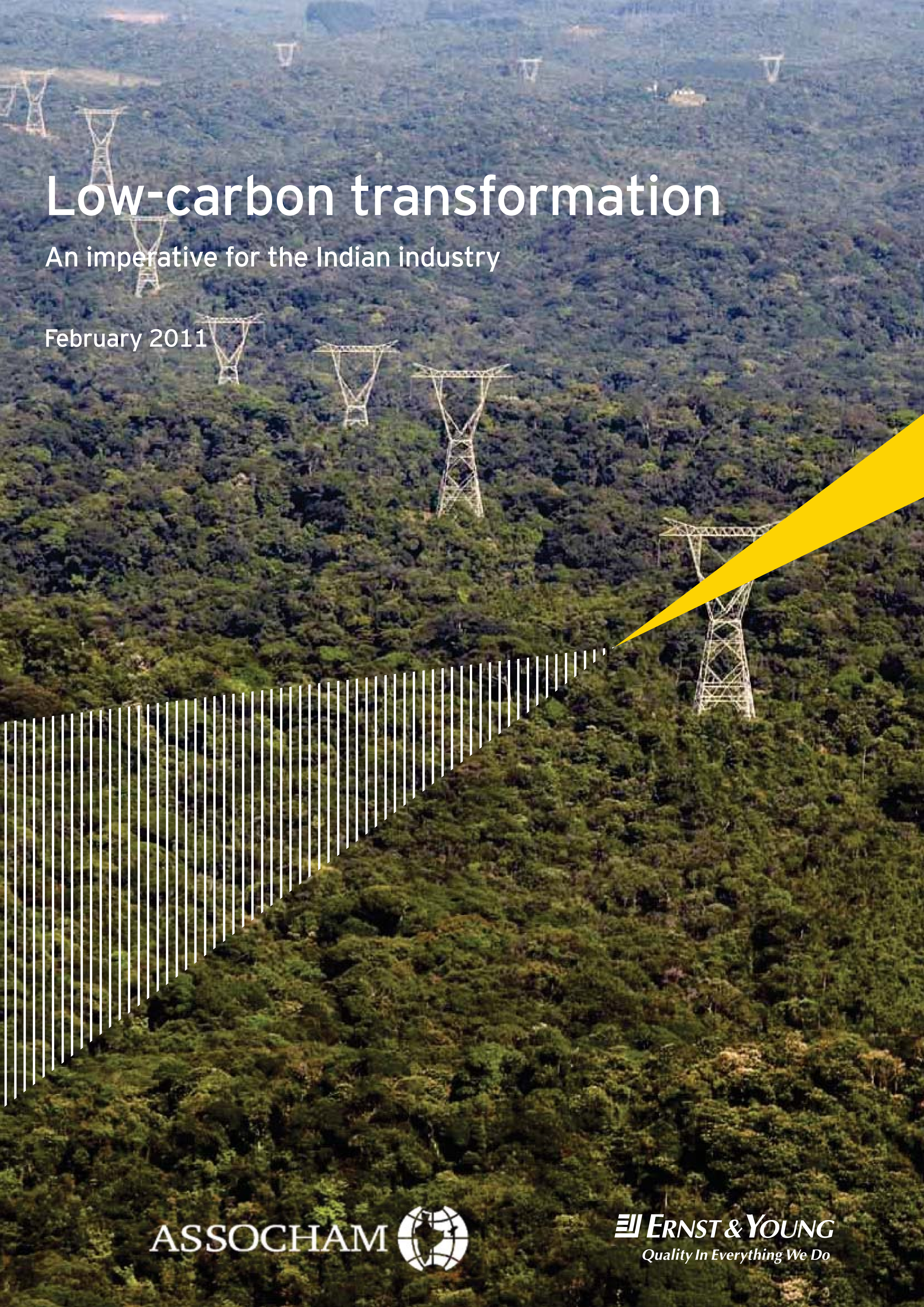
Low-carbon transformation

An imperative for the Indian industry

February 2011



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Acknowledgement

It gives me great pleasure that ASSOCHAM is organizing a conference on "A Call to Low Carbon Economy." This conference is of particular significance as the threat of global warming has changed the way governments and businesses define sustainable economic growth. With climate summits at Copenhagen and Cancun capturing the attention of the entire world, climate change is now a part of strategic discussions at the topmost management levels across major corporations.

With these global concerns percolating through various economies, India too faces this mammoth challenge to sustain its rapid economic growth, while dealing with the adverse impact of climate change. The Government of India seems to have acknowledged that a low-carbon growth strategy is an essential aspect of sustainable development. India has set up a Low Carbon Expert Group, adopted a National Action Plan on Climate Change, and Indian policies are undergoing a noticeable paradigm shift for promoting clean technologies. However, there is a long road ahead and transitioning to a low-carbon economy will require significant investments in low carbon technologies across sectors of the Indian economy, as well as planning and coordination among different stakeholders to remove barriers in the path of low-carbon growth.

The socio-economic and technological benefits of adopting a low-carbon growth trajectory are undeniable. In this report, we explore how and why India can answer the "call to a low-carbon economy" and reap its benefits.

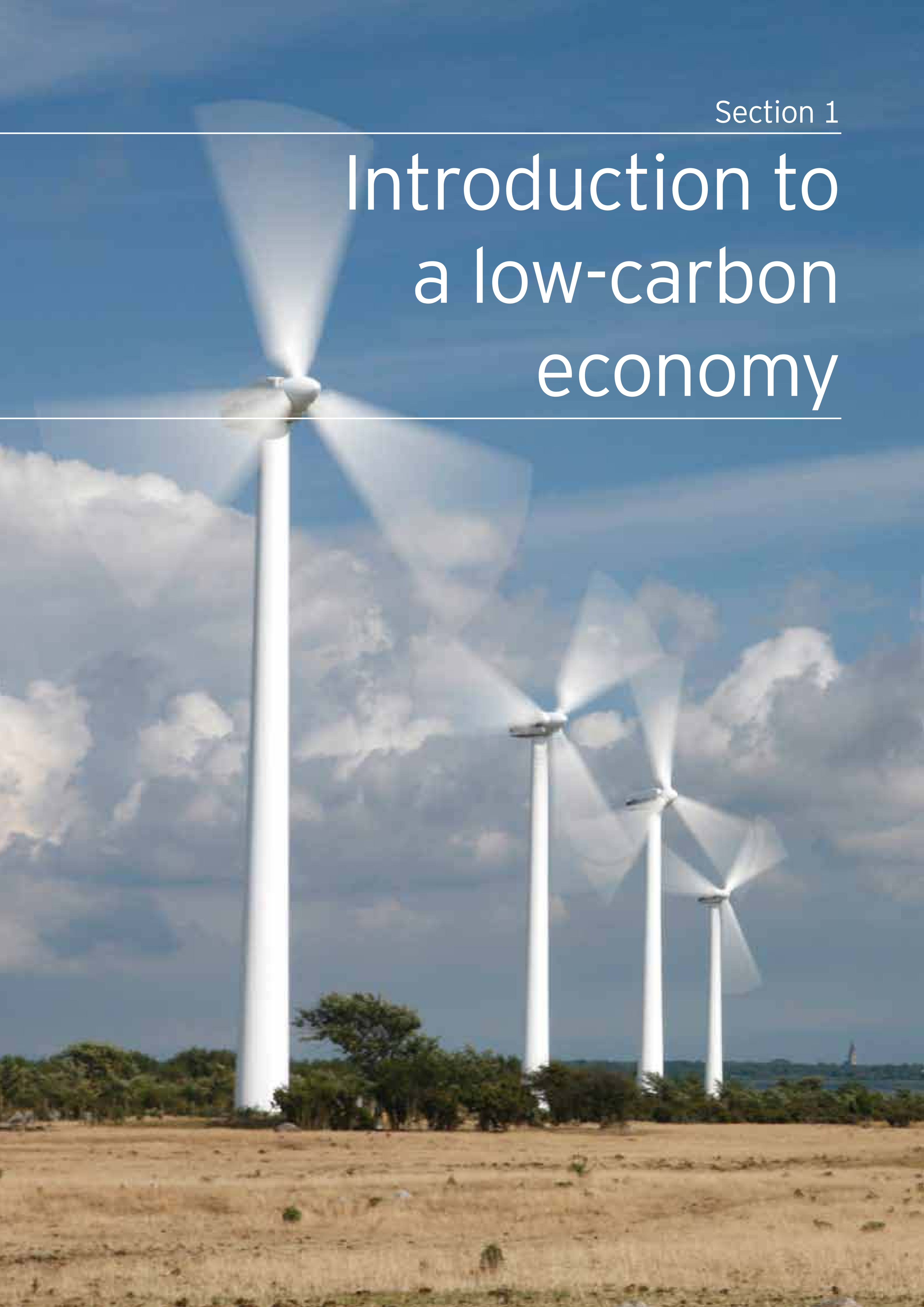
I thank our knowledge partner, Ernst & Young Pvt. Ltd., for their efforts in publishing this report. I also express my gratitude to all the speakers, sponsors and media partners. I wish the conference great success and sincerely hope that you find both the sessions as well as this publication insightful, relevant and informative.

(D.S. Rawat)

Content

Section 1

Introduction to a low-carbon economy



There is an emerging global consensus among decision makers and the scientific community that combating climate change is one of the most paramount challenges of the 21st century and that anthropogenic greenhouse gas (GHG) emissions are the main reason for global warming and climate change. India faces the continued challenge of sustaining its rapid economic growth, which could lead to increasing GHG emissions, while dealing with this global threat. The predicted impact of climate change on the Indian subcontinent includes changes in precipitation patterns, submergence of low-lying/ coastal lands, the melting of glaciers in the Indian Himalayas and its impact on water security. Due to its dependence on various climate-sensitive sectors such as agriculture, water and forestry, India may face a major threat because of the projected changes in climate. Therefore, given the repercussions, it is imperative to take well-informed decisions to make climate change-related efforts truly productive.

India's response to climate change is proactive and broad-based, enabling the country to move consistently toward a stage of decoupling of growth and carbon emissions. The country has taken various initiatives in this direction, including:

- Changing trends in overall consumption patterns
- A thrust on the use of renewable energy sources
- Improved energy efficiency in the power and manufacturing sectors
- A transport policy that seeks to encourage an efficient rail-road mix and developing an efficient highways network
- An automobile policy that is aligned to the best international safety and emission norms
- Urban planning that aims to optimize living and working spaces as well as restore the depleted green cover

The efforts to mitigate climate change offer new opportunities for the Indian industry and business to leapfrog the energy and resource-intensive development process witnessed in the developed world through the development, production and use of new cleaner technologies.

As a non-Annex 1 party to the UNFCCC and the Kyoto Protocol, India is under no legal obligation to curtail its GHG emissions. At a GDP growth rate of 7.51% over the next 20 years, India's GHG emissions are expected to be around 5.7 billion tonnes (including methane emissions from agriculture) and the per capita emissions will be around 3.9 tonnes CO_2e in 2030[1]. A testament to India's commitment to low-carbon growth is the declaration made by the government in December 2009, which aims at achieving 20%–25% reduction in carbon intensity below 2005 levels by 2020. This is significant, given the huge developmental imperatives. India is strongly inclined to be a part of the solution and is actively involved in discussions that will lead to a "post-Kyoto" regime that addresses the problem.

The concept of a "low-carbon" economy is subject to interpretation, but it generally refers to a development path, which reduces GHG emissions, while maintaining a steady drive toward innovation (particularly in clean technologies), increase of productivity and employment generation. To achieve low-carbon growth, there would be a need for significantly more investment in clean technologies. Although the government can provide the necessary incentives, the majority of this investment will have to come from the private sector. While the effects of climate change are increasingly a risk to the socio-economic well-being and environment of the country, economists are also recognizing that there are financial opportunities to be reaped from mitigating climate change and transitioning to a low-carbon economy.

The transition to a low-carbon economy will have economic implications that will transform businesses. Indian businesses are beginning to adopt a transformational approach, underpinned by an integrated climate change strategy to adopt a low-carbon growth trajectory. India Inc. can make a significant contribution to India's foreseeable low-carbon economy. The transition is an achievable goal, but it will require a massive and coordinated effort assisted by strategic long-term planning and innovation.

Section 2

Why does India need low-carbon growth?

India's carbon emissions

According to the Indian Network for Climate Change Assessment (INCCA), annual GHG emissions from India amount to 1.727 billion tonnes of CO_2 equivalent, based on data from 2007. India is the world's fourth-largest GHG emitting nation in absolute terms after China, the US and Russia. With the country's rapid economic growth, GHG emissions are set to increase to around 5.7 billion tonnes of CO_2 equivalent by 2030[2]. India is planning multiple initiatives to limit this rise in GHG emissions as scientific evidence clearly suggests that anthropogenic GHG emissions are a major contributing factor to climate change.

Drivers and benefits of low-carbon growth

Drivers

Impact of climate change

While climate change is a global phenomenon, India is particularly vulnerable to its effects for the following reasons:

- India is the second-most populous country in the world with a population of more than one billion.
- India is home to an estimated one-third of the world's poor.
- More than half of India's workforce is employed in agriculture and allied sectors and India is primarily an agrarian economy.
- The country has large population residing along its coasts.

Due to the above, the effects of climate change such as changes in precipitation patterns, temperature rise, sea level rise, escalation in frequency/intensity of storms, increased incidences of floods and droughts would have a pronounced impact on the Indian economy and people at large.

Mounting international pressure

The scientific evidence for climate change has resulted in coordinated international efforts and dialogues to manage the phenomenon of global warming and stabilize GHG concentrations in the atmosphere. In the recent UN Climate Change Talks (Copenhagen and Cancun), India has played an important role as one of the world's largest developing nations and a member of the BASIC (Brazil, South Africa, India and China) countries. India, along with other developing nations, has faced rising international pressure to curb its rising GHG emissions. After the Climate Change Conference at Copenhagen in December 2009, India voluntarily adopted a target for reduction in emissions intensity (GHG emissions per unit GDP).

Further, with the interplay of India's economy with the global economy, the country faces the risks of the cascading effects of climate change regulations in other countries. For instance, India's export of goods and services could be subject to carbon tax regulations or other forms of "carbon costs" in importing nations. This could potentially affect the competitiveness of India's exports if GHG emissions from India's industries are more carbon intensive than those in other countries.

Climate change risks may be categorized as physical, socio-economic and regulatory risks as illustrated below.

Climate change risks

Physical risks
- Increased intensity/frequency of floods, droughts and other natural calamities
- Damage to low-lying infrastructure due to rising sea levels
- Further degradation of ecosystems and decreased biodiversity

Socio-economic risks
- Decreased crop productivity, food security and the income of farmers
- Displacement of population from flood-prone regions
- Rising prevalence of disease due to warmer temperatures
- Adverse impact on water security due to changes in precipitation, Himalayan glacial system
- High energy costs due to extreme weather conditions

Regulatory risks
- International pressure to adopt emission reduction targets, external monitoring and verification
- Impact of climate change regulations in the EU, the US, etc., on the export of products/services to those countries
- Implementation of carbon tax on carbon-intensive products

Opportunities presented by the challenge of climate change

India's economy is expected to continue growing at a rapid pace over the next 20 years. An estimated three-fourths of the infrastructure that will be used in India in 2030 is yet to be built. Therefore, India is presented with a unique opportunity to continue to its rapid economic growth and develop its infrastructure through a low-carbon pathway. The benefits of a low-carbon economy include meeting the objectives of fast-paced economic growth and addressing the challenge of climate change.

Further, low-carbon growth is also intended to help address India's energy security by avoiding fossil fuel usage. The dependence on the imports of foreign oil and coal can be reduced by increasing the share of renewable energy generation and optimizing energy performance across all sectors of the economy. This would have the added benefit of creating "green jobs" and new avenues for economic growth.

The transition to a low-carbon economy can drive sustainable growth, while managing GHG emissions and addressing the risks of climate change. Although the Government of India (GOI) has already put in place numerous policy initiatives to promote mitigation and adaptation to climate change, a coordinated effort from all sectors of the industry, government and public will be required to take India on its low-carbon growth trajectory.

Drivers

India has made commitments to lower its emissions intensity to the international community and inaction could hurt India's credibility.

India is particularly vulnerable to the impact of climate change because large portions of its growing population are:

- Dependent on agriculture as a livelihood
- Below the poverty line
- Living in coastal areas

India is set to undertake rapid expansion in infrastructure. However, it is equally critical to account for the impact of climate change-related costs, while making technological choices so that the country does not lose out on pertinent opportunities.

India's proactive stance can open diverse avenues for the country to strengthen its global footing through:

- International efforts to combat climate change
- Clean technologies
- Sustainable growth

Benefits

If India is proactive, it will have more leverage to press developed nations to do their part by reducing emissions and facilitating technology transfer, adaptation and finance.

By adopting low-carbon growth, India will contribute to the mitigation of climate change and encourage other nations to do the same. This will curb the adverse impact of climate change the world over.

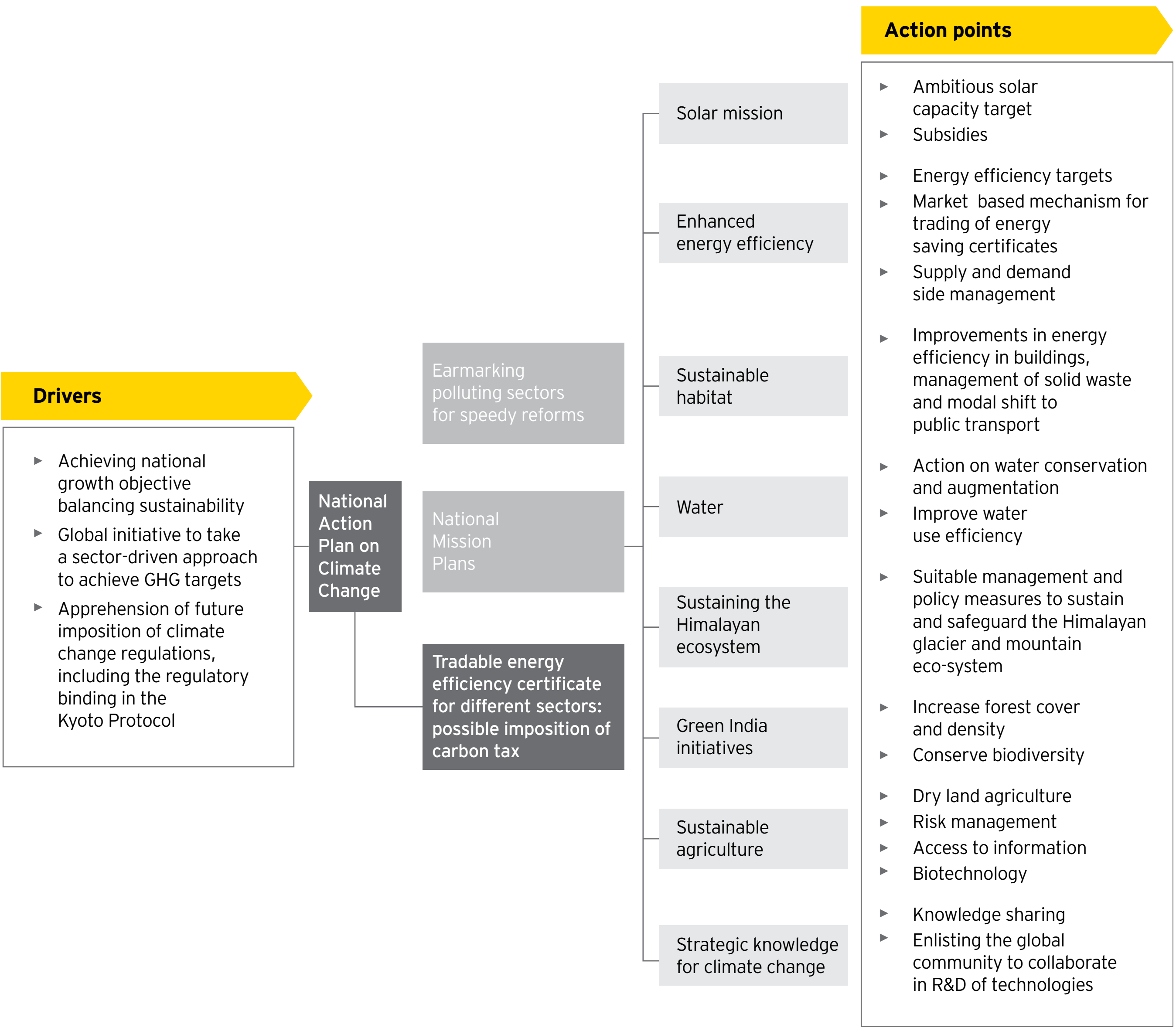
A low-carbon development path would entail less dependence on fossil fuels and increased investments in clean technology, resulting in increased energy security, job creation and economic growth.

Section 3

Current regulations and policies relevant to low-carbon growth in India

National Action Plan on Climate Change

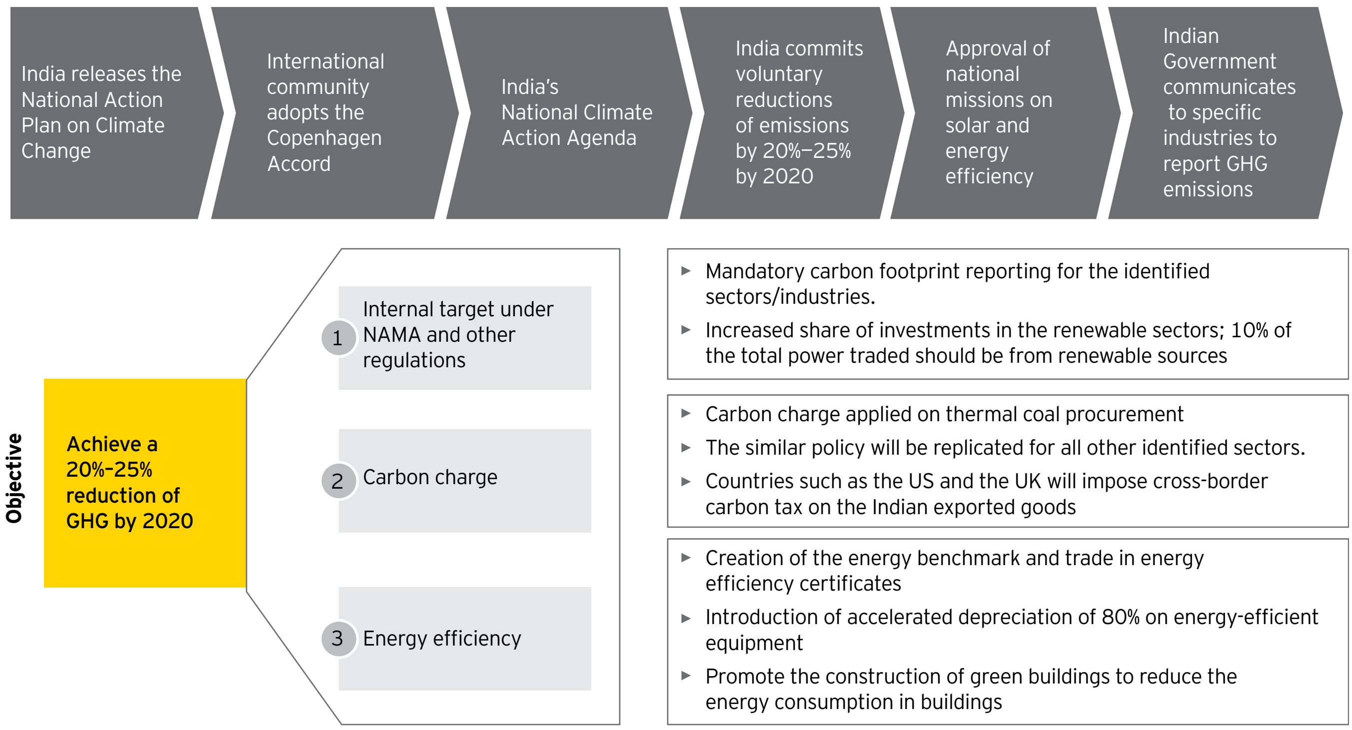
The National Action Plan on Climate Change (NAPCC) was formally unveiled in June 2008, endeavoring to outline the strategy for confronting the challenge of sustaining economic growth, while coping with the global threat of climate change. The NAPCC primarily aims at identifying potential opportunities and delineating the path forward for the implementation of technologies that address India's twin needs: sustainable development, and adaptation and mitigation of commercial emissions in an accelerated manner. The NAPCC outlines



the focal components of the strategy in the form of eight National Missions, representing a multi-pronged, long-term and integrated strategy to achieve key goals in the context of climate change.

Among the eight national missions under the NAPCC, the National Solar Mission, National Mission for Enhanced Energy Efficiency and the National Mission on Sustainable Habitat are the key components of the strategy to achieve climate change mitigation-related objectives. The National Mission for a Green India outlines the nation's strategies to enhance carbon sinks, increase the forest cover and preserve biodiversity. The focus of the National Mission for Sustaining the Himalayan Ecosystem, the National Mission for Sustainable Agriculture, and the National Water Mission focus on strategies for adaptation to climate change and management of natural resources. Finally, the National Mission for Strategic Knowledge for Climate Change will promote research and development in the climate change sciences, including seeking international cooperation in technology development, setting up a climate change research fund and disseminating climate change knowledge.

Post the Climate Change Conference in Copenhagen in 2009, India committed to reduce emissions intensity (GHG emissions per unit GDP) by 20%–25% below the 2005 levels by 2020. The climate change policies in India are focused to achieve the voluntary target, while maintaining the growth of the economy. A multi-pronged approach has been adopted as illustrated below:



Source: Ministry of Environment & Forests website

Low Carbon Expert Group

It is important that the implementation of India's efforts to combat climate change can be channelized through a strategy consistent with the national objectives of poverty alleviation, sustainable development and inclusive growth. For this purpose, the Planning Commission instituted an Expert Group headed by Dr. Kirit Parikh, the former member of India's Planning Commission, to develop a strategy for a low-carbon economy for India. The expert group consists of members from the government, industry, academia and civil society.

The mandate of the low-carbon expert group is to:

- Review the existing studies on low-carbon growth conducted by various organizations
- Assess low-carbon options relevant to the Indian economy
- Draft an action plan comprising critical low-carbon initiatives
- Provide a list of the enabling legislations, rules and policies to operationalize the low-carbon roadmap

The Low Carbon Expert Group has identified the following focus sectors: power, iron and steel, cement, buildings and transportation. The low-carbon options for these sectors are discussed in the section 4: "The path to a low-carbon economy."

Renewable Purchase Obligation and Renewable Energy Certificates

The Central Electricity Regulatory Commission (CERC) oversees the Renewable Purchase Obligations (RPO) and Renewable Energy Certificate (REC) mechanism, which is aimed at meeting the targets for renewable energy specified in the NAPCC. Under the NAPCC, the target for the purchase of renewable energy was set as 5% of the total grid power purchase for FY09–10, with an increase by 1% every year for the next decade. Obligated entities (OEs) such as the distribution licensees, captive power plant owners and open access consumers will be mandated to fulfill their RPOs.

CERC approved the detailed procedure for the REC mechanism on 1 June 2010. RECs represent an aggregation of certain non-energy and societal beneficial attributes, e.g., environmental and socio-economic benefits, of electricity generated from renewable energy sources and are an ideal solution to overcome the challenges posed by RPOs. These attributes, embodied in the form of certificates, may be traded separately from the electricity. **One REC** will be issued to renewable energy generator for **one MWh of renewable electrical energy** fed into the grid and the same will remain valid for a period of **one year from the date of issuance**.

The promotion of renewable energy through RPO and trading of RECs will increase renewable energy generation in India, displace fossil fuels and contribute to India's low-carbon growth.

Perform Achieve and Trade (PAT)

The Perform Achieve and Trade (PAT) scheme is an initiative under the National Mission for Enhanced Energy Efficiency. It is a market-based mechanism to enhance the cost-effectiveness of improvements in the energy efficiency of designated consumers. The designated consumers (DCs) are energy-intensive facilities/establishments across the nine energy intensive sectors identified by the Bureau of Energy Efficiency (BEE).

The scheme received the in-principle approval of the Prime Minister's Council on Climate Change in August 2009 and the approval of the Union Cabinet on June 2010. The regulatory functions of the PAT scheme will be implemented by BEE and Energy Efficiency Services Ltd. (EESL) under the Ministry of Power. BEE is expected to announce energy efficiency targets for DCs in 2011.

Each DC will be mandated to reduce its specific energy consumption (SEC) by a fixed percentage within a specified time period of three years. The energy-efficiency improvement targets will be "unit-specific." The targets will specify by which percentage a DC has to improve its energy intensity from the base line value in a period of three years. Under the scheme, DCs will have the choice to reduce energy consumption either through the implementation of energy efficiency measures or through the purchase of energy saving certificates (ESCerts). If DC is capable of exceeding its energy-saving targets, then through the PAT scheme, DC can avail ESCerts and sell them to other DCs.

The PAT scheme can make a vital contribution to India's low-carbon growth through the promotion of investments in energy-efficiency measures and mandatory energy efficiency benchmarks for energy-intensive industries.

Energy Conservation Building Code

The Ministry of Power launched the Energy Conservation and Building Code (ECBC) in 2007. The code sets minimum energy efficiency standards for commercial buildings. ECBC encourage energy efficient buildings or the retrofit of buildings such that it does not constrain the building function, comfort, health or productivity of the occupants and life cycle costs are minimized. ECBC is applicable to buildings or building complexes that have a connected load of 500 kW or greater or a contract demand of 600 kVA or greater[3]. Energy-efficiency standards set by the ECBC code will contribute to energy savings from buildings, a major source of GHG emissions in India.

National Urban Transport Policy and Jawaharlal Nehru Urban Renewable Mission

The Ministry of Urban Development, through the National Urban Transport Policy (NUTP) (2006), has formulated a central policy to enable and guide state-level action plans within an overall framework. The policy proposes a much closer integration of land use and transport planning as well as emphasizes the greater use of public transport and non-motorized modes of travel since these modes occupy less road space and emit fewer pollutants compared to personal motor vehicles. The policy recognizes the importance of effectively managing freight traffic and implementing well-planned parking facilities in urban areas.

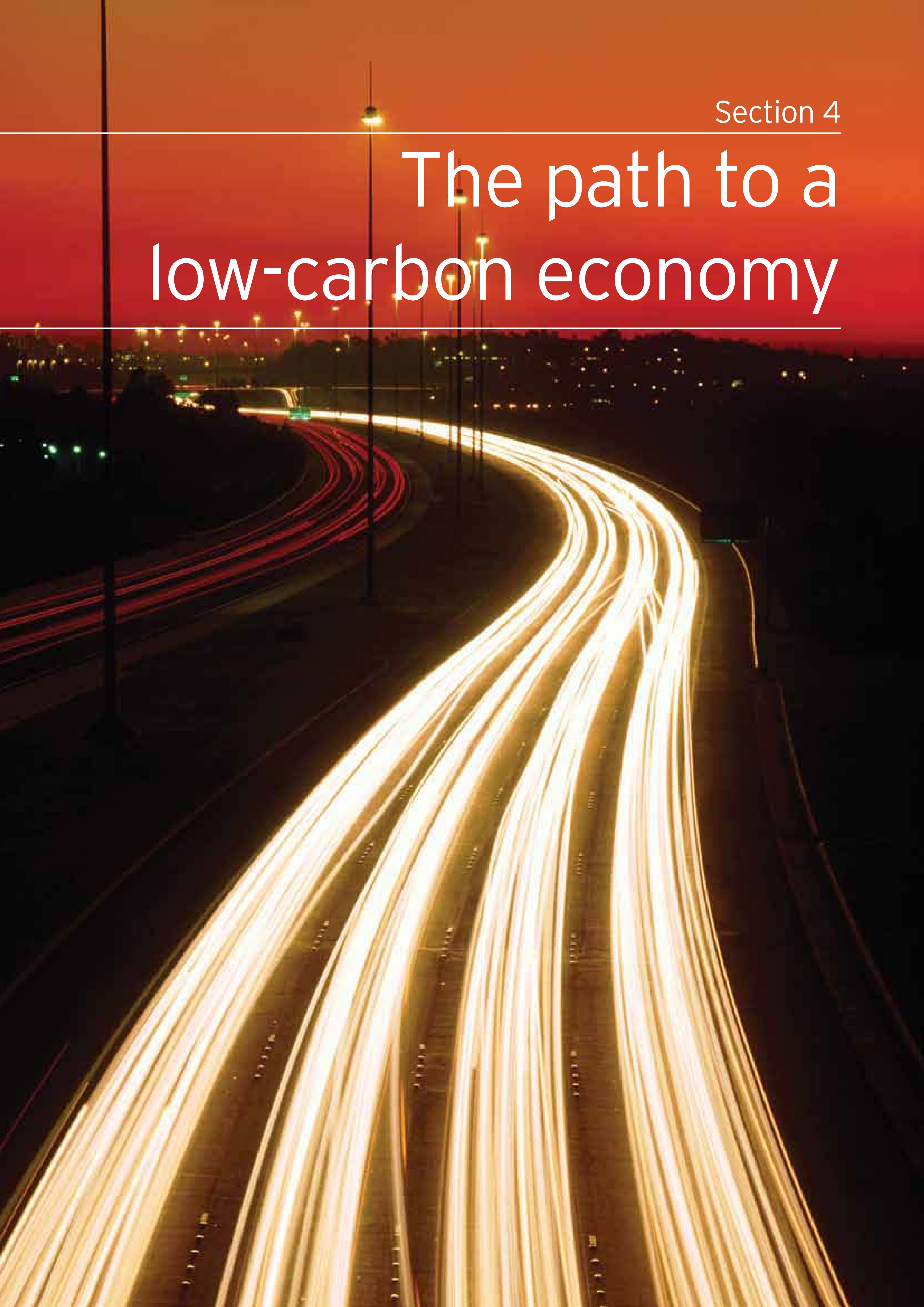
Set up in 2005, the Jawaharlal Nehru National Urban Renewal Mission (JNNURM) seeks to bring about comprehensive improvements in urban infrastructure, committing substantial funds for this purpose and promoting reforms that would make the investments sustainable. The measures promoted under JNNURM and NUTP to improve India's transport infrastructure could have a major impact on reducing GHG emissions from India's transport sector.

Standards and labeling scheme

The standards and labeling scheme implemented by BEE is aimed at promoting energy-efficient appliances and increasing awareness about energy efficiency among end-users. The scheme currently covers 10 categories of high-energy consuming domestic and industrial equipment. It targets the display of energy performance labels on household and other equipment. The labelling scheme is currently mandatory for frost-free refrigerators, air conditioners, tubular fluorescent lamps and distribution transformers. Energy-efficient appliances are an important aspect of low-carbon growth as they can result in energy savings in buildings as well as industries.

Section 4

The path to a low-carbon economy



Methodology for adopting low-carbon growth

Adopting low-carbon growth requires a phased plan for the development and implementation of a low-carbon roadmap. To begin with, it is useful to establish the GHG inventory of the nation and the projected emissions over a period of time. This may be followed by identifying key carbon abatement levers and establishing the low-carbon roadmap. Further, it is imperative to identify barriers for the implementation of low-carbon abatement levers/low-carbon growth, review the existing policy framework and recommend the required incentives, institutional and regulatory framework to enable the transition to a low-carbon economy. A plausible phase-wise methodology for adopting low-carbon growth has been discussed below:

Phase 1	▶ Estimation and forecasting of baseline GHG emissions	▶ Develop a reference case for the nation's GHG inventory ▶ Scenario modeling and forecasting of GHG emissions
Phase 2	▶ Identification of low-carbon options	▶ Identify options for low-carbon growth ▶ Techno-economic analysis of low-carbon options (quantitative and qualitative)
Phase 3	▶ Barriers identification and review of the existing policy framework	▶ Identify barriers to low-carbon growth ▶ Review of existing/upcoming policies
Phase 4	▶ Low-carbon roadmap	▶ Suggest a new policy framework to overcome identified barriers and implement changes in existing policies, if required

Phase 1: Estimation and forecasting of baseline GHG emissions

Step 1: Develop a reference case GHG inventory for the nation

- Identify key GHG emitting sources
- Identify GHG emission reduction potential for individual sectors and sub-sectors
- Estimate baseline GHG emissions adopting a "bottom-up" approach

Step 2: Scenario modeling and forecasting GHG emissions

- Forecast GHG emission profile up to 2020 and 2030 under different predictable scenarios
- Key inputs for the scenario modeling:
  - Announced plans and policies and possible technology shifts
  - Macro variables such as economic growth, climate policy, carbon tax, regulations, market impact, approved plans, capacity addition in power generation, land use pattern, consumption pattern, etc.

Developing a GHG inventory requires the examination of all sources of energy consumption (industry, transport) as well as other sources of GHG emissions (waste, agriculture) and destruction of carbon sinks (deforestation). An illustrative example of various sectors that contribute to GHG emissions has been given below:

Sectors			
Sectors	Land use, land-use change and forestry (LULUCF)	Agriculture	Consumption of fuel in pumps for irrigation
		Deforestation	Cutting down forests for mining activities, fuel wood, etc.
	Transport	Light duty vehicles	Consumption of fuel in cars, taxis, etc.
		Heavy duty vehicles	Consumption of fuel in trucks
		Railways	Consumption of fuel in railways
	Waste	Municipal waste	Methane emissions, emissions from incineration
	Industry	Power	Consumption of fuel in power generation
		Manufacturing sectors	Consumption of fuel in different manufacturing operations Captive power generation
		Cottage industries	Consumption of fuel in different agro-processing operations
	Buildings	Commercial	Consumption of fuel in in gen sets and cooking
		Residential	Consumption of fuel in gen sets and cooking

The estimation of baseline GHG emissions and forecasting of emissions from different sectors may be followed by the identification of strategic sectors to achieve low-carbon growth. Four sectors, namely power, manufacturing sectors, building and transport, are a part of the main focus areas for the Low Carbon Expert Group of India. Furthermore, these sectors may be collectively responsible for approximately 70% of India's GHG emissions in 2030[4]. With the identification of the focus sectors, specific carbon abatement levers in the focus sectors can be analyzed, as covered in phase two.

Phase 2: Identification of low-carbon options

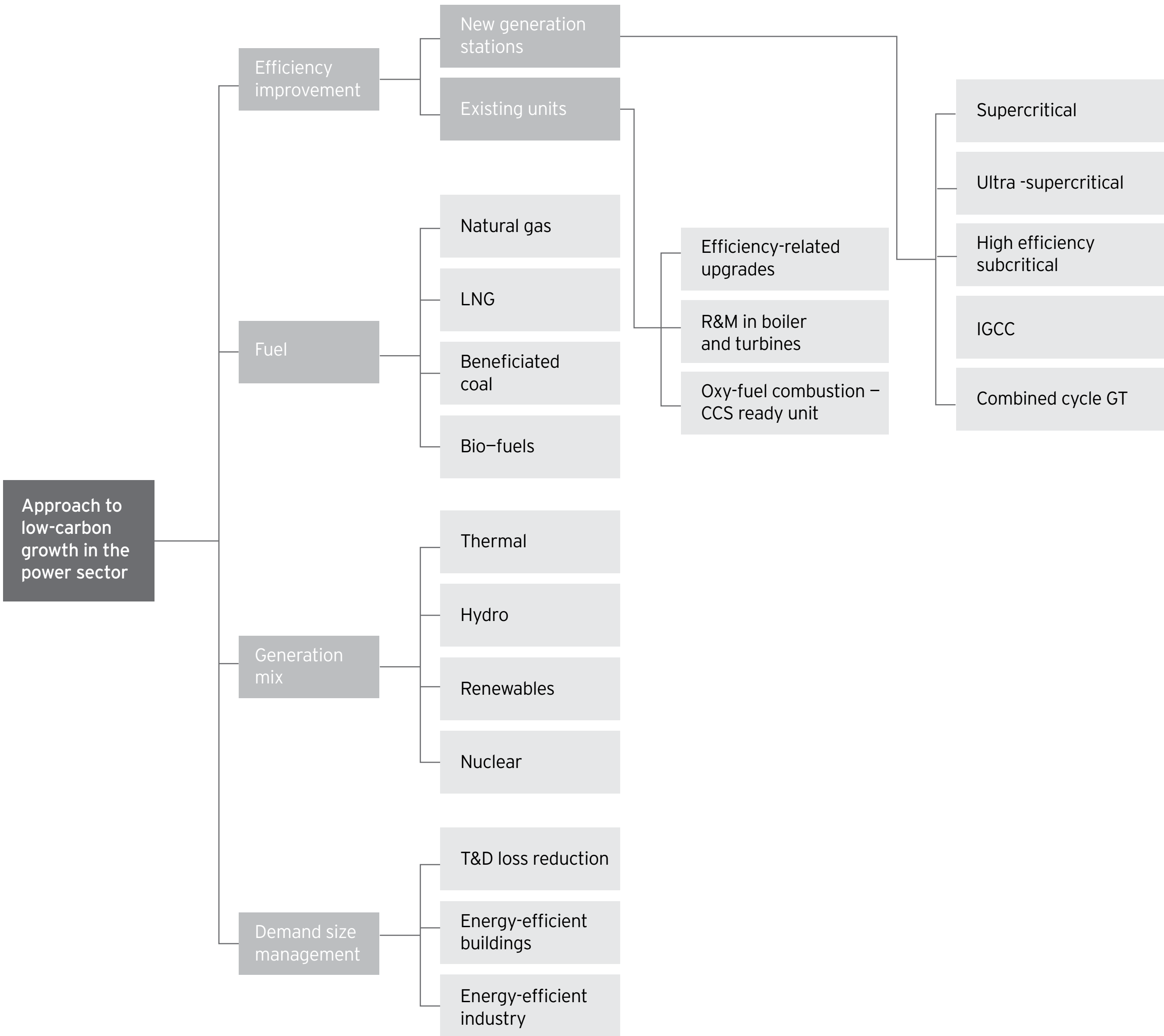
Step 1: Identify options for low-carbon growth

- Analyze various national and international climate change mitigation and adaptation plans, policies and best practices for low-carbon growth
- Identify carbon abatement levers to achieve low-carbon growth
- Study various technology options, map low-carbon resources and screen technology options to match the country's resource potential
- Estimate GHG abatement potential of the above options, identify key success factors and analyze their socio-economic cost-benefit using the economic internal rate of return (EIRR) approach

Step 2: Techno-economic analysis of low-carbon options (quantitative and qualitative)

- Develop indicative business models around the carbon abatement levers, evaluate their contribution to sustainable development and estimate their potential to generate "green employment"
- Classify and categorize GHG emission reduction measures according to sector/sub-sector
- Classify and categorize GHG emission reduction measures according to the level of risk
- Identify key focus areas and abatement levers and develop the low-carbon roadmap
- Identify necessary areas of policy intervention and specific policy tools to improve the viability of low-carbon options, e.g., tax incentives, subsidies, fiscal stimulus, generation-based incentives, etc.

An illustrative example of identification and classification of low-carbon options for the power sector has been presented below:



LNG: Liquefied natural gas
CCS: Carbon capture and storage
IGCC: Integrated gasification combined cycle
GT: Gas turbine
R&M: Renovation and modernization
T&D: Transmission and distribution

Once the low-carbon options are identified, they may be evaluated for techno-economic feasibility as well as contribution to sustainable development. Each of the low-carbon options may be classified by sector and sub-sector, as well as by the level of risk involved. A thorough feasibility analysis of the low-carbon options available to the economy can serve as a useful tool to prioritize investments and make policy decisions. Following the techno-economic feasibility review, a detailed analysis can be carried out to identify barriers (apart from the fiscal barriers) to implement low-carbon options, as discussed in phase three.

Phase 3: Barrier identification and review of the existing policy framework

Step 1: Identification of barriers to low-carbon growth

- Barriers to the implementation of low-carbon options may be related to:
    - Availability of funds and economic feasibility
    - Indigenous capacity for the development of technology
    - Awareness regarding the advanced technology and availability of trained manpower for implementation
    - Indigenous R&D support for technology
    - Technology transfer-related issues, e.g., intellectual property rights, etc.

Step 2: Review of the existing and upcoming polices and regulations

- Review of existing/upcoming policies and regulations with respect to barriers
- Policies outlined by NAPCC and other climate change initiatives of GOI
- State-level regulations and incentives
- Tariff structures and orders
- Gap analysis of existing and upcoming policies and regulations
- Analyze the impact of NAMA (Nationally Appropriate Mitigation Actions) on different sectors

Barriers can be identified through consultation with various stakeholders, including industries, industry bodies, technology suppliers, policy makers, consumers, academia, research institutions and relevant ministries in the government. Following this, a review of existing and upcoming policies and regulations is required to understand the limitations and the gap in the policy framework. The improvements in the policy framework necessary for the implementation of the low-carbon roadmap have been covered in phase four.

Phase 4: Low-carbon roadmap

Various policy initiatives to promote low-carbon growth may be classified under fiscal incentives, institutional mechanisms and regulatory frameworks. The policy initiatives to implement a low-carbon roadmap may incorporate the following:

- Integration of energy security and climate change policies into all policy decision making aspects
- Consideration of different stages of industrialization, while developing low-carbon development strategies
- Financial and investment support channels for low-carbon growth
- Encouragement for R&D in clean energy technology
- Enhancement of institutional mechanism to support low-carbon development, including capacity building of institutions, industries and a national coordination mechanism for the implementation and monitoring of low-carbon growth
- Utilization of public-private partnerships to promote the transition to a low-carbon economy
- Public awareness about the low-carbon roadmap

The low-carbon roadmap may include various policy initiatives such as fiscal incentives, institutional and regulatory framework for low-carbon development. Further, the mechanisms to monitor the effectiveness of the policy framework and the implementation of the low-carbon options may be included. This can be carried out through stakeholder engagement and reporting of GHG performance of the various sectors of the economy.

The final outcome of the phased approach would be a holistic system to promote and track low-carbon growth. Though the sweeping changes may require significant investment, planning and massive coordination among all levels of the government and the sectors of the economy, the potential benefits to businesses and people, who ultimately drive the economy, is undeniable.

The sectors of the economy in which low-carbon development would make the strongest impact include the power sector, energy intensive manufacturing sectors, transportation and buildings. The next section discusses low-carbon development options for each of these sectors with a descriptive overview.

Power sector

An overview

Power generation

As on 30 November 2010, India's total installed power generation capacity was 167,077.36 MW, with thermal power accounting for around 65% of the total capacity[5]. The total electricity generation in the country has increased from 420.6 billion units (BU) in 1997–98 to 723.8 BU in 2008-09[6].

The capacity addition during the Eleventh Five Year Plan is estimated at 78,700 MW, of which approximately 75% will be through thermal power plants[7]. With India's heavy dependence on coal for power generation, the efficiency in thermal power plants is of utmost importance.

Power transmission and distribution

The transmission and distribution (T&D) system in India currently consists of regional grids supplying power to several states, state-level grids and local distribution networks, and the transmission systems supply power to the distribution systems. India's main challenge lies in the losses in the transmission and distribution of power. The aggregate technical and commercial (AT&C) losses for the year 2008–09 were reported at 33%[8]. The Eleventh Five Year Plan aims to reduce the AT&C losses to 15% by March 2012. A single percentage point reduction in the T&D losses would be equivalent to the power generated from a 600–700 MW power plant[9].

The total CO_2 emissions from the sector are expected to be around 948 million tCO_2 per annum in the year 2020 and 1,919 million tCO_2 per annum in 2030[10].

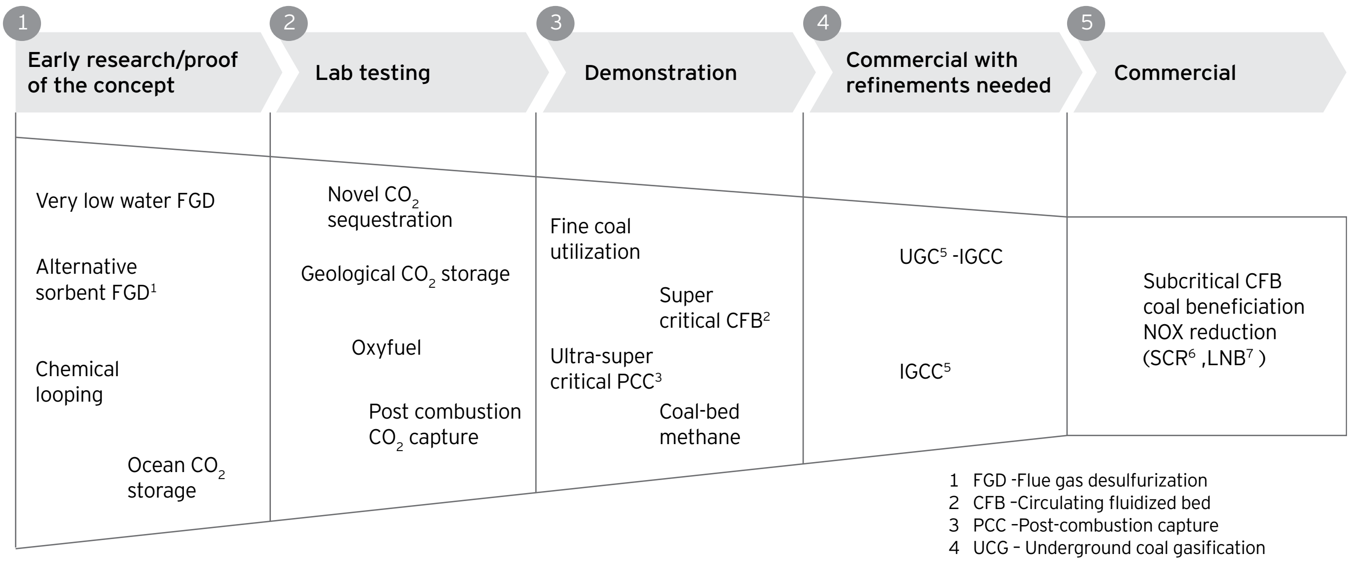
Low-carbon options for the power sector

Despite the fact that the aggressive promotion of renewable power is integral to India's path to low-carbon growth, coal-based power plants are expected to continue as the main source of power production in India for the next few decades. There are significant opportunities to reduce GHG emissions by increasing the efficiency of thermal power plants.
However, a multi-pronged approach is essential, which includes high-efficiency power generation, clean coal technologies, renewable energy/low-carbon fuels and demand-side management.

Reducing GHG emissions from power generation

As mentioned earlier, coal is expected to remain the main source of power generation for India for the next few decades. There are numerous options to increase the efficiency of coal-based power generation and implement clean coal technologies, some which are currently in early development stages and some which are closer to commercialization. The technology development pipeline for power generation from coal has been illustrated below.

Technology development pipeline for coal-based power generation



1 FGD -Flue gas desulfurization
2 CFB –Circulating fluidized bed
3 PCC –Post-combustion capture
4 UCG – Underground coal gasification
5 IGCC- Integrated gasification combined cycle
6 SCR – Selective catalytic reduction
7 LNB –Low NOX burners

Supercritical and ultra-supercritical power

Supercritical power plants operate at a temperature and pressure at which the liquid/vapor distinction for water/steam ceases to exist. Ultra supercritical plants operate at even higher temperatures and pressures. Operating beyond the critical point of water allows power plants to generate power at higher efficiencies of up to 42% net higher heating value (HHV) with conventional materials and processes and up to 50% with high performance alloys and waste heat recovery[11].

Integrated gasification combined cycle

Integrated gasification combined cycle (IGCC) involves pyrolysis and partial oxidation of coal to generate synthesis gas (syngas) in a coal gasification facility. The syngas is further processed to remove impurities and then combusted it in a gas turbine. Further, the excess heat from the primary combustion is used to generate steam and passed through a steam cycle to generate power. IGCC increases the efficiency of power generation from coal and results in cleaner gaseous emissions (including lesser sulfur oxides and particulate matter). IGCCs can also be retrofitted for carbon capture much more easily than conventional thermal power plants.

Underground coal gasification

An alternative to generation of syngas in a gasification facility is the underground or in situ gasification of coal, which can then be utilized for power generation. The technology involves the conversion of coal to gas through the injection of oxidants (air, oxygen, or steam) into underground coal seams, followed by the extraction and processing of the resulting gases. This process is particularly useful for deep underground coal, which cannot be economically extracted through other means.

Renovation and modernization of thermal power plants

Efficiency improvements in thermal power plants can result in increased power generation without the addition of power capacity or increase in fuel consumption. As older less-efficient plants cannot be phased out overnight, the renovation and modernization of existing thermal power plants is essential to mitigate GHG emissions from the power sector.

Alternative fuels

It has becoming increasingly critical to reduce dependence on coal and minimize GHG emissions by using less carbon-intensive fuels such as natural gas, biomass and bio-fuels. Natural gas may be fired in gas turbines or combined cycle power plants. Biomass may be co-fired with coal in thermal power plants or standalone biomass-based power plants.

Renewable energy

India is one of the world's leading nations in renewable energy, with ongoing capacity expansion in wind, biomass, and hydro power. However, there are untapped opportunities in solar, geothermal, tidal and other renewable energy technologies. An overview of these low-carbon options has been presented below:

Technology	Description
Solar photovoltaic power plants	A combination of solar modules in series/parallel combination, storage battery, interface electronics, mechanical support structure, cable and switches, etc., constitute a solar PV system. Multiple PV systems connected together can be used to generate a higher quantum of electricity.
Solar parabolic trough	Parabolic trough shaped mirrors collect and reflect the solar energy onto receiver tubes positioned along the focal line of parabolic mirrors. Heat transfer fluid (synthetic oil flowing through these receiver tubes) is used to generate steam through steam generators and drive turbine to generate electricity.
Solar towers	Solar towers deploy numerous flat sun tracking mirrors, known as heliostats, to focus sunlight onto a fixed receiver mounted on a tower. The collected heat is transferred to a power station below.
Geothermal power plants	The energy generated by the heat stored beneath the earth's surface can be tapped to generate electrical energy or for other direct uses.
Tidal power plants	While India has a long coastline, the estuaries and gulfs where tides are pronounced enough to mobilize turbines are very few. The tidal power potential sites in India are in the Gulf of Kutch, Gulf of Cambay in Gujarat and the Delta of the Ganges in West Bengal.
Energy from algae	Microalgae are mono-cellular, plant-like organisms engaged in photosynthesis, converting carbon dioxide (CO_2) into biomass. This biomass may be used to produce potential resources and active substances as well as fuels such as biodiesel.

Managing transmission and distribution through smart grids

Smart grids are electrical grids that are capable of responding to changes in conditions in the demand and supply of power in an electricity system and are designed to route power in the most optimal way. A smart grid applies sensing, measurement and control devices to capture information from power generation, transmission and distribution and consumption components of the grid. A smart grid can control demand by switching the usage of appliances to off-peak hours. It can aggregate distributed power sources such as renewable power plants, batteries, and diesel generators to help balance the generation and load, which can decrease the frequency of black outs or brown outs. This can reduce reliance on power generation through diesel generators, which are inefficient and carbon-intensive. Smart grids also enable the distribution of power from small-scale renewable energy power plants, e.g., photovoltaic cells in a more efficient way. Smart grids can help cut down on transmission and distribution losses, which will ultimately reduce power demand and carbon emissions.

Manufacturing sectors

Iron and steel

India is the world's fifth-largest producer of crude steel in the world (2008) and the largest producer of direct reduced iron (DRI) (around 20 million tonnes of production in the year 2008–09[12]). The country is expected to become the second-largest producer of steel in the world in the year 2015[13], owing to the proposed installation of large integrated steel plants in the private sector and capacity expansion of public sector plants.

The production of crude steel has increased more than 8% annually since the year 2003–04 and was 54.52 million tonnes in the year 2008-09[14]. According to industry estimates, the country is expected to generate around 121 million tonnes of crude steel in the year 2020 and 248 million tonnes of crude steel in the year 2030[15]. The variation in specific energy consumption (SEC) among steel plants is primarily a result of different processes, quality of coal, types of products and different energy-efficiency levels.

The iron and steel sector is expected to contribute 332 million tCO_2 GHG emissions in the year 2020 and 657 million tCO_2 GHG emissions in 2030[16].

Low-carbon options for the iron and steel sector

GHG emission reduction in the iron and steel sector can be realized through the application of available and emerging technologies in various operations in the iron and steel manufacturing process, from raw material preparation to finishing/rolling and utilities, as illustrated below.

A few indicative abatement levers for the iron and steel industry

Raw material preparation section	Iron manufacturing	Steel manufacturing	Casting	Finishing/rolling	Support facilities
Upstream operations	Main production operations		Downstream operations		Supporting operations
► Lowering the quantity of volatile hydrocarbons in the sinter feed ► Sinter cooler waste gas recirculation ► Coke dry quenching ► Minimization of leakage in the heating chambers and coke oven chamber ► Coal moisture control using waste heat	► Direct injection of reducing agents in the blast furnace ► Energy recovery using top-pressure recovery turbines (TRTs) ► Energy savings at the hot stove ► Preheating of DRI Feed, reducing coal consumption ► Introduction of the recuperator hot blast stove	► BOF gas heat recovery ► Reducing impurities from scrap ► Increased rate of insulation in the induction furnace with roof design modification ► Introduction of CONARC replacing EAF ► Improvement in ladle design to reduce heat loss ► Direct charging of hot DRI without cooling	► Introduction of the centrifugal casting technology instead of static casting ► Better utilization of the chiller for optimal material use	► Replacement of fossil fuel with waste gases in the reheating furnaces ► Introduction of recuperative burners ► Waste heat recovery with Ormat technology from the furnace off-gases	► Replacement of PRDS with the back pressure turbine ► Increased efficiency of the boiler and turbine in the captive power plant ► Cogeneration systems

EAF: Electric arc furnace
BOF: Basic oxygen furnace
DRI: Direct reduced iron
PRDS: Pressure reducing and desuperheating system

Some of the key areas to reduce GHG emissions include:

Waste heat/Pressure recovery: The recovery and utilization of waste energy in iron and steel manufacturing presents the greatest potential for energy savings in the sector. Energy may be recovered from various process units, including coking, sinter plant, blast furnace, basic oxygen furnace and casting. The examples of technologies in this area include:

- **Coke dry quenching (CDQ)**: CDQ involves the use of an inert gas to cool coke in coke ovens in place of water. The waste heat in the inert gas can be utilized to generate steam and produce power, resulting in energy savings of approximately 1.2 GJ/MT pig iron[17].
- **Waste heat recovery in sintering plants**: Heat recovered in the sintering plant can be utilized to pre-heat combustion air for burners and generate power.
- **Recuperator hot-blast stove**: Waste heat can be recovered from hot blast stove flue gases and used to pre-heat the combustion air entering the blast furnace. This can result in fuel savings of approximately 0.08–0.085 GJ/MT of hot metal[18].
- **Waste heat recovery in the annealing line**: Heat from the annealing line may be recovered through the installation of recuperative or regenerative burners.
- **Top pressure recovery turbines (TRTs)**: TRTs convert the physical energy (pressure) of blast furnace top gas into power. Approximately 40–60 kWH/MT of pig iron can be generated through this technology[19].

Energy efficiency: Energy saving measures can be applied at various stages of the iron and steel manufacturing. The examples of energy-efficiency measures are:

- **Energy savings in hot stove**: The improvement in combustion in the hot stove can be effected through high-efficiency burners and by optimizing fuel/oxygen ratios.
- **Improvement in ladle design to reduce heat loss**: Heat losses from the ladle can result from radiation and the lack of lids. These losses can be reduced through the installation of temperature controls, installing hoods, the efficient ladle management to reduce pre-heating requirements, the use of recuperative burners and the use of oxy-fuel burners.
- **Enhanced insulation of furnaces**: The replacement of conventional insulating materials with ceramic low-thermal-mass insulation materials reduces heat loss from furnace walls.
- **Reduction of air leakage**: Reducing air leakage from the sintering plant can result in lower fan power consumption.
- **Cogeneration**: The cogeneration or combined heat and power generation can be implemented based on combined cycle power plants or with high-pressure boilers coupled with steam turbine generators. Cogeneration, when integrated with waste heat recovery boilers, can improve the efficiency of the waste heat recovery system.

Cement

Overview of the cement sector

India accounts for about 6% of the world's cement production with a total production capacity of 219 million tonnes per annum; second only to China[20]. Owing to the rapid expansion predicted in the sector, it is expected to produce 403 million tonnes of cement in the year 2020 and 833 million tonnes in the year 2030[21]. The modern Indian cement plants are at par with the global best[22].

Cement production is an energy-intensive process; energy cost constitutes about 40% of the total manufacturing costs[23]. The main source of energy in cement industry is coal, followed by electricity. A declining trend has been observed in the specific energy consumption of cement plants in India. The specific energy consumption for some of the modern plants is as low as 685 kCal/kg clinker and 71 kWh/tonne cement[24], which is comparable to global standards.

The cement sector is expected to contribute 120 million tCO_2 emissions in the year 2020 and 239 million tCO_2 emissions in the year 2030[25].

Low-carbon options for the cement sector

In the cement sector, many industries have already taken various initiatives toward low-carbon growth. However, there is potential for further energy savings and emission reductions. The following are some of the possible low-carbon options:

Power from waste heat recovery:

The full potential for power generation from waste heat recovery is not yet tapped by the cement sector, owing to the high initial investment costs. For instance, the waste heat of pre-heater and cooler exhausts is commonly used to dry raw materials and coal. However, there is immense potential to use this energy source more efficiently by generating power from it. In addition, there is potential to generate 3–4 MW per million tonne of installed capacity, using this waste heat[26].

Use of alternate fuels in kilns:

1. **Substitution of coal with waste materials and biomass**: Fuels derived from biomass, industrial wastes, municipal wastes and tire wastes can be used to displace coal consumption in kilns, resulting in reduced GHG emissions.
2. **Hydrogen from syngas as a fuel for cement kiln burners**: Syngas is a gas mixture consisting predominantly of H2, CO and CO_2, is generated as an intermediate step from fossil fuels such as coal or gas. Due to its explosive properties, pure hydrogen could not be used in existing cement kilns, but could be utilized after dilution with other gaseous fuels or inert gases such as nitrogen or steam. The utilization of hydrogen from syngas as against the direct combustion of fossil fuels would result in GHG emission reductions.

Energy efficiency in cement production:

1. **Improve burnability of raw meals**: Fluoride-based minerals, when added to the raw material, improve the burnability of the raw meal in the kiln, resulting in lower energy demand for the process.
2. **Six stage pre-heaters with pre-calciner kilns**: Most Indian plants use multi-stage pre-heaters and pre-calciner kilns. However, older kilns still utilize less-efficient four-stage or five-stage systems, and there is immense potential to upgrade all pre-heaters and pre-calciner kilns to the six-stage system.

3. **Fluidized bed advanced cement kiln system**: In the Fluidized Bed Technology (FBT) developed in Japan, the clinker is produced in a fluidized bed system after adding grinded coal, and injecting raw material. This results in a finely granulated clinker and lower energy consumption.
4. **Vertical roller mills (VRMs)**: Currently, this technology has proven to be the most efficient to crush raw material. Though the penetration of VRMs is good in the Indian cement sector, its potential can be further realized by replacing all older grinding systems with VRMs.
5. **Increasing percentage of fly ash in (Portland Pozzolna Cement) PPC cement**: Most PPC cement plants use fly ash to an extent of 20%–30% even though the Bureau of Indian Standards permits usage of up to 35%. The full potential with respect to fly ash blending has not yet been achieved.
6. **Use of alternative de-carbonated raw material for clinker production**: The utilization of alternate raw material containing calcium (e.g., concrete crusher sand, aerated concrete meal, etc.), which are already de-carbonated, reduces energy consumption as well as carbon dioxide emissions from the process.

Change in product mix:

1. **Rising the share of blended cement**: Although the market share of blended cement (Portland Pozzolna Cement and Portland Slag Cement) is high in India compared to other countries, there is great potential to increase it further. Blended cement is less carbon-intensive than ordinary Portland Cement.
2. **Composite cement**: Composite cement replaces clinker with both fly ash and blast furnace slag. Quality standards have not been defined in India for the blending of multiple additives. The manufacture of composite cement could further result in GHG emission reductions.
3. **Geopolymer cement**: Geopolymer cement is an alternative cementitious material composed of a three-dimensional alkaline aluminosilicate polymer network. The technology used to manufacture geopolymer cement is still in its infancy stage.
4. **Low-grade cement**: The Bureau of Indian Standards allows for the use of fillers such as limestone in cement to an extent of 5% for the manufacture of low-grade cement, which has a lower "one-day strength." However, due to marketing strategies in India for high-strength cement, most cement manufacturers do not prefer to apply this option, despite its energy-saving potential. This type of low-grade cement product is used in other countries to a greater extent.

Logistics and site selection: Energy consumption from the transportation of additives such as fly ash and slag can be reduced by locating grinding units closer to the sources of the additives. Bulk transportation through rail and bulk tankers instead of smaller trucks can improve fuel efficiency. Further, route optimization can be enabled by employing technologies such as the Global Positioning System (GPS) to increase the efficiency of logistics operations and reducing fuel consumption.

Fertilizer sector

An overview

The fertilizer industry is of extreme importance owing to India's predominantly agrarian economy. The industry is controlled by government regulations through the retention pricing scheme (RPS). The fertilizers produced in India can be classified into two broad categories, which are nitrogenous fertilizers and phosphatic fertilizers. The country had an installed capacity of 12.284 million tonnes of nitrogenous and 5.859 million tonnes of phosphatic fertilizers in 2007–08[27]. Currently, there are 59 large fertilizer plants operating in the country, out of which, 31 produce urea, 19 produce DAP and complex fertilizers, 2 produce calcium ammonium nitrate (CAN) and ammonium chloride and the remaining 10 produce ammonium sulphate.

The total urea production is expected to be 28 million tonnes by the year 2020 and 37.32 million tonnes by 2030[28]. The specific energy consumption of urea was 6.29 GCal/tonne[29] in the year 2007–08, as compared to the 2001–02 levels of 6.67 GCal/tonne[30].

The total CO_2 emissions in the sector are expected to be around 42 million tCO_2 per annum in the year 2020 and 54 million tCO_2 per annum in 2030[31].

Low-carbon options for the fertilizer sector

The fertilizer sector can reduce its GHG emissions by adopting the following technologies:

Switching to natural gas in feed/fuel: Even though natural gas is already used as a feed and as a source of fuel to an extent of 78%[32], there is great potential for the further usage of natural gas. As natural gas is less carbon-intensive than other fossil fuels, switching to natural gas reduces GHG emissions.

Advanced process control (APC): APC involves the application of automatic control systems to improve quality, increase throughput, reduce energy usage and ultimately improve process profitability. The key features of an APC include process modelling, multi-variable controller generation, real-time adaptive control and constrained optimization.

Installation of carbon dioxide recovery (CDR) plants: The CDR plant recovers CO_2 from flue gasses from the primary reformer/boiler for utilization in the process, resulting in GHG emission reductions.

Improving the efficiency of the CO_2 removal section: Removing carbon dioxide from the ammonia production process can be carried out more efficiently by adopting the following:

1. Use of advanced solvents such as sexol
2. Adopting pressure swing absorption or membrane-based CO_2 removal

Lower synthesis pressure for ammonia production: Lower synthesis pressure with appropriate catalyst selection reduces power consumption in the compressor.

Transport sector

An overview

The transport sector accounts for approximately 15% of India's commercial energy consumption as against the world average of approximately 25%[33]. The demand for mobility and vehicle use in India has been driven by the steady increase in per capita GDP. The transport sector is a major contributor to CO_2 emissions.

The energy sources used in this sector include coal, diesel, petroleum and electricity. Transportation through road, rail and air contribute around 80%, 13% and 6% of the total CO_2 emissions, respectively[34]. Historically, the consumption of energy has increased at an annual growth rate of 2.9%[35]. The urban population of India is predominantly dependent on road transport with around 80% of the passengers and 60% of the freight movement depending on road transport[36]. The GHG emissions from the transport sector are expected to increase to 714 million tonnes of CO_2 equivalent by 2030[37].

Low-carbon options for the transport sector

Low-carbon options for the transport sector include infrastructural changes, improvement of operational efficiency, improvement in vehicle efficiency, and the displacement of gasoline/diesel with bio-fuels.

Thrust area	Category	Abatement levers
Transport	Transport infrastructure	▸ Dedicated freight corridor ▸ Modal shift from road to rail ▸ Mass rapid transit system ▸ Long-range urban planning ▸ Usage on inland waterways ▸ Non-motorized vehicles
	Operational efficiency	▸ Intelligent traffic management systems ▸ Route optimization
	Vehicle efficiency	▸ Use of hybrid and electric vehicles ▸ Design improvements to increase fuel efficiency
	Bio-fuels	▸ Blending of ethanol with gasoline ▸ Bio-diesel

Transport infrastructure: Reducing emissions through investments in transport infrastructure and effective utilization of infrastructure is imperative to achieve low-carbon growth in the transport sector. This includes:

1. Implementation of **dedicated freight corridors** to avoid traffic congestion on regular railway lines to increase the fuel efficiency of freight transportation
2. Facilitating a **modal shift** from road to rail
3. Implementation of **mass rapid transit systems** such as metro train, bus rapid transit (BRT), etc., to increase the effectiveness and utilization of public transportation
4. **Long-range urban planning** including the integration of land use, planning and development of transport networks to shorten commuting time and avoid traffic congestion
5. **Usage of inland waterways** such as rivers, canals, backwaters and creeks for freight transportation
6. Infrastructure, e.g., dedicated lanes, for the increased usage of **non-motorized vehicle (NMV) transport** such as bicycles and cycle-rickshaws

Operational efficiency: The effective management of transport operations can minimize traffic congestion and result in increased fuel efficiency. The transport operations can be managed more effectively by using:

1. **Intelligent traffic management systems**: These systems are capable of offering real-time information about current traffic conditions and online information for journey planning. This information enables authorities and individuals to make better informed and more coordinated decisions regarding travel routes and schedules.
2. **Route optimization through the global positioning system (GPS)**: GPS can be used to effectively manage transportation networks or fleets by providing information on location, position, speed and idle time of vehicles. This information can then be used to optimize routes and the efficiency of the transportation network.

Vehicle efficiency: The improvement in vehicle efficiency can be effected through the following measures:

1. **Hybrid and electric vehicles**: The introduction of hybrid and electric vehicles would displace oil consumption with electricity consumption. Vehicles powered by the grid would be less emissions-intensive than conventional vehicles.
2. **Design improvements in vehicles to increase fuel efficiency**: The fuel efficiency of vehicles can be optimized by reducing tire and engine friction, improving power trains, lowering vehicle weight and improving the aerodynamic design of vehicles.

Bio-fuels: The following types of bio-fuels can substitute fossil usage for transportation:

1. **Ethanol**: India is a large producer of ethanol with an average output of 1.9 billion liters per year. This output would be sufficient for blending 5% ethanol with gasoline, resulting in a reduction of 3% in carbon emissions[38].
2. **Biodiesel**: Biodiesel also has high potential for curbing emissions by displacing up to 20% diesel consumption. However, the risks associated with the competition of land use between biodiesel crops and food crops have to be addressed[39].

Residential and commercial buildings

An overview

India's population is about 120 crores, which is the second-largest in the world. The country's building sector is expected to grow at a brisk pace, owing to the rapid growth in infrastructure and the substantial rural-to-urban population shift. The construction in both the commercial and residential sectors contributes significantly to the economy, approximately 6.5% of the GDP. These sectors, in turn, consume a substantial quantum of energy throughout the lifecycle of buildings, contributing to around 6% of India's total GHG emissions. Therefore, the buildings sector and the

associated mitigation options available are a vital focus of the NAPCC mitigation strategy. The building stock is expected to grow more than five-fold by 2030 compared to 2005, and will be accompanied by an increase in energy intensity. Given the massive expansion of buildings and the increased use of appliances up to 2030 and beyond, it is essential to formulate actionable steps to bring down the energy consumption of the sector.

Low-carbon options in residential and commercial buildings

The vast potential for reducing energy consumption and GHG emissions from buildings can be realized through appropriate design considerations and the application of energy-efficient technologies. These low-carbon options include:

Energy-efficient building design: This includes the use of simulation software tools at the design phase of a building to optimize energy performance with a given set of conditions, including local weather conditions, building location and budgetary constraints, among others. The considerations for energy-efficient design include:

- Energy-efficient equipment: HVAC systems, lighting, motors and pumps
- Building orientation: Minimizing heat ingress through roof and windows, and the effective use of day-lighting by optimizing window locations and sizes
- Building envelope: Application of glazing materials for glass, and insulation materials for walls and roof

The green building certification process and ECBC can be effective tools for gauging the energy performance of buildings, apart from ensuring other sustainable aspects of building design.

Intelligent building management system (IBMS): An IBMS can be used to automatically control and adjust heating, cooling, lighting and energy use. It can make automated adjustments in response to changes in the external environment and needs of the users. The system may employ multiple sensors, including temperature sensors, light level sensors, occupancy sensors, etc. An IBMS is an effective tool for reducing the energy consumption of any building.

Energy efficiency rating system for appliances: The Bureau of Energy Efficiency (BEE) has introduced a labeling scheme covering ten categories of household/industrial appliances. The scheme is currently mandatory for frost free refrigerators, air conditioners, fluorescent lamps and distribution transformers. The purpose of the labeling scheme is to increase awareness about the energy efficiency of appliances among end-users and assist them to make decisions based on a standard energy efficiency rating system.

Smart appliances: Smart appliances automatically monitor and adjust their operations according to the needs of users. These appliances can reduce their usage as per the consumer's previously established guidelines or manual overrides. They may also be integrated with a smart grid and respond to utility signals, improving the capability of the smart grid to manage peak demand.

Energy-efficient lighting: Alternatives such as compact fluorescent lamps (CFL) and light-emitting diodes (LED) can result in significant energy savings over conventional lighting. Further, lighting controls based on occupancy levels in a building can automatically adjust their illumination levels or operate on a prescribed schedule. Lighting controls may form a part of an IBMS.

Street lighting management systems: Street lighting across the country offers significant potential for energy savings, as it currently constitutes about 13% of the country's total electrical energy consumption. Smart street lighting management systems may include features such as remote switching, dimming controls, voltage control and remote energy metering. These systems can be applied to save energy in residential and commercial areas as well as industrial facilities.

Section 5

Conclusion

In the face of climate change adversities, which can be an impediment to the sustainable growth of the economy, India can benefit from a low-carbon growth trajectory to achieve its objectives for economic development and mitigation of climate change. As one of the largest and fastest-growing economies in the world, India is facing increasing international pressure to mitigate its GHG emissions. Transitioning to a low-carbon economy presents multiple opportunities to India, including sustainable economic growth, infrastructure development through low-carbon technologies, enhanced energy security, "green jobs" and a leading role in the clean technology sector.

The primary sources of GHG emissions in India include the power sector, energy-intensive manufacturing sectors, transportation and buildings. Carbon abatement levers can be adopted in each of these sectors to enable a transition to a low-carbon economy. Many of the low-carbon options would result in increased competiveness and reduced energy costs. However, the barriers in the form of technology costs, availability of funds and adequate institutional and regulatory framework may need to be addressed before low-carbon development can be aggressively implemented.

Some of the critical factors to achieve low-carbon growth include mapping and forecasting of India's baseline GHG emissions, identification of plausible carbon abatement levers in the key focus sectors, gap analysis of the existing/upcoming policies and a policy framework for overcoming barriers to low-carbon growth. India may also engage stakeholders, monitor GHG emissions from various sectors, and track performance against the identified low-carbon roadmap to increase its effectiveness. The successful implementation of this transition would require significant investment, planning and massive coordination among all levels of government and sectors of the economy. However, once realized, the transition to a low-carbon economy would strengthen India's economy, energy security and its capability to meet the challenge of climate change.

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About ASSOCHAM

The Associated Chambers of Commerce and Industry of India (ASSOCHAM) acknowledged as Knowledge Chamber of India has emerged as a forceful, pro-active, effective and forward looking institution playing its role as a catalyst between the Government and the Industry. ASSOCHAM was established in 1920 and has been successful in influencing the Government in shaping India's economic, trade, fiscal and social policies which will be of benefit to the trade and industry.

ASSOCHAM renders its services to over 3,50,000 members which includes multinational companies, India's top corporate, medium and small scale units and Associations representing all the sectors of Industry. ASSOCHAM is also known as a Chamber of Chambers representing the interest of more than 300 Chambers & Trade Associations from all over India encompassing all sectors.

ASSOCHAM has over 80 Expert Committees covering the entire gamut of economic activities in India. It has been especially acknowledged as a significant voice of Indian industry in the field of Corporate Social Responsibility, Environment & Safety, Corporate Governance, Information Technology, Agriculture, Nanotechnology, Biotechnology, Pharmaceutics, Telecom, Banking & Finance, Company Law, Corporate Finance, Economic and International Affairs, Tourism, Civil Aviation, Infrastructure, Energy & Power, Education, Legal Reforms, Real Estate, Rural Development etc. The Chamber has its international offices in China, Sharjah, Moscow, UK and USA. ASSOCHAM has also signed MoU partnership with Business Chambers in more than 45 countries.

D.S. Rawat
Secretary General
The Associated Chambers of Commerce and Industry of India

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