization low-carbon technologies (such as carbon capture and storage and hydrogen) to market within the next few years
- Enforcing more stringent **biofuel mandates** and corporate responsibility requirements for companies to **invest in reforestation and natural carbon sinks**

TABLE 3.4: KEY POLICY RECOMMENDATIONS						
	SECTORS WHERE THERE IS MOST IMPACT	PERIOD WHEN THERE IS MOST IMPACT	OPPORTUNITIES	CONSTRAINTS OR TRADE-OFFS	COMPLEMENTARY POLICIES INCLUDED IN THE MODELLING	COMPLEMENTARY POLICIES NOT INCLUDED IN THE MODELLING
Carbon pricing from 2025 for energy-intensive sectors and 2031 for other sectors	All sectors especially energy-intensive sectors (power generation and industry)	Short to long term	Incentivises switching to renewables by making fossil fuels more expensive and acts as a source of funding for other measures	Regressive for low-income households and creates inflationary pressures when costs are passed on to consumers through higher prices	Revenue recycling and policies that include subsidies for, or otherwise kick-start, low carbon technologies	-
Energy efficiency investments	All sectors, especially buildings	Short to long term	Effective at reducing building emissions (where there are large reduction potentials) at relatively low costs in the short term	Constrained by non-market barriers (e.g. the housing stock, production processes) at least in the short term	Carbon pricing, revenue recycling	-
No new coal regulation from 2023	Power generation	Short and medium term (especially before 2030)	Most effective at reducing emissions in the short- and medium-term	Costly to implement due to stranded asset compensation	Carbon pricing, renewables subsidies, innovation & R&D, complete phase-out regulation	-
Renewables subsidies	Power generation	Short term (before price parity is achieved this decade)	Incentivises switching to renewables from fossil fuels by making them more cost-competitive	Costly to implement in the short term	Coal power regulations, innovation & R&D, revenue recycling	-
EV subsidies	Transport	Short term (before price parity is achieved this decade)	Incentivises switching to EVs by making them more affordable	Costly to implement in the short term and effectiveness constrained by non-market barriers (e.g. lack of charging infrastructure) and domestic production capacity	Carbon pricing, revenue recycling	Policies aimed at expanding domestic production capacity to build comparative advantage
Decarboniza-tion of cooling systems	Buildings	Short to long term	Emissions reductions are achieved indirectly through decarbonization of the power sector thanks to electrification	Similar to energy efficiency, constrained by non-market barriers at least in the short term	Policies aimed at decarbonizing the power sector	-
Biofuel mandates	Transport (especially freight road transport, air and marine transport) and agriculture	Medium to long term (after 2030)	Enforces fuel switching where market-based incentives are low	Low-carbon or less emissions-intensive alternatives with low market shares may be more expensive in the short term	Carbon pricing, innovation and R&D	-

TABLE 3.4: KEY POLICY RECOMMENDATIONS

	SECTORS WHERE THERE IS MOST IMPACT	PERIOD WHEN THERE IS MOST IMPACT	OPPORTUNITIES	CONSTRAINTS OR TRADE-OFFS	COMPLEMENTARY POLICIES INCLUDED IN THE MODELLING	COMPLEMENTARY POLICIES NOT INCLUDED IN THE MODELLING
Innovation and R&D for low-carbon technologies in the next 5 years	Power generation and industry	Short term (before 2030, during pre-commercialisation stage of new technologies)	Allows low-carbon technologies that are not commercially available to participate in the market, leading to learning-by-doing effects and faster future cost reductions	Costly to implement in the short term and takes a long time to see visible effects	Carbon pricing, revenue recycling, policies that include regulation of fossil fuel use and support for low carbon technologies	Investment in retraining and developing the workforce to adapt to new technologies
Carbon sink investment and regulation	Agriculture	Medium to long term (after 2030)	Exploits local forestry and land use potentials and improves agricultural productivity	A potential shift from labour to capital in the agriculture sector, putting jobs at risk	Carbon pricing	Investment in retraining and developing the workforce to adapt to new technologies
Revenue recycling	Limited secondary impact on all sectors	Short to long term	Allows carbon revenues to be earmarked for low-carbon measures	Impacts households negatively if there is a large investment requirement and no international support	Carbon pricing	International support and alternative funding mechanisms for low carbon investments

CONCLUSIONS

SOCIOECONOMIC AND CLIMATE IMPACTS

Although global action to honor all NDCs, net zero targets, and other announced commitments would limit warming to well-below 2°C, stronger decarbonization action and reaching global net zero by 2050 would be needed to limit global warming to 1.5°C by the end of the century. There is a strong case for closing this gap, because the adverse effects on ecosystems and human lives, already evident from a temperature increase so far of 1°C compared to preindustrial levels, will be vast and unevenly distributed, with tropical and developing countries such as India at a higher risk.

Our modelling shows that by meeting all of its 2030 commitments through various policy packages, India would be well on its way to reach carbon neutrality by 2070 and decarbonize its economy substantially. Utilizing all viable policy options and increasing these ambitions can lead to India's CO_2 emissions peaking this decade, as early as 2025 in the most ambitious scenarios, and declining consistently thereafter toward net zero by 2050.

Such a transition will be driven by rapid decarbonization of the whole energy system and economy, in particular moving away from fossil fuels to renewables electricity generation, increased electrification, innovation to make new low-carbon technologies cost competitive and ready for commercialization, promotion of electric vehicles for road transport, and low-carbon technologies and alternative fuels in other sectors.

The modelling shows that increasing climate ambition and actions generate substantial macroeconomic benefits in GDP and employment for the economy.

These economic impacts are positive throughout the transition and strongest in more ambitious scenarios aimed at reaching net zero emissions by 2050. High levels of investment drive them, particularly in the power sector, as well as by energy efficiency and carbon sink investments. In addition, a net trade balance improvement occurs in the long term due to lower demand for fossil fuel imports.

However, should the transition only be funded domestically, Indian households would be negatively affected through revenue balancing, carbon pricing, and higher prices across the economy. Despite an overall positive impact on employment, there are a significant number of potential job losses in fossil fuel supply industries as a result of the low-carbon transition, which presents a distributional and social challenge for local communities. Government social programs could provide income support and reskilling, such that vulnerable populations could cope with increasing living costs and take advantage of the opportunities arising in the low-carbon economy. Such policies and the cost of these programs are not modelled in these scenarios.

The low-carbon transition in India also depends on climate action in other countries. With the rest of the world decarbonizing, the costs of low-carbon technologies will decrease rapidly, making the transition less expensive. Should India's actions be delayed or deviate from those of the rest of the world, India may face higher costs in the form of stranded assets and higher taxes due to carbon border adjustment schemes imposed by other countries (which are not quantified in the modelling).

India, currently one of the largest emitters globally, has a strong impact on global cumulative emissions. India's decarbonization therefore has a role to play in global efforts to limit global warming below 1.5°C. This analysis does not include the costs of inaction (climate damages due to impacts of higher temperature increases, extreme weather events, and natural disasters) and health co-benefits from reducing air pollution levels. As such, the total benefits of stronger climate action will be substantially higher than estimated in this study if avoided climate damages and improved health outcomes are included.

POLICY IMPLICATIONS

The modelling shows that additional and more ambitious policies are needed to deliver long-term emissions targets and align with 1.5°C temperature goals than the currently committed ones. Extending and strengthening existing regulations and market-based measures can result in different feasible policy packages delivering the same emissions targets.

While all policy packages modelled are expected to generate economic benefits, the costs and savings from policy implementation vary according to how they complement each other. On the one hand, regulation is more effective at decarbonizing power and transport sectors. An unabated coal phaseout regulation in power generation, in particular, is very effective at delivering large emissions reductions in the medium term but can be costly because of the high costs of government compensation for stranded assets. On the other hand, market-based instruments are likely more effective than regulation due to higher social acceptance for these policies in industry and residential sectors, especially in the medium term where no regulatory measures are in the pipeline. As a result, a comprehensive package with a mix of regulatory and market-based measures is needed and should be tailored to sector characteristics. Under the most ambitious scenarios with a balanced mix of policies, estimated savings in energy bills (for households and the economy as a whole) are also largest.

More ambitious decarbonization goals could boost India's economy, powered by a substantial volume of investment. As part of the transition, reducing fossil fuel import dependency means improving the trade balance and energy security, which in turn provides better access to adequate, reliable, and affordable supplies for low-income households.

However, these benefits come with a number of trade-offs. First, consumers are generally worse off from the transition costs, facing higher prices and higher taxes to help finance additional investments. Second, employment impacts are positive overall but there will be winners and losers with many jobs lost in fossil fuel supply.

To deliver a just transition for vulnerable groups, additional policies and international support are needed to complement climate policies. While recycling carbon revenues and leveraging other tax-raising mechanisms play an important role as potential funding mechanisms for green investments, international financial support specifically aimed at assisting the low-carbon transition will free up domestic finance for development, poverty reduction, and the management of social impacts. Policies to support reskilling and upskilling of the Indian workforce will also allow workers to take full advantage of the new employment opportunities that arise in a low-carbon economy.

ADDITIONAL APPENDICES

APPENDIX A: BIBLIOGRAPHY

Bundervoet, T., Davalos, M. E., and Garcia, N. 2021. *The Short-Term Impacts of COVID-19 on Households in Developing Countries. An Overview Based on a Harmonized Data Set of High-Frequency Surveys.* Policy Research Working Paper 9582, The World Bank Group.

Burke, M., Hsiang, S. M., and Miguel, E. 2015. Global non-linear effect of temperature on economic production. Nature 527, 235–239.

Burke, M., Davis, W. M., and Diffenbaugh, N. S. 2018. Large potential reduction in economic damages under UN mitigation targets. Nature 557.7706, 549.

Burke, M., and Tanutama, V. 2019. Climatic Constraints on Aggregate Economic Output. No. w25779. National Bureau of Economic Research. Cambridge Econometrics. 2022. "Russian isolationism: High oil and gas prices are bad news for the global economy." https://www.camecon.com/blog/russian-isolationism-high-oil-and-gas-prices-are-bad-news-for-the-global-economy/#

CEEW. 2021a. "State of clean cooking energy access in India: insights from the India Residential Energy Survey (IRES) 2020." https://www.ceew.in/sites/default/files/ires-report-on-state-of-clean-cooking-energy-access-in-india.pdf.

CEEW. 2021b. "Implications of a net-zero target for India's sectoral energy transitions and climate policy." https://www.ceew.in/publications/implications-of-net-zero-target-for-indias-sectoral-energy-transitions-and-climate-policy.

CEEW. 2021c. "Mapping India's climate vulnerability: A district-level assessment." https://www.ceew.in/sites/default/files/ceew-study-on-climate-change-vulnerability-index-and-district-level-risk-assessment.pdf.

CEEW. 2021d. "investment sizing India's 2070 net-zero target." https://www.ceew.in/cef/solutions-factory/publications/CEEW-CEF-Investment-Sizing-India%E2%80%99s-2070-Net-Zero-Target.pdf.

Climate Action Tracker. 2022. "India." https://climateactiontracker.org/countries/india/

Climate Knowledge Portal, World Bank. 2022. "India." https://climateknowledgeportal.worldbank.org/country/india/vulnerability

CSE. 2021. "India's enhanced climate targets and commitments: What do they mean?" https://www.cseindia.org/india-s-enhanced-climate-targets-and-commitments-what-do-they-mean-11043

Ember. 2021. " Peaking coal? India's coal power may have already peaked, if it seizes the opportunity." https://ember-climate.org/app/uploads/2022/01/India-Peaking-Coal.pdf

Environment Agency. 2017. "Climate change agreements - Guidance." Accessed Mar 21, 2019. https://www.gov.uk/guidance/climate-change-agreements--2#about-climate-change-agreements.

European Commission. 2018. "A Clean Planet for all: A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy." https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_en.pdf.

Garg, V., Schmidt, M., and Beaton, C. 2021. *How Green Is India's Stimulus for Economic Recovery? How India Can Raise Its Ambition for a Green Stimulus in 2021.* Institute for Energy Economics and Financial Analysis.

Government of Indonesia. 2021. "Indonesia Long-Term Strategy for Low Carbon and Climate Resilience 2050." https://unfccc.int/sites/default/files/resource/Indonesia_LTS-LCCR_2021.pdf.

HM Government. 2018. "A green future: Our 25 year plan to improve the environment." https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/693158/25-year-environment-plan.pdf

IEA. 2021a. "India Energy Outlook 2021." https://iea.blob.core.windows.net/assets/1de6d91e-e23f-4e02-b1fb-51fdd6283b22/India_Energy_Outlook_2021.pdf

IEA. 2021b. "Global energy-related CO_2 emissions by sector." https://www.iea.org/data-and-statistics/charts/global-energy-related-co2-emissions-by-sector

IEA. 2022. "Global energy review: CO_2 emissions in 2021." https://www.iea.org/reports/global-energy-review-co2-emissions-in-2021-2

IEEFA. 2021. "New coal-fired power plants in India: Reality or just numbers?" https://ieefa.org/wp-content/uploads/2021/05/New-Coalfired-Power-Plants-in-India_Reality-or-Just-Numbers_June-2021.pdf

IEEFA. 2022. "Boosting domestic solar PV manufacturing will fuel green hydrogen takeoff in India." https://ieefa.org/ieefa-boosting-domestic-solar-pv-manufacturing-will-fuel-green-hydrogen-takeoff-in-india/

IISD. 2022 [add citation]

IPCC. 2022. "Sixth Assessment Report, Climate Change 2022: Mitigation of Climate Change, the Working Group III contribution." https://www.ipcc.ch/report/ar6/wg3/

IRENA. 2021. "India's energy outlook 2021." https://iea.blob.core.windows.net/assets/1de6d91e-e23f-4e02-b1fb-51fdd6283b22/India_Energy_Outlook_2021.pdf

IISD. 2022. “Mapping India’s energy policy 2022.” https://www.iisd.org/publications/mapping-india-energy-policy-2022 Jaiswal, S., and Gadre, R. 2022. *Financing India’s 2030 Renewables Ambition.* White Paper, The BloombergNEF. https://assets.bbhub.io/professional/sites/24/BNEF-Financing-India%E2%80%99s-2030-Renewables-Ambition_FINAL.pdf

MCC. 2021. “Phasing-out coal in India.” https://www.mcc-berlin.net/fileadmin/data/C18_MCC_Publications/Phasing-out_coal_in_India.pdf

Millar R., and Friedlingstein P. 2018. The utility of the historical record for assessing the transient climate response to cumulative emissions. *Phil. Trans.* R. Soc. A. 376: 20160449. 20160449. http://doi.org/10.1098/rsta.2016.0449 Ministry of External Affairs. 2021. *mea.gov.in*. 02 11. https://www.mea.gov.in/Speeches-Statements.htm?dtl/34466/National+Statement+by+Prime+Minister+Shri+Narendra+-Modi+at+COP26+Summit+in+Glasgow

Ministry of External Affairs. 2022. “ Coal demand to peak in India by 2030: NITI Aayog.” https://indbiz.gov.in/coal-demand-to-peak-in-india-by-2030-niti-aayog/#:~:text=NITI%20Aayog%27s%20report%20also%20mentioned,will%20likely%20peak%20in%202040

Ministry of Power. 2022a. “A major policy enabler by government for production of green hydrogen/green ammonia using renewable sources of energy.” https://pib.gov.in/PressReleasePage.aspx?PRID=1799067#:~:text=The%20Mission%20aims%20to%20aid,development%20of%20renewable%20energy%20capacity

Ministry of Power. 2022b. “Power sector at a glance.” https://powermin.gov.in/en/content/power-sector-glance-all-india.

MINT. 2022. “Bringing green hydrogen Ccost to below 2$ per kg may be a game changer for India.” https://www.livemint.com/industry/energy/bringing-green-hydrogen-cost-to-below-2-per-kg-may-be-a-game-changer-ambani-11630840372788.html

Narayan, A., Cojocaru, A., Agrawal, S., Bundervoet, T. Davalos, M. E., Garcia, N., Lakner, C. et al. 2022. *COVID-19 and Economic Inequality: Short-Term Impacts with Long-Term Consequences.* Policy Research Working Paper 9902, The World Bank Group.

NERL. 2020. “Least-cost pathways for India’s electric power sector. https://www.nrel.gov/docs/fy20osti/76153.pdf

RECHARGE. 2022. “India’s new interim H_2 strategy will push down cost of green hydrogen by up to 75% by 2030.” https://www.rechargenews.com/energy-transition/india-s-new-interim-h2-strategy-will-push-down-cost-of-green-hydrogen-by-up-to-75-by-2030/2-1-1173376

Rodgers, G. 2018. “Inequality in the Indian Growth Regime.” *Indian Journal of Human Development* 134–148. [volume number available?]

TERI. 2020. “Renewable power pathway: Modelling the integration of wind and solar in India by 2030.” https://www.teriin.org/sites/default/files/2020-07/Renewable-Power-Pathways-Report.pdf.-

TERI. 2021a. “Will India attain its forestry NDC target of achieving 2.5–3 billion tonnes of CO_2 equivalent through additional forest and tree cover by 2030?” https://www.teriin.org/sites/default/files/2021-02/will-india-attain-forestry.pdf

TERI. 2021b. “The Potential Role of Hydrogen in India.” https://www.teriin.org/sites/default/files/2021-07/Report_on_The_Potential_Role_of_%20Hydrogen_in_India.pdf

The Economic Times. 2022. “New policy to cut green hydrogen cost by 40-50 per cent, says Indian Oil.” https://economictimes.indiatimes.com/industry/renewables/new-policy-to-cut-green-hydrogen-cost-by-40-50-per-cent-says-indian-oil/articleshow/89699187.cms

UNCTAD. 2021. *Trade and Development Report 2021.* Report, Geneva: United Nations Conference on Trade and Development.

UNFCCC. 2022a. “UN chief calls for immediate global action to phase-out coal.” https://unfccc.int/news/un-chief-calls-for-immediate-global-action-to-phaseout-coal

UNFCCC. 2022b. “Australia’s Nationally Determined Contribution.” https://unfccc.int/sites/default/files/NDC/2022-06/Australia%20Nationally%20Determined%20Contribution%20Update%20October%202021%20WEB.pdf

vivideconomics. 2021. “Greenness of Stimulus Index.” https://643e8587-b887-4b39-86d3-edefb98f6abf.usrfiles.com/ugd/643e85_ff2e6bc7fbd242e7bcb50d05b7219e8b.pdf

Wood Mackenzie. 2022. “Renewable power in Asia Pacific gains competitiveness amidst cost inflation.” https://www.woodmac.com/press-releases/renewable-power-in-asia-pacific-gains-competitiveness-amidst-cost-inflation/

World Bank. 2021a. “Catalyzing clean air in India.” https://www.worldbank.org/en/country/india/publication/catalyzing-clean-air-in-india

World Bank. 2021b. *Global Economic Prospects.* A World Bank Group Flagship Report. Washington D.C: The World Bank. https://www.worldbank.org/en/country/india/overview#1

World Resources Institute (WRI). Forthcoming in 2022. “Long-Term climate compatible growth for India.”

WRI India. 2021. “COP26: Unpacking India’s major new climate targets.” https://wri-india.org/blog/cop26-unpacking-india%E2%80%99s-major-new-climate-targets.

APPENDIX B: LAND-USE EMISSIONS METHODOLOGY

Context

LULUCF targets are featured in the NDCs and play a role in achieving announced net zero targets. India's NDC goals for the forestry sector are assumed to create an additional carbon sink of 2.5–3bn tonnes of CO_2equivalent through increasing forest and tree cover by 2030 (TERI 2021).

General Methodology

E3ME does not include endogenous modelling for land use; therefore, a simple treatment was designed to account for the economic impacts of reducing LULUCF emissions in the modelling using the following assumptions:

- Exogenous emissions adjustments are added to the modelled emissions levels to account for land-use emissions
- Additional policy costs are assumed (if any) depending on types of policies to increase LULUCF emissions (investment, regulations, market based)
- Economic impacts from changes in land use are considered (direct labor impacts, knock-on effects on agriculture and housing)

Modelled LULUCF Levels

The modelling assumptions for India are based on a recent assessment of India's forestry targets by The Energy and Resources Institute (TERI, (2021) and consultation with local experts.

Assumed LULUCF emissions are different for the main scenario narratives modelled. The baseline ambition level assumes the continuation of historical trends in LULUCF levels and is used in the *pre-COP26 policies baseline* scenario. The medium ambition level assumes that 2030 LULUCF targets are achieved for carbon sinks and forested land cover, and this same negative emissions level stays approximately in place until the end of the modelled period. Medium LULUCF ambition is used for scenarios assuming 2030 NDC targets are met. High ambition level assumes that the high end of the 2030 target is achieved and approximately the same LULUCF level stays in place for the rest of the modelled period. This ambition level is used in net zero scenarios that aim to go beyond meeting the 2030 targets.

TABLE 0.1: NET LULUCF ASSUMPTIONS BY AMBITION LEVEL, $MTCO_2$ EQUIVALENT PER YEAR

$MTCO_2$-EQ	2022	2030	2040	2050	2060
Baseline ambition	-306.0	-329.9	-322.4	-334.9	-337.4
Medium ambition	-313.8	-369.0	-368.0	-367.0	-366.0
High ambition	-338.4	-492.0	-490.0	-488.0	-486.2

Source(s): (TERI 2021) and local experts.

Policy Costs and Investment in Other Sectors

TERI (2021a) suggests a financial allocation of about 60,000 crore[17] per year for forest development, livelihood activities, implementation of the Minimum Support Price scheme for agroforestry, and the provision of liquefied petroleum gas (LPG) to the forest-dependent communities until 2030 to achieve targets in India. According to the policy brief, innovative financing is needed but should come from within India. There is no mention of how meeting the LULUCF target impacts other sectors in India in TERI (2021) or the other literature used. However, given that India's population and income are growing, it is fair to assume that there needs to be an improvement in agriculture productivity to cover growing food demand without using more land.

In the modelling, it is assumed that LULUCF targets are to be achieved through regulation and investments in both forest development and increasing land productivity. The investment is funded through corporate social responsibility contributions from industries with high land-use requirements in their supply chain (e.g., food and drinks, coal, oil and gas, wood and paper, and furniture manufacturing).

We assumed the following additional investments in agriculture for two ambition levels used in NDC compliant and net zero scenarios (no additional investment is assumed under the pre-COP26 policies baseline case):

- Medium ambition: 15 percent increase from existing agriculture investment by 2050
- High ambition: 30 percent increase from existing agriculture investment by 2050

17 1 crore = 10,000,000 rupees so 60,000 crores ~ $8bn USD a year

APPENDIX C: HYDROGEN METHODOLOGY

Context

India's government recently announced a Green Hydrogen Policy (Ministry of Power 2022a), including several policy measures to address the cost of hydrogen and incentivize adoption, with a view to producing up to 5m tonnes of hydrogen by 2030. This policy has huge potential in India's energy transition, as it is key in decarbonizing hard-to-abate sectors like fertilizer manufacturing, oil refining, and others and is an important step toward increasing energy security and self-reliance (IDDFA 2022; TERI 2021b).

General Methodology

E3ME does not include endogenous treatment for hydrogen; therefore, a simple treatment was designed to incorporate the macroeconomic impacts of green hydrogen supply in the modelling using the following assumptions:

- *Exogenous energy demand adjustments* through fuel switching to represent the increased use of hydrogen across sectors
- *Investment in hydrogen production* such that it ensures the necessary supply to meet the increasing demand
- *Impacts on energy prices* following the different composition of fuel demand
- *Supply chain impacts* on other sectors capturing how hydrogen supplier and user sectors are impacted by the changing composition of fuel demand.

The hydrogen modelling assumptions for India are based on recent assessments of India's potential (i.e., IEEFA 2022; TERI 2021b).

Exogenous energy demand adjustments through fuel switching

Exogenous assumptions on the demand for hydrogen and how it impacts the use of other fuels are taken from the TERI (2021b) report. The report provides hydrogen demand projections for industry, transport, and power sectors under a low-carbon scenario.

Analysis by TERI (2021b) shows that grey (fossil fuel-based) hydrogen is already being consumed, and demand is projected to remain relatively stable in the future. The assumption is that the impact of grey hydrogen is already embedded within our pre-COP26 policies baseline scenario. Therefore, we only model impacts of green hydrogen as an addition to the baseline. It is assumed that green hydrogen substitutes middle distillates and natural gas in these sectors with a 1:1 ratio.

Two sets of assumptions are made for low-ambition and high-ambition scenarios. The low-ambition hydrogen demand assumption is used in the NDC-compliant and coal-phaseout scenarios, while high ambition is assumed under the net zero pathways. Assumptions are available until 2050, after which a linear extrapolation out to 2060 is applied.

Based on TERI (2021b), the ammonia, methanol, and refining sectors are most readily prepared to adopt hydrogen, whereas demand in the other sectors is expected to pick up later and is likely to require additional policies to support adoption alongside other low-carbon measures:

- The low-ambition assumptions are based on the low-carbon scenario from TERI analysis
- The high-ambition assumptions are based on the government's target to produce 5m tonnes of green hydrogen by 2030

In addition to TERI (2021b), for industrial processes we also adopted assumptions from CEEW (2021b) that the share of hydrogen used in those sectors is 15 percent by 2050 and 19 percent by 2070 under ambitious decarbonization scenarios and less than 1 percent by 2070 in a less ambitious case.

Investment in hydrogen production

To meet the assumed increase in hydrogen demand, additional investment into its production is needed. The necessary investment has been calculated based on the demanded volume and a unit cost estimate based on TERI (2021b):

Investment = Volume produced x Unit CAPEX cost

Industries that demand hydrogen bear the costs of consumption, whereas investment in production is by the hydrogen industry, which generates demand for inputs, as well as further investment responses from other industries.

It is assumed that investment is 50 percent privately funded and 50 percent is subsidised by the Indian government.

Impacts on energy prices

The energy price changes for fuels reflect the change in fuel demand by end users. For example, a switch from using gas in the baseline to hydrogen in the scenario means that industry will no longer pay for gas and instead will pay for hydrogen.

TABLE 0.2: HYDROGEN PRICE ESTIMATES IN THE LITERATURE

$/KG	SOURCE	2022	2030	2031 ONWARDS
Hydrogen price – low	IEEFA (2022)	5.5	1	1
Hydrogen price - medium	Average of low and high	5.5	2.5	2.5
Hydrogen price – high	TERI (2021b) and IEEFA (2022)	5.5	3.6	2
Hydrogen cost of production - low	TERI (2021b) and news outlet (RECHARGE 2022)	4.5	1.5	1.5
Hydrogen cost of production - medium	News outlet (MINT 2022)	4.5	2	2
Hydrogen cost of production - high	TERI (2021b) and news outlet (The Economic Times 2022)	6.5	3	3

Source(s): as listed

A wide range of hydrogen price estimates are available from the literature. Consolidating those estimates, we assumed that hydrogen is produced by the most cost-effective method (at $1.5/kg by 2030) and is sold at a higher price than the cost of production (at $2.5/kg by 2030). This price level is in the middle of the range and equivalent to a 50 percent reduction by 2030 compared to current rates (in line with a 50 percent reduction in cost of production as a result of the government's hydrogen policy, as expected by industry experts (The Economic Times 2022). After 2030, we will assume that both costs and prices stay constant until 2060. A comparison of these assumptions with alternative ones is included in Table 0.2.

Impacts on other sectors

The supply chain impacts are captured through input-output linkages. Coefficients to capture these are not readily available within E3ME, as hydrogen production is not an economic sector in the model. We assumed the supply chain is structured in a similar way to those in other comparable industries, such as gas distribution, that already exist in E3ME. In particular, we assumed demand for intermediate inputs is sourced from the same providers as those for the production of chemicals and coke and petroleum. In addition, we also assumed the employment intensity of hydrogen production is similar to the average of the chemicals and coke and petroleum industries.

APPENDIX D: MODELLING ASSUMPTIONS

Table 0.3 summarizes the policy assumptions modelled for all scenarios and sensitivities.

TABLE 0.3: DETAILED POLICY ASSUMPTIONS

SECTOR	POLICIES	NEW OR STRENGTH-ENED?	2030 TARGETS	2070 NET ZERO (BALANCED POLICY MIX)	2070 NET ZERO (REGULATION FOCUS)	2070 NET ZERO (MARKET -BASED FOCUS)	ACCELER-ATED COAL PHASE-OUT	2050 NET ZERO (BALANCED POLICY MIX)	2050 NET ZERO (REGULATION FOCUS)	2050 NET ZERO (MARKET -BASED FOCUS)
Economy wide	Emissions reductions target	Strengthened	–	Net zero by 2070	Same as 2070 net zero commit-ments (balanced policies)	Same as 2070 net zero commit-ments (balanced policies)	Same as 2070 net zero commit-ments (balanced policies)	Net zero by 2050	Same as Net zero 2050 (bal-anced policies)	Same as Net zero 2050 (balanced policies)
	Carbon tax (non-ETS sectors) – set exogenously	New	–	From 2031 at \$2/ tCO_2, increasing to \$154/tCO_2 by 2050 and \$195/ tCO_2 by 2060	From 2031 at \$2/ tCO_2, increasing to \$149/tCO_2 by 2050 and \$190/ tCO_2 by 2060	From 2031 at \$2/ tCO_2, increasing to \$156/tCO_2 by 2050 and \$198/ tCO_2 by 2060	Same as 2070 net zero commit-ments (balanced policies)	From 2031 at \$5/ tCO_2, increasing to \$197/tCO_2 by 2050 and con-stant thereafter	From 2031 at \$5/ tCO_2, increasing to \$189/tCO_2 by 2050 and con-stant thereafter	From 2031 at \$5/ tCO_2, increasing to \$205/tCO_2 by 2050 and con-stant thereafter
	ETS (energy intensive sectors + process emissions)	New	From 2025 with a cap in line with pathway to net zero by 2070 for energy inten-sive industries	From 2025 with a cap in line with pathway to net zero by 2070	Same as 2070 net zero commit-ments (balanced policies)	Same as 2070 net zero commit-ments (balanced policies)	From 2025 with a cap in line with pathway to net zero between 2050-70	From 2025 with a cap in line with pathway to net zero by 2050	Same as Net zero 2050 (bal-anced policies)	Same as Net zero 2050 (balanced policies)
	Revenue recy-cling to support low carbon technologies	New	Yes	Yes	Same as 2070 net zero commit-ments (balanced policies)	Same as 2070 net zero commit-ments (balanced policies)	Same as 2070 net zero commit-ments (balanced policies)	Yes	Same as Net zero 2050 (bal-anced policies)	Same as Net zero 2050 (balanced policies)
	Energy efficiency programs (applies to non-ETS sectors)	Strengthened	Yes	Yes	Same as 2070 net zero commit-ments (balanced policies)	Same as 2070 net zero commit-ments (balanced policies)	Same as 2070 net zero commit-ments (balanced policies)	Yes	Same as Net zero 2050 (bal-anced policies)	Same as Net zero 2050 (balanced policies)
Power sector	Renewables target	New	500GW of renewables capacity (50% of total capacity) by 2030, includ-ing 70GW of hydro capacity	500GW of renewables capacity (50% of total capacity) by 2030, includ-ing 70GW of hydro capacity	Same as 2070 net zero commit-ments (balanced policies)	Same as 2070 net zero commit-ments (balanced policies)	Same as 2070 net zero commit-ments (balanced policies)	More than 500GW of renewables capacity by 2030	Same as Net zero 2050 (bal-anced policies)	Same as Net zero 2050 (balanced policies)
	New coal capacity regulation	New	–	–	–	–	No new coal construction from 2023	No new coal construction from 2023	No new coal from 2023 including plants commissioned and under construction	No new coal from 2023 excluding plants already commis-sioned or under construction
	New coal capacity regulation	New	–	–	–	–	No new coal construction from 2023	No new coal construction from 2023	No new coal from 2023 including plants commissioned and under construction	No new coal from 2023 excluding plants already commis-sioned or under construction
	Coal phase-out	New	–	By 2070	By 2065	By 2075	By 2040	By 2040	By 2035	By 2040
	Public procurement for biomass CCS	New	–	–	Same as 2070 net zero commit-ments (balanced policies)	Same as 2070 net zero commit-ments (balanced policies)	Same as 2070 net zero commit-ments (balanced policies)	1GW/year over 2023-40	Same as Net zero 2050 (bal-anced policies)	Same as Net zero 2050 (balanced policies)

TABLE 0.3: DETAILED POLICY ASSUMPTIONS

SECTOR	POLICIES	NEW OR STRENGTH-ENED?	2030 TARGETS	2070 NET ZERO (BALANCED POLICY MIX)	2070 NET ZERO (REGULATION FOCUS)	2070 NET ZERO (MARKET -BASED FOCUS)	ACCELER-ATED COAL PHASE-OUT	2050 NET ZERO (BALANCED POLICY MIX)	2050 NET ZERO (REGULATION FOCUS)	2050 NET ZERO (MARKET -BASED FOCUS)
	Subsidies for renewables	Strengthened	Hydro - 20% over 2023-30, phased out by 2040 Wind - 20% over 2023-36, phased out by 2046	Hydro - 20% over 2023-30, phased out by 2040 Wind - 20% over 2023-36, phased out by 2046	Hydro - 10% over 2023-30, phased out by 2040 Wind - 10% over 2023-36, phased out by 2046	Same as 2070 net zero commitments (balanced policies)	Same as 2070 net zero commit-ments (balanced policies)	Hydro - 20% over 2023-30, phased out by 2040 Wind - 20% over 2023-36, phased out by 2046	Hydro - 20% over 2023-30, phased out by 2040 Wind - 20% over 2023-36, phased out by 2046	Same as Net zero 2050 (balanced policies)
Industries	Subsidies for EAF steel making	New	From 2023 at 25%, phased out over 2045-55	From 2023 at 25%, phased out over 2045-55	From 2023 at 12%, phased out over 2045-55	Same as 2070 net zero commit-ments (balanced policies)	Same as 2070 net zero commit-ments (balanced policies)	From 2023 at 25%, phased out over 2045-55	From 2023 at 12%, phased out over 2045-55	Same as Net zero 2050 (balanced policies)
	Subsidies for CCS steel making	New	–	–	From 2023 at 5%, phased out over 2045-55	Same as 2070 net zero commit-ments (balanced policies)	Same as 2070 net zero commit-ments (balanced policies)	From 2023 at 10%, phased out over 2045-55	From 2023 at 5%, phased out over 2045-55	Same as Net zero 2050 (balanced policies)
	Subsidies for hydrogen steel making	New	From 2023 at 25%, phased out over 2045-55	From 2023 at 25%, phased out over 2045-55	From 2023 at 12%, phased out over 2045-55	Same as 2070 net zero commit-ments (balanced policies)	Same as 2070 net zero commit-ments (balanced policies)	From 2023 at 25%, phased out over 2045-55	From 2023 at 12%, phased out over 2045-55	Same as Net zero 2050 (balanced policies)
	Kick start for hydrogen-based steel making	New	Capacity is built gradually from 2023 (when hydrogen is expected to become commercially available) to reach 10 million tonnes of hydro-gen used for steelmaking by 2050 and con-tinue expanding thereafter.	Capacity is built gradually from 2023 (when hydrogen is expected to become commercially available) to reach 10 million tonnes of hydro-gen used for steelmaking by 2050 and con-tinue expanding thereafter.	Same as 2070 net zero commit-ments (balanced policies)	Same as 2070 net zero commit-ments (balanced policies)	Same as 2070 net zero commit-ments (balanced policies)	Capacity is built gradually from 2023 (when hydrogen is expected to become commercially available) to reach 10 million tonnes of hydro-gen used for steelmaking by 2040 and con-tinue expanding thereafter.	Same as Net zero 2050 (bal-anced policies)	Same as Net zero 2050 (bal-anced policies)
Road transport	EV sales target	New	30% of EVs in new sales by 2030	30% of EVs in new sales by 2030	Same as 2070 net zero commit-ments (balanced policies)	Same as 2070 net zero commit-ments (balanced policies)	Same as 2070 net zero commit-ments (balanced policies)	100% of EVs in new sales by 2035	Same as Net zero 2050 (bal-anced policies)	Same as Net zero 2050 (balanced policies)
	EV subsidies	Strengthened	From 2023, an additional vehicle subsidy is applied on EV purchases: 3351.50 $/veh for luxury class EVs, 3658.50 $/veh for medium class EVs, and 4008.50 $/veh for economy class vehicles. Subsidies are phased out over 2025-30 (assum-ing price parity is reached this decade).	From 2023, an additional vehicle subsidy is applied on EV purchases: 3351.50 $/veh for luxury class EVs, 3658.50 $/veh for medium class EVs, and 4008.50 $/veh for economy class vehicles. Subsidies are phased out over 2025-30 (assum-ing price parity is reached this decade).	From 2023, an additional vehicle subsidy is applied on EV purchases: 1675 $/veh for luxury class EVs, 1829 $/veh for medium class EVs, and 2004 $/veh for economy class vehicles. Subsidies are phased out over 2025-30 (assum-ing price parity is reached this decade).	Same as 2070 net zero commit-ments (balanced policies)	Same as 2070 net zero commit-ments (balanced policies)	From 2023, an additional vehicle subsidy is applied on EV purchases: 3351.50 $/veh for luxury class EVs, 3658.50 $/veh for medium class EVs, and 4008.50 $/veh for economy class vehicles. Subsidies are phased out over 2025-30 (assum-ing price parity is reached this decade).	From 2023, an additional vehicle subsidy is applied on EV purchases: 1675 $/veh for luxury class EVs, 1829 $/veh for medium class EVs, and 2004 $/veh for economy class vehicles. Subsidies are phased out over 2025-30 (assum-ing price parity is reached this decade).	Same as Net zero 2050 (balanced policies)
	Fuel duties	Strengthened	No addition	No addition	Same as 2070 net zero commit-ments (balanced policies)	Same as 2070 net zero commit-ments (balanced policies)	Same as 2070 net zero commit-ments (balanced policies)	From 2025, increased by $0.02/litre, returning to pre-pandemic rates by 2030 and constant thereafter	Same as Net zero 2050 (bal-anced policies)	Same as Net zero 2050 (balanced policies)

TABLE 0.3: DETAILED POLICY ASSUMPTIONS

SECTOR	POLICIES	NEW OR STRENGTH-ENED?	2030 TARGETS	2070 NET ZERO (BALANCED POLICY MIX)	2070 NET ZERO (REGULATION FOCUS)	2070 NET ZERO (MARKET -BASED FOCUS)	ACCELER-ATED COAL PHASE-OUT	2050 NET ZERO (BALANCED POLICY MIX)	2050 NET ZERO (REGULATION FOCUS)	2050 NET ZERO (MARKET -BASED FOCUS)
	Phase-out of ICE sales	New	—	—	Same as 2070 net zero commit-ments (balanced policies)	Same as 2070 net zero commit-ments (balanced policies)	Same as 2070 net zero commit-ments (balanced policies)	Sales cap from 2023, in line with complete phase-out by 2035	Same as Net zero 2050 (bal-anced policies)	Same as Net zero 2050 (balanced policies)
	Ban in the use of ICEs	New	—	—	Same as 2070 net zero commit-ments (balanced policies)	Same as 2070 net zero commit-ments (balanced policies)	Same as 2070 net zero commit-ments (balanced policies)	No new sales from 2035 and complete ban by 2050	Same as Net zero 2050 (bal-anced policies)	Same as Net zero 2050 (balanced policies)
Other transport and agriculture	Biofuel mandate	Strengthened	Increasing to 10% by 2030 and 40% by 2060. Mandate applies to remaining petrol and diesel use after accounting for electricity and hydrogen use.	Increasing to 10% by 2030 and 100% by 2060. Mandate applies to remaining petrol and diesel use after accounting for electricity and hydrogen use.	Increasing to 10% by 2030 and 100% by 2055. Mandate applies to remaining petrol and diesel use after accounting for electricity and hydrogen use.	Increasing to 10% by 2030 and 100% by 2065. Mandate applies to remaining petrol and diesel use after accounting for electricity and hydrogen use.	Same as 2070 net zero commit-ments (balanced policies)	Increasing to 25% by 2030 and 100% by 2050. Mandate applies to remaining petrol and diesel use after accounting for electricity and hydrogen use.	Increasing to 25% by 2030 and 100% by 2045. Mandate applies to remaining petrol and diesel use after accounting for electricity and hydrogen use.	Increasing to 25% by 2030 and 100% by 2055. Mandate applies to remaining petrol and diesel use after accounting for electricity and hydrogen use.
	Electrification regulation	Strengthened	100% electri-fication of rail transport by 2024	100% electri-fication of rail transport by 2024	Same as 2070 net zero commit-ments (balanced policies)	Same as 2070 net zero commit-ments (balanced policies)	Same as 2070 net zero commit-ments (balanced policies)	100% electri-fication of rail transport by 2024	Same as Net zero 2050 (bal-anced policies)	Same as Net zero 2050 (balanced policies)
Residentials	Regulation of fossil fuel-based heating or cooling	New	No	From 2031	From 2026	From 2036	Same as 2070 net zero commit-ments (balanced policies)	From 2023	Same as Net zero 2050 (bal-anced policies)	Same as Net zero 2050 (balanced policies)
	Subsidies for renewable boilers	New	From 2023 onwards, all renewable boilers receive a 50% subsidy on the upfront investment costs, which is linearly phased out between 2030 and 2050.	From 2023 onwards, all renewable boilers receive a 50% subsidy on the upfront investment costs, which is linearly phased out between 2030 and 2050.	From 2023 onwards, all renewable boilers receive a 25% subsidy on the upfront investment costs, which is linearly phased out between 2030 and 2050.	Same as 2070 net zero commit-ments (balanced policies)	Same as 2070 net zero commit-ments (balanced policies)	From 2023 onwards, all renewable boilers receive a 50% subsidy on the upfront investment costs, which is linearly phased out between 2030 and 2050.	From 2023 onwards, all renewable boilers receive a 25% subsidy on the upfront investment costs, which is linearly phased out between 2030 and 2050.	Same as Net zero 2050 (balanced policies)
Land use	Regulation on land use emissions and removals	New	From 2023, regulation is in place so that, together with investments, carbon sink potential increases from -300MtCO_2 in 2020 to around -367MtCO_2 by 2050.	From 2023, regulation is in place so that, together with investments, carbon sink potential increases from -300MtCO_2 in 2020 to around -367MtCO_2 by 2050.	Same as 2070 net zero commit-ments (balanced policies)	Same as 2070 net zero commit-ments (balanced policies)	Same as 2070 net zero commit-ments (balanced policies)	From 2023, regulation is in place so that, together with investments, carbon sink potential increases from -300MtCO_2 in 2020 to around -488MtCO_2 by 2050.	Same as Net zero 2050 (bal-anced policies)	Same as Net zero 2050 (balanced policies)

TABLE 0.3: DETAILED POLICY ASSUMPTIONS

SECTOR	POLICIES	NEW OR STRENGTH-ENED?	2030 TARGETS	2070 NET ZERO (BALANCED POLICY MIX)	2070 NET ZERO (REGULATION FOCUS)	2070 NET ZERO (MARKET -BASED FOCUS)	ACCELER-ATED COAL PHASE-OUT	2050 NET ZERO (BALANCED POLICY MIX)	2050 NET ZERO (REGULATION FOCUS)	2050 NET ZERO (MARKET -BASED FOCUS)
	Investment to increase land productivity	New	Government invests in forest development and innovation. Investment is funded through corporate social responsibility contributions from industries with high land use requirements in their supply chain (food & drinks, coal, oil & gas, wood & paper, furniture manufacturing). Investment is equivalent to 15% of agricul-tural investment by 2050.	Government invests in forest development and innovation. Investment is funded through corporate social responsibility contributions from industries with high land use requirements in their supply chain (food & drinks, coal, oil & gas, wood & paper, furniture manufacturing). Investment is equivalent to 15% of agricul-tural investment by 2050.	Same as 2070 net zero commit-ments (balanced policies)	Same as 2070 net zero commit-ments (balanced policies)	Same as 2070 net zero commit-ments (balanced policies)	Government invests in forest development and innovation. Investment is funded through corporate social responsibility contributions from industries with high land use requirements in their supply chain (food & drinks, coal, oil & gas, wood & paper, furniture manufacturing). Investment is equivalent to 30% of agricul-tural investment by 2050.	Same as Net zero 2050 (balanced policies)	Same as Net zero 2050 (balanced policies)

In addition to the policy assumptions, the following assumptions were also made:

- Changes to policies start in 2023 in all scenarios.
- In the sensitivities, only existing/announced policies are scaled up and down; no new policies are introduced.
- There is no crowding out of existing investment (but there are endogenous constraints for product, finance, and labor markets).
- Land-use change and green hydrogen investments are partially modelled: energy and emission impacts are incorporated off-model, and only economic impacts are captured by E3ME.
- The analysis excludes climate risks and co-benefits.
- Outside of target countries and regions with explicit targets, similar policies that align with the target country's level of ambition are set up across all regions, for example, in the *2050 net zero* scenarios, all other countries also decarbonize rapidly in line with the Paris Agreement.

APPENDIX E: MODEL RESULTS

TABLE 0.4: CO_2 EMISSIONS

	2022	2030	2040	2050	2060
					MILLION TONNES
Baseline	2,457	3,317	4,569	6,063	8,377
2030 targets	2,457	2,849	3,072	2,922	3,328
2070 net zero (balanced policy mix)	2,457	2,430	1,477	619	238
2070 net zero (with regulation focus)	2,457	2,400	1,375	542	235
2070 net zero (with market-based focus)	2,457	2,462	1,512	717	307
Accelerated coal phase-out	2,457	1,863	871	516	147
2050 net zero (balanced policy mix)	2,457	1,529	435	-26	-214
2050 net zero (with regulation focus)	2,457	1,501	419	-18	-206
2050 net zero (with market-based focus)	2,457	2,054	441	-15	-198

TABLE 0.5: GHG EMISSIONS

	2022	2030	2040	2050	2060
					MILLION TONNES OF CO_2-EQUIVALENT
Baseline	3,197	4,481	6,076	7,950	10,702
2030 targets	3,197	4,020	4,742	5,254	6,389
2070 net zero (balanced policy mix)	3,197	3,530	3,245	3,027	3,349
2070 net zero (with regulation focus)	3,197	3,503	3,167	2,966	3,347
2070 net zero (with market-based focus)	3,197	3,554	3,271	3,103	3,402
Accelerated coal phase-out	3,197	3,064	2,766	2,938	3,268
2050 net zero (balanced policy mix)	3,197	2,639	2,229	2,270	2,753
2050 net zero (with regulation focus)	3,197	2,617	2,215	2,282	2,766
2050 net zero (with market-based focus)	3,197	3,058	2,233	2,276	2,764

TABLE 0.6: GDP IMPACTS (ABSOLUTE DIFFERENCES FROM BASELINE)

	2030	2040	2050	2060
				$2021M
2030 targets	83,945	214,658	326,031	381,623
2070 net zero (balanced policy mix)	156,939	385,953	487,523	551,197
2070 net zero (with regulation focus)	162,232	412,863	460,488	552,827
2070 net zero (with market-based focus)	151,438	385,975	480,950	562,354
Accelerated coal phase-out	314,805	373,710	428,998	509,086
2050 net zero (balanced policy mix)	339,894	440,877	470,888	536,099
2050 net zero (with regulation focus)	344,936	420,345	473,250	543,667
2050 net zero (with market-based focus)	217,011	443,872	464,881	531,718

TABLE 0.7: HOUSEHOLD CONSUMPTION IMPACTS (ABSOLUTE DIFFERENCES FROM BASELINE)

	2030	2040	2050	2060
				$2021M
2030 targets	-448	-3,175	-6,977	-6,645
2070 net zero (balanced policy mix)	-829	-5,573	-9,112	-9,703
2070 net zero (with regulation focus)	-930	-5,699	-9,190	-9,696
2070 net zero (with market-based focus)	-799	-5,440	-9,021	-9,585
Accelerated coal phase-out	-969	-6,012	-9,195	-9,682
2050 net zero (balanced policy mix)	-1,221	-6,615	-9,832	-10,351
2050 net zero (with regulation focus)	-1,399	-6,740	-9,822	-10,350
2050 net zero (with market-based focus)	-1,173	-6,540	-9,800	-10,340

TABLE 0.8: ECONOMY-WIDE INVESTMENT REQUIREMENTS (IN ADDITION TO BASELINE)			
	2022-30	2022-50	2022-60
			$2021BN
2030 targets	562	3,530	5,638
2070 net zero (balanced policy mix)	817	6,596	10,101
2070 net zero (with regulation focus)	830	6,661	10,101
2070 net zero (with market-based focus)	803	6,499	10,020
Accelerated coal phase-out	1,267	7,144	10,453
2050 net zero (balanced policy mix)	1,596	9,134	13,486
2050 net zero (with regulation focus)	1,597	9,089	13,502
2050 net zero (with market-based focus)	1,213	8,887	13,246

TABLE 0.9: NET POLICY COSTS				
	2030	2040	2050	2060
				$2021M
2030 targets	-27,793	-58,444	-22,074	-18,248
2070 net zero (balanced policy mix)	-28,694	-39,883	-23,149	-15,901
2070 net zero (with regulation focus)	-28,888	-60,354	-38,244	-25,325
2070 net zero (with market-based focus)	-12,425	-28,588	-27,043	-9,323
Accelerated coal phase-out	-10,375	-6,482	27,350	49,468
2050 net zero (balanced policy mix)	-11,184	-4,585	28,623	50,076
2050 net zero (with regulation focus)	-33,387	-8,429	24,378	46,548
2050 net zero (with market-based focus)	-24,286	-63,613	-78,694	-93,989

Note: Negative costs imply savings

TABLE 0.10: FINAL ENERGY INTENSITY OF GDP					
	2022	2030	2040	2050	2060
					TOE PER $2021M
Baseline	206.4	154.3	123.1	122.5	122.4
2030 targets	206.4	149.0	110.8	104.5	106.6
2070 net zero (balanced policy mix)	206.4	134.5	93.6	89.3	93.7
2070 net zero (with regulation focus)	206.4	134.4	93.8	89.7	93.8
2070 net zero (with market-based focus)	206.4	134.5	93.5	89.2	93.5
Accelerated coal phase-out	206.4	131.8	93.1	89.5	94.0
2050 net zero (balanced policy mix)	206.4	120.2	82.8	82.1	89.2
2050 net zero (with regulation focus)	206.4	120.3	83.1	82.3	89.3
2050 net zero (with market-based focus)	206.4	121.3	82.6	82.0	89.1

TABLE 0.11: SHARES OF ELECTRIC VEHICLES IN THE PASSENGER CAR FLEET					
	2022	2030	2040	2050	2060
					%
Baseline	0	0	0	1	4
2030 targets	0	10	49	92	99
2070 net zero (balanced policy mix)	0	19	72	96	100
2070 net zero (with regulation focus)	0	19	71	95	99
2070 net zero (with market-based focus)	0	19	72	96	100
Accelerated coal phase-out	0	22	81	98	100
2050 net zero (balanced policy mix)	0	26	91	100	100
2050 net zero (with regulation focus)	0	26	91	100	100
2050 net zero (with market-based focus)	0	26	91	100	100

TABLE 0.12: POWER CAPACITY AND GENERATION MIX IN THE PRE-COP26 BASELINE

		2022	2030	2040	2050	2060
Power capacity	GW	402	638	1,027	1,571	2,381
Coal	% of total	52	47	42	40	41
Oil & gas	% of total	8	9	10	11	11
Fossil fuels with CCS	% of total	0	0	0	0	0
Nuclear	% of total	2	2	2	2	2
Biomass (inc. with CCS)	% of total	2	2	2	2	1
Wind	% of total	16	21	19	14	11
Solar	% of total	8	12	20	28	32
Hydro	% of total	11	8	5	3	2
Power generation	TWh	1,850	2,667	3,885	5,697	8,605
Coal	% of total	76	74	70	67	68
Oil & gas	% of total	1	2	2	3	3
Fossil fuels with CCS	% of total	0	0	0	0	0
Nuclear	% of total	3	4	4	4	4
Biomass (inc. with CCS)	% of total	2	2	2	2	2
Wind	% of total	6	8	8	6	4
Solar	% of total	4	6	11	17	19
Hydro	% of total	6	4	3	1	1

TABLE 0.13: POWER CAPACITY AND GENERATION MIX IN THE 2030 TARGETS SCENARIO						
		2022	2030	2040	2050	2060
Power capacity	GW	402	821	1,788	3,468	5,710
Coal	% of total	52	35	21	12	9
Oil & gas	% of total	8	3	1	1	1
Fossil fuels with CCS	% of total	0	0	0	0	0
Nuclear	% of total	2	1	2	2	2
Biomass (inc. with CCS)	% of total	2	2	2	1	1
Wind	% of total	16	15	15	9	7
Solar	% of total	8	35	56	72	80
Hydro	% of total	11	8	3	2	1
Power generation	TWh	1,850	2,877	4,928	8,405	13,181
Coal	% of total	76	58	36	21	16
Oil & gas	% of total	1	0	0	0	1
Fossil fuels with CCS	% of total	0	0	0	0	0
Nuclear	% of total	3	3	5	6	5
Biomass (inc. with CCS)	% of total	2	2	2	2	1
Wind	% of total	6	7	8	6	4
Solar	% of total	4	22	43	62	71
Hydro	% of total	6	7	4	2	1

TABLE 0.14: POWER CAPACITY AND GENERATION MIX IN THE 2070 NET ZERO (BALANCED POLICY MIX) SCENARIO						
		2022	**2030**	**2040**	**2050**	**2060**
Power capacity	GW	402	867	2,564	4,556	7,601
Coal	% of total	52	29	7	1	0
Oil & gas	% of total	8	3	1	0	0
Fossil fuels with CCS	% of total	0	0	0	0	0
Nuclear	% of total	2	2	2	3	2
Biomass (inc. with CCS)	% of total	2	2	1	1	1
Wind	% of total	16	20	13	8	6
Solar	% of total	8	36	74	87	90
Hydro	% of total	11	8	2	1	1
Power generation	TWh	1,850	2,811	5,901	9,967	15,886
Coal	% of total	76	50	11	1	0
Oil & gas	% of total	1	1	0	0	0
Fossil fuels with CCS	% of total	0	0	0	0	1
Nuclear	% of total	3	4	8	9	7
Biomass (inc. with CCS)	% of total	2	3	2	2	2
Wind	% of total	6	10	8	5	4
Solar	% of total	4	24	67	81	86
Hydro	% of total	6	9	3	2	1

TABLE 0.15: POWER CAPACITY AND GENERATION MIX IN THE 2070 NET ZERO (WITH REGULATION FOCUS) SCENARIO

		2022	2030	2040	2050	2060
Power capacity	GW	402	880	2,596	4,567	7,570
Coal	% of total	52	28	6	0	0
Oil & gas	% of total	8	3	0	0	0
Fossil fuels with CCS	% of total	0	0	0	0	0
Nuclear	% of total	2	2	3	3	2
Biomass (inc. with CCS)	% of total	2	2	1	1	1
Wind	% of total	16	21	13	8	6
Solar	% of total	8	35	75	87	90
Hydro	% of total	11	8	2	1	1
Power generation	TWh	1,850	2,814	5,946	9,992	15,860
Coal	% of total	76	49	9	0	0
Oil & gas	% of total	1	1	0	0	0
Fossil fuels with CCS	% of total	0	0	0	1	1
Nuclear	% of total	3	4	8	9	7
Biomass (inc. with CCS)	% of total	2	3	2	2	2
Wind	% of total	6	10	8	5	4
Solar	% of total	4	24	69	82	86
Hydro	% of total	6	9	3	2	1

TABLE 0.16: POWER CAPACITY AND GENERATION MIX IN THE 2070 NET ZERO (WITH MARKET-BASED FOCUS) SCENARIO

		2022	2030	2040	2050	2060
Power capacity	GW	402	857	2,555	4,513	7,589
Coal	% of total	52	30	7	1	0
Oil & gas	% of total	8	3	1	0	0
Fossil fuels with CCS	% of total	0	0	0	0	0
Nuclear	% of total	2	2	2	2	2
Biomass (inc. with CCS)	% of total	2	2	1	1	1
Wind	% of total	16	19	13	8	6
Solar	% of total	8	36	73	86	90
Hydro	% of total	11	8	2	1	1
Power generation	TWh	1,850	2,809	5,888	9,908	15,864
Coal	% of total	76	51	12	2	0
Oil & gas	% of total	1	1	0	0	0
Fossil fuels with CCS	% of total	0	0	0	0	1
Nuclear	% of total	3	3	7	8	7
Biomass (inc. with CCS)	% of total	2	3	2	2	2
Wind	% of total	6	9	8	5	4
Solar	% of total	4	23	67	81	86
Hydro	% of total	6	9	3	2	1

TABLE 0.17: POWER CAPACITY AND GENERATION MIX IN THE ACCELERATED COAL PHASE-OUT SCENARIO

		2022	2030	2040	2050	2060
Power capacity	GW	402	1,286	2,813	4,532	7,520
Coal	% of total	52	11	0	0	0
Oil & gas	% of total	8	5	0	0	0
Fossil fuels with CCS	% of total	0	1	0	0	0
Nuclear	% of total	2	2	3	3	2
Biomass (inc. with CCS)	% of total	2	4	1	1	1
Wind	% of total	16	44	13	8	6
Solar	% of total	8	28	80	87	89
Hydro	% of total	11	5	1	1	1
Power generation	TWh	1,850	2,912	6,271	9,964	15,803
Coal	% of total	76	24	0	0	0
Oil & gas	% of total	1	3	0	0	0
Fossil fuels with CCS	% of total	0	1	1	1	1
Nuclear	% of total	3	8	11	10	7
Biomass (inc. with CCS)	% of total	2	8	2	2	3
Wind	% of total	6	23	8	5	4
Solar	% of total	4	26	75	81	85
Hydro	% of total	6	7	2	1	1

TABLE 0.18: POWER CAPACITY AND GENERATION MIX IN THE 2050 NET ZERO (BALANCED POLICY MIX) SCENARIO

		2022	2030	2040	2050	2060
Power capacity	GW	402	1,162	2,716	4,278	7,307
Coal	% of total	52	12	0	0	0
Oil & gas	% of total	8	5	0	0	0
Fossil fuels with CCS	% of total	0	1	0	0	0
Nuclear	% of total	2	2	3	3	2
Biomass (inc. with CCS)	% of total	2	6	3	3	2
Wind	% of total	16	40	14	8	7
Solar	% of total	8	30	78	85	89
Hydro	% of total	11	6	1	1	1
Power generation	TWh	1,850	2,784	6,030	9,483	15,425
Coal	% of total	76	24	0	0	0
Oil & gas	% of total	1	3	0	0	0
Fossil fuels with CCS	% of total	0	1	1	1	1
Nuclear	% of total	3	7	11	9	7
Biomass (inc. with CCS)	% of total	2	10	4	4	3
Wind	% of total	6	21	9	5	4
Solar	% of total	4	27	74	79	84
Hydro	% of total	6	8	2	1	1

TABLE 0.19: POWER CAPACITY AND GENERATION MIX IN THE 2050 NET ZERO (WITH REGULATION FOCUS) SCENARIO

		2022	2030	2040	2050	2060
Power capacity	GW	402	1,171	2,712	4,272	7,309
Coal	% of total	52	12	0	0	0
Oil & gas	% of total	8	5	0	0	0
Fossil fuels with CCS	% of total	0	1	0	0	0
Nuclear	% of total	2	2	3	3	2
Biomass (inc. with CCS)	% of total	2	6	3	3	2
Wind	% of total	16	40	13	8	7
Solar	% of total	8	30	79	85	89
Hydro	% of total	11	6	1	1	1
Power generation	TWh	1,850	2,783	6,040	9,480	15,430
Coal	% of total	76	24	0	0	0
Oil & gas	% of total	1	3	0	0	0
Fossil fuels with CCS	% of total	0	1	1	1	1
Nuclear	% of total	3	7	11	10	7
Biomass (inc. with CCS)	% of total	2	10	4	4	3
Wind	% of total	6	21	8	5	4
Solar	% of total	4	27	74	79	84
Hydro	% of total	6	8	2	1	1

TABLE 0.20: POWER CAPACITY AND GENERATION MIX IN THE 2050 NET ZERO (WITH MARKET-BASED FOCUS) SCENARIO

		2022	2030	2040	2050	2060
Power capacity	GW	402	846	2,789	4,330	7,330
Coal	% of total	52	28	0	0	0
Oil & gas	% of total	8	3	0	0	0
Fossil fuels with CCS	% of total	0	0	0	0	0
Nuclear	% of total	2	1	2	2	2
Biomass (inc. with CCS)	% of total	2	4	3	3	2
Wind	% of total	16	19	13	8	7
Solar	% of total	8	36	80	85	89
Hydro	% of total	11	8	1	1	1
Power generation	TWh	1,850	2,722	6,114	9,525	15,441
Coal	% of total	76	48	0	0	0
Oil & gas	% of total	1	1	0	0	0
Fossil fuels with CCS	% of total	0	0	0	0	1
Nuclear	% of total	3	3	8	8	6
Biomass (inc. with CCS)	% of total	2	5	4	4	3
Wind	% of total	6	10	8	5	4
Solar	% of total	4	24	77	80	85
Hydro	% of total	6	9	2	1	1

TABLE 0.21: FINAL ENERGY DEMAND FOR TRANSPORT - BASELINE						
		2022	**2030**	**2040**	**2050**	**2060**
Total	ktoe	94,545	139,904	223,420	265,449	279,280
Electricity	% of total	2	2	3	4	9
Coal	% of total	0	0	0	0	0
Oil	% of total	95	94	90	81	69
Gas	% of total	1	1	4	11	20
Biofuels	% of total	1	2	3	3	3
Hydrogen	% of total	0	0	0	0	0

TABLE 0.22: FINAL ENERGY DEMAND FOR TRANSPORT - 2030 TARGETS						
		2022	**2030**	**2040**	**2050**	**2060**
Total	ktoe	94,545	132,384	168,623	153,549	178,960
Electricity	% of total	2	5	23	55	59
Coal	% of total	0	0	0	0	0
Oil	% of total	95	85	62	32	27
Gas	% of total	1	1	2	1	0
Biofuels	% of total	1	8	13	9	9
Hydrogen	% of total	0	0	0	3	5

TABLE 0.23: FINAL ENERGY DEMAND FOR TRANSPORT - 2070 NET ZERO (BALANCED POLICY MIX)						
		2022	**2030**	**2040**	**2050**	**2060**
Total	ktoe	94,545	125,083	145,746	151,946	182,080
Electricity	% of total	2	10	42	59	58
Coal	% of total	0	0	0	0	0
Oil	% of total	95	79	33	18	16
Gas	% of total	1	3	8	5	4
Biofuels	% of total	1	8	17	14	17
Hydrogen	% of total	0	0	0	3	5

TABLE 0.24: FINAL ENERGY DEMAND FOR TRANSPORT - 2070 NET ZERO (REGULATION FOCUS)

		2022	2030	2040	2050	2060
Total	ktoe	94,545	124,581	146,959	153,749	182,650
Electricity	% of total	2	10	41	58	58
Coal	% of total	0	0	0	0	0
Oil	% of total	95	77	29	17	16
Gas	% of total	1	3	10	7	4
Biofuels	% of total	1	11	19	16	17
Hydrogen	% of total	0	0	0	3	5

TABLE 0.25: FINAL ENERGY DEMAND FOR TRANSPORT - 2070 NET ZERO (MARKET-BASED FOCUS)

		2022	2030	2040	2050	2060
Total	ktoe	94,545	124,801	144,984	150,826	180,077
Electricity	% of total	2	10	42	59	59
Coal	% of total	0	0	0	0	0
Oil	% of total	95	83	36	20	18
Gas	% of total	1	3	8	5	3
Biofuels	% of total	1	5	13	12	15
Hydrogen	% of total	0	0	0	3	5

TABLE 0.26: FINAL ENERGY DEMAND FOR TRANSPORT - ACCELERATED COAL PHASE-OUT

		2022	2030	2040	2050	2060
Total	ktoe	94,545	121,626	136,169	148,576	181,055
Electricity	% of total	2	12	49	61	58
Coal	% of total	0	0	0	0	0
Oil	% of total	95	77	28	18	16
Gas	% of total	1	3	10	5	4
Biofuels	% of total	1	8	13	13	17
Hydrogen	% of total	0	0	0	3	5

TABLE 0.27: FINAL ENERGY DEMAND FOR TRANSPORT - 2050 NET ZERO (BALANCED POLICY MIX)

		2022	2030	2040	2050	2060
Total	ktoe	94,545	128,362	132,482	150,270	182,792
Electricity	% of total	2	12	56	61	58
Coal	% of total	0	0	0	0	0
Oil	% of total	95	67	21	14	15
Gas	% of total	1	1	2	3	3
Biofuels	% of total	1	20	18	16	17
Hydrogen	% of total	0	0	4	6	7

TABLE 0.28: FINAL ENERGY DEMAND FOR TRANSPORT - 2050 NET ZERO (REGULATION FOCUS)

		2022	2030	2040	2050	2060
Total	ktoe	94,545	128,890	133,261	151,277	183,294
Electricity	% of total	2	12	55	60	57
Coal	% of total	0	0	0	0	0
Oil	% of total	95	60	17	15	15
Gas	% of total	1	1	2	3	3
Biofuels	% of total	1	26	22	16	17
Hydrogen	% of total	0	0	4	6	7

TABLE 0.29: FINAL ENERGY DEMAND FOR TRANSPORT - 2050 NET ZERO (MARKET-BASED FOCUS)

		2022	2030	2040	2050	2060
Total	ktoe	94,545	127,325	132,018	149,740	182,557
Electricity	% of total	2	12	56	61	58
Coal	% of total	0	0	0	0	0
Oil	% of total	95	68	22	16	15
Gas	% of total	1	1	2	3	3
Biofuels	% of total	1	18	16	14	16
Hydrogen	% of total	0	0	4	6	7

TABLE 0.30: FINAL ENERGY DEMAND FOR BUILDINGS - BASELINE

		2022	2030	2040	2050	2060
Total	ktoe	242,897	284,565	346,012	447,661	628,432
Electricity	% of total	21	31	44	57	69
Coal	% of total	7	6	4	3	2
Oil	% of total	17	18	17	16	13
Gas	% of total	2	3	3	4	4
Biofuels	% of total	54	43	31	20	12
Hydrogen	% of total	0	0	0	0	0

TABLE 0.31: FINAL ENERGY DEMAND FOR BUILDINGS - 2030 TARGETS

		2022	2030	2040	2050	2060
Total	ktoe	242,897	280,752	336,659	435,702	616,501
Electricity	% of total	21	32	47	61	73
Coal	% of total	7	6	4	3	2
Oil	% of total	17	17	17	15	13
Gas	% of total	2	2	2	1	1
Biofuels	% of total	54	43	30	19	11
Hydrogen	% of total	0	0	0	0	0

TABLE 0.32: FINAL ENERGY DEMAND FOR BUILDINGS - 2070 NET ZERO (BALANCED POLICY MIX)

		2022	2030	2040	2050	2060
Total	ktoe	242,897	244,788	268,788	352,216	512,395
Electricity	% of total	21	35	56	72	84
Coal	% of total	7	7	3	2	1
Oil	% of total	17	16	12	9	6
Gas	% of total	2	2	1	1	0
Biofuels	% of total	54	41	28	18	9
Hydrogen	% of total	0	0	0	0	0

TABLE 0.33: FINAL ENERGY DEMAND FOR BUILDINGS - 2070 NET ZERO (REGULATION FOCUS)

		2022	2030	2040	2050	2060
Total	ktoe	242,897	245,540	270,638	353,388	513,009
Electricity	% of total	21	35	56	72	84
Coal	% of total	7	7	3	2	1
Oil	% of total	17	16	12	9	6
Gas	% of total	2	2	1	1	0
Biofuels	% of total	54	40	28	18	9
Hydrogen	% of total	0	0	0	0	0

TABLE 0.34: FINAL ENERGY DEMAND FOR BUILDINGS - 2070 NET ZERO (MARKET-BASED FOCUS)

		2022	2030	2040	2050	2060
Total	ktoe	242,897	244,788	268,817	352,241	512,394
Electricity	% of total	21	35	56	72	84
Coal	% of total	7	7	3	2	1
Oil	% of total	17	16	12	9	6
Gas	% of total	2	2	1	1	0
Biofuels	% of total	54	41	28	18	9
Hydrogen	% of total	0	0	0	0	0

TABLE 0.35: FINAL ENERGY DEMAND FOR BUILDINGS - ACCELERATED COAL PHASE-OUT

		2022	2030	2040	2050	2060
Total	ktoe	242,897	244,828	268,660	352,133	512,378
Electricity	% of total	21	35	56	72	84
Coal	% of total	7	7	3	2	1
Oil	% of total	17	16	12	9	6
Gas	% of total	2	2	1	1	0
Biofuels	% of total	54	40	27	18	9
Hydrogen	% of total	0	0	0	0	0

TABLE 0.36: FINAL ENERGY DEMAND FOR BUILDINGS - 2050 NET ZERO (BALANCED POLICY MIX)

		2022	2030	2040	2050	2060
Total	ktoe	242,897	192,507	210,776	305,631	473,594
Electricity	% of total	21	42	65	77	88
Coal	% of total	7	7	4	2	1
Oil	% of total	17	17	11	8	5
Gas	% of total	2	2	1	0	0
Biofuels	% of total	54	32	19	13	6
Hydrogen	% of total	0	0	0	0	0

TABLE 0.37: FINAL ENERGY DEMAND FOR BUILDINGS - 2050 NET ZERO (REGULATION FOCUS)

		2022	2030	2040	2050	2060
Total	ktoe	242,897	193,242	212,676	306,813	474,188
Electricity	% of total	21	41	64	77	88
Coal	% of total	7	7	4	2	1
Oil	% of total	17	17	12	8	5
Gas	% of total	2	2	1	0	0
Biofuels	% of total	54	32	19	13	6
Hydrogen	% of total	0	0	0	0	0

TABLE 0.38: FINAL ENERGY DEMAND FOR BUILDINGS - 2050 NET ZERO (MARKET-BASED FOCUS)

		2022	2030	2040	2050	2060
Total	ktoe	242,897	192,507	210,776	305,631	473,594
Electricity	% of total	21	42	65	77	88
Coal	% of total	7	7	4	2	1
Oil	% of total	17	17	11	8	5
Gas	% of total	2	2	1	0	0
Biofuels	% of total	54	32	19	13	6
Hydrogen	% of total	0	0	0	0	0

TABLE 0.39: FINAL ENERGY DEMAND FOR INDUSTRY AND CONSTRUCTION - BASELINE

		2022	2030	2040	2050	2060
Total	ktoe	303,254	420,351	551,971	704,568	896,833
Electricity	% of total	17	17	18	19	20
Coal	% of total	33	33	35	37	38
Oil	% of total	24	24	22	21	20
Gas	% of total	14	14	14	13	13
Biofuels	% of total	13	12	11	10	9
Hydrogen	% of total	0	0	0	0	0

TABLE 0.40: FINAL ENERGY DEMAND FOR INDUSTRY AND CONSTRUCTION - 2030 TARGETS

		2022	2030	2040	2050	2060
Total	ktoe	303,254	414,961	522,918	643,582	807,111
Electricity	% of total	17	20	24	30	36
Coal	% of total	33	30	28	23	20
Oil	% of total	24	25	24	24	23
Gas	% of total	14	13	12	10	9
Biofuels	% of total	13	12	11	10	10
Hydrogen	% of total	0	0	1	3	3

TABLE 0.41: FINAL ENERGY DEMAND FOR INDUSTRY AND CONSTRUCTION - 2070 NET ZERO (BALANCED POLICY MIX)

		2022	2030	2040	2050	2060
Total	ktoe	303,254	389,938	467,962	562,290	729,903
Electricity	% of total	17	20	31	44	56
Coal	% of total	33	30	24	14	6
Oil	% of total	24	27	27	26	23
Gas	% of total	14	13	10	7	5
Biofuels	% of total	13	9	7	6	6
Hydrogen	% of total	0	0	1	3	4

TABLE 0.42: FINAL ENERGY DEMAND FOR INDUSTRY AND CONSTRUCTION - 2070 NET ZERO (REGULATION FOCUS)

		2022	2030	2040	2050	2060
Total	ktoe	303,254	390,187	469,570	562,338	730,486
Electricity	% of total	17	20	31	44	56
Coal	% of total	33	30	24	14	6
Oil	% of total	24	27	27	26	23
Gas	% of total	14	13	10	7	5
Biofuels	% of total	13	9	7	6	6
Hydrogen	% of total	0	0	1	3	4

TABLE 0.43: FINAL ENERGY DEMAND FOR INDUSTRY AND CONSTRUCTION - 2070 NET ZERO (MARKET-BASED FOCUS)

		2022	2030	2040	2050	2060
Total	ktoe	303,254	389,745	467,852	561,403	729,225
Electricity	% of total	17	20	31	44	56
Coal	% of total	33	30	24	14	6
Oil	% of total	24	27	27	26	23
Gas	% of total	14	13	10	7	5
Biofuels	% of total	13	9	7	6	6
Hydrogen	% of total	0	0	1	3	4

TABLE 0.44: FINAL ENERGY DEMAND FOR INDUSTRY AND CONSTRUCTION - ACCELERATED COAL PHASE-OUT

		2022	2030	2040	2050	2060
Total	ktoe	303,254	398,404	471,149	563,362	731,464
Electricity	% of total	17	20	31	44	56
Coal	% of total	33	31	24	14	6
Oil	% of total	24	27	27	26	23
Gas	% of total	14	13	10	7	5
Biofuels	% of total	13	9	7	6	6
Hydrogen	% of total	0	0	1	3	4

TABLE 0.45: FINAL ENERGY DEMAND FOR INDUSTRY AND CONSTRUCTION - 2050 NET ZERO (BALANCED POLICY MIX)

		2022	2030	2040	2050	2060
Total	ktoe	303,254	380,376	439,714	524,798	700,625
Electricity	% of total	17	21	33	47	58
Coal	% of total	33	31	22	11	4
Oil	% of total	24	26	27	23	20
Gas	% of total	14	14	11	7	5
Biofuels	% of total	13	7	4	3	3
Hydrogen	% of total	0	1	3	9	10

TABLE 0.46: FINAL ENERGY DEMAND FOR INDUSTRY AND CONSTRUCTION - 2050 NET ZERO (REGULATION FOCUS)

		2022	2030	2040	2050	2060
Total	ktoe	303,254	380,621	439,322	524,992	701,675
Electricity	% of total	17	21	33	47	58
Coal	% of total	33	31	22	11	4
Oil	% of total	24	26	27	23	20
Gas	% of total	14	14	11	7	5
Biofuels	% of total	13	7	4	3	3
Hydrogen	% of total	0	1	3	9	10

TABLE 0.47: FINAL ENERGY DEMAND FOR INDUSTRY AND CONSTRUCTION - 2050 NET ZERO (MARKET-BASED FOCUS)

		2022	2030	2040	2050	2060
Total	ktoe	303,254	373,619	438,994	523,097	699,217
Electricity	% of total	17	21	33	47	58
Coal	% of total	33	30	22	11	4
Oil	% of total	24	26	27	23	20
Gas	% of total	14	14	11	7	5
Biofuels	% of total	13	7	4	3	3
Hydrogen	% of total	0	1	3	9	10

For more information about the High-level Policy Commission on Getting Asia to Net Zero, visit: AsiaSociety.org/NetZero.

ASIA SOCIETY

Navigating Shared Futures